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INTRODUCTION

The performance testing of beef cattle has been the subject of considerable investigation during the last few years. The fact that there is great variation in the response of individuals to the same ration is established in all classes of livestock. The point in question, then, is not the fact that differences are present but rather the physiological processes which contribute to these variations. This is important both from the standpoint of addition to fundamental knowledge and as a possible key to faster and more economical methods of selecting animals possessing superior performance ability. The differences in efficiency of feed utilization must first be studied with the idea of establishing whether the differences in feed efficiency take place before or after absorption of nutrients from the gut, or possibly both.

The digestion trial has been very widely used as a tool for determining differences in completeness of the absorption of nutrients from the digestive tract.

According to Morrison (1948), digestion coefficients from individual animals on the same ration do not ordinarily vary more than 3 to 4 percent, while Mumford et al. (1914) report variations as high as 8 or 9 percent. However, Ringen (1940) believes that individual variation is often exaggerated by technical errors in determination and that

the true variation is much less than the estimates above.

Baker et al. (1951) correlated digestion coefficients of the various nutrients with the efficieny of feed utilization of 10 beef calves fed the same ration. This was done for both a growing and a fattening ration. Crude fiber digestion was significantly correlated with feed efficiency on the growing ration but not the fattening ration. Neither dry matter, nitrogen-free extract, crude protein, or ether extract digestibilities were significantly correlated with feed efficiency. None of the digestion coefficients were significantly correlated with rate of gain.

The study described in this thesis is an effort to obtain information as to whether beef cattle exhibiting differences in gaining ability on the same ration also show a variation in efficiency of absorption of nutrients from the digestive tract. This problem is approached by the use of digestion trials which employ both a conventional method based on known feed intake and total collection of feces, and an indirect procedure which involves the use of an "indicator" occurring naturally in the forage and an external one fed in known amounts. The digestion coefficients obtained are of primary interest but numerous data concerned with the mechanics of conducting such trials are also presented and discussed.

REVIEW OF LITERATURE

The Use of Indicators in Digestion Studies

The technique usually employed in digestion trials unfortunately requires tedious, time and labor consuming attention to the accurate weighing of feed consumed and the total collection of feces. In addition, the subjection of animals to the artificial conditions resulting from cramped positions, lack of exercise, and various impedimenta have caused subnormal feed intake in most instances and suggest possible physiological differences from those occuring under feedlot and pasture conditions. In particular, the estimation of the digestibility of pasture has presented a problem in that in conventional digestion trials the forage must be clipped or manually collected in some manner and fed to animals in weighed amounts. That there is inconsistency between this method of forage collection and the natural prehension of forage by the animals themselves has been pointed out by Kane (1953) and is unquestioned.

The above facts have led to repeated efforts to develop a technique which would overcome the difficulties encountered, most of which have involved the use of some substance as an "indicator." Schneider et al. (1955), in a review of digestion trial procedures, referred to the work of the German investigator, Wildt, who used naturally-occurring silica as an

"indicator" in digestion studies as early as 1874. According to Maynard (1956) "the ideal reference substance or indicator for digestion studies should be totally indigestible, unabsorbable, have no pharmacological action on the digestive tract, pass through the tract at a uniform rate, and be readily determined chemically." This being the case, the digestibility of a feed or nutrient can be calculated according to the following formula.

$$\text{Digestibility} = 100 - 100 \frac{\frac{\%\text{ of indicator in feed}}{\%\text{ of indicator in feces}} \times \frac{\%\text{ of nutrient in feces}}{\%\text{ of nutrient in feed}}}{}$$

Chromium Sesquioxide (Cr_2O_3) as an "Indicator"

Edin et al. (1944), Swedish workers, were apparently the first to use chromium oxide as an indicator. They reported its successful use as early as 1918.

There is general agreement in the literature that chromium oxide is excellent for determining digestibility in simple-stomached animals. Barnicoat (1945) reported that the use of chromic oxide yielded digestion coefficients that were accurate estimates of those determined by conventional methods in swine. Schurch et al. (1952) checked the method by including chromium oxide as 1% of self-fed swine rations and found no significant differences between these digestibility values and those determined by simultaneous conventional procedure. Clawson et al. (1955), also studying the method with swine, observed results comparable with those obtained by total

collection of feces. These workers reported that a three to four day preliminary period was sufficient to permit uniform excretion of chromium oxide in the feces.

Schurch et al. (1950) tested the method for determining dry matter digestibility with rats. When mixed with the ration at a 1% level a five-day preliminary and a six-day collection period produced results in agreement with the conventional method.

Kreula (1947) reported chromium oxide to be excellent for determining the absorption of carotene by humans. Irwin and Crampton (1950), also studying human subjects, obtained dry matter digestibilities of 88.3% and 89.0%, respectively, for the chromium oxide method and total collection of feces.

Dansky and Hill (1952) used chromium oxide as an indicator in digestion studies with chickens and observed that it allowed results which were even more consistently repeated than did the conventional method.

Kane et al. (1950, 1953), Chanda (1951), and Crampton (1951) reported excellent agreement of dry matter digestibility coefficients determined by either the conventional or the chromium oxide method where the indicator was mixed with the grain portion of the ration and fed to ruminants. These results agree regardless of whether the fecal samples used for chromium oxide determination were from total voided feces for the trial or the result of the "grab sampling" technique at any time of day. However, when Crampton (1951) administered the indicator by capsule (to sheep on a ration of hay alone) "grab" samples gave results considerably lower than

those obtained by the standard procedure. Jarl et al. (1951) used the method and obtained results in agreement with published digestibility estimates but did not use simultaneous total collection. Barnicoat (1945) used 1 young calf and 2 wethers and observed only about 80% recovery of chromium oxide when it was administered by capsule 3 times daily. Obviously, these incomplete recoveries resulted in digestibility estimates much lower than those obtained by total collection of feces. A young lamb receiving chromium oxide was slaughtered and chromium oxide was found in the folds of the stomach.

Kane et al. (1952) reported a diurnal variation in chromium oxide excretion in a study with dairy cows. They plotted excretion rates by sampling from the rectum every 4 hours and suggested 1:00 to 3:00 P. M. or 4:00 to 6:00 A. M. as periods when "grab" samples would approximate the mean for a 24-hour period. The indicator was mixed with the grain. It was concluded that the diurnal variation occurred regardless of time of chromium oxide intake and he suggests a parallel between this phenomenon and the diurnal variation in blood and urine glucose, which apparently occurs independent of time of food intake. Linkous et al. (1954) also observed a very similar diurnal variation and suggests the compositing of fecal samples taken from 6:00 to 8:00 A. M. and 6:00 to 8:00 P. M. on an equal weight basis as the best sampling technique.

Hardison et al. (1953) studied chromium oxide excretion in both hand-fed and grazing steers. He observed the rate

of excretion to be lowest (71.8%) at 6:00 A. M. and highest (129.3%) at 4:00 P. M. Wet bulking of "grab" samples taken at these two times gave average recoveries of 99.95%.

Smith et al. (1955) used 17 dairy cows and studied the excretion rates of chromium oxide. No differences were observed between methods of administration. The indicator was given in a gelatin capsule once a day, in capsule twice a day, and mixed with the grain portion of the ration. "Grab" samples were taken every 2 hours and values ranging from as low as 65% up to 141% were recorded. However, samples taken at 6:00 A. M. and 4:00 P. M. and composited on an equal weight basis gave an average recovery of 100.58± 0.87%.

Hardison et al. (1956), using 12 dairy cows and sampling every 2 hours, observed recoveries ranging from 91% to 111% when the indicator was administered by capsule at 6:00 A. M. daily. When one-half this amount was given at 6:00 A. M. and the remainder at 2:30 P. M. the range was narrowed to 97% to 103%.

Mahaffey et al. (1954) conducted a similar trial and observed the greatest range in concentration of chromium oxide in feces when the indicator was administered 6 times daily and the narrowest range when fed once daily. He likewise recorded lowest values in the morning and highest concentrations in the evening.

Lancaster (1954) and his co-workers were able to obtain excellent recoveries of chromium oxide when total feces voided was sampled. However, morning and evening grab samples estimated mean excretion with 10% error. These data are unique

in that highest concentrations of the indicator were observed in the morning samples and the lowest levels in the evening samples.

Brannon et al. (1954) used 3 pairs of steers to study the use of the indicator as a measure of fecal output. One pair received only pasture, another received pasture plus molasses, and the last pair was allowed pasture plus corn. Actual fecal output was measured from collection with harness and bag. Excellent agreement between estimated output and actual values were observed. Smith et al. (1955) used chromium oxide for the same purpose and concluded that accurate estimates of output were possible. The above workers used the formula:

$$\text{Fecal Output (gm. D.M./day)} = \frac{Cr_2O_3 \text{ intake (gm./day)}}{Cr_2O_3 \text{ Conc. of feces (gm/gm. D. M.)}}$$

Hardison et al. (1953) sampled at 6:00 A. M. and 4:00 P. M. in order to obtain estimates of fecal output. Estimated output was in agreement with actual output. These workers reviewed the work of Coup (1950), a New Zealand worker, who also observed agreement between estimated feces output and that measured by collection bag. He took morning and evening samples and composited them over a 14-day period.

Chromogen as an Indicator

Reid et al. (1950) introduced a new method for determining digestibility using pigment(s) occuring naturally in forage. These workers studied the absorption spectra of various extracts of different forages and their respective feces samples and observed that a maximum absorption point near 406 mu. existed in all cases. They hypothesized, since some chromogenic substance was present in forage and the resulting feces in equal amounts, that indigestibility was indicated and the substance could be used as an "indicator."

The absorption measurements were made on 85 per cent acetone extracts of forages and the resulting feces by use of a Beckman DU spectrophotometer. This instrument was calibrated using solutions of Na_2CrO_4 in concentrations from 0 to 20 mg. per cent. Use of Na_2CrO_4 was necessary since the chromogenic substances absorbing maximally at 406 mu. were unknown. Maximum absorption of Na_2CrO_4 is 370-375 mu. which is reasonably close. The amount of light absorbed by a solution containing 1 mg. per cent Na_2CrO_4 was termed equivalent to 1 unit of chromogen per 100 ml. of extract. The apparent digestibility coefficients for any nutrient or for dry matter were then calculated, without knowing either the total quantity of forage consumed or of feces produced, by the following formula:

$$\text{Apparent Digestibility} = 100 - 100\ \frac{A \cdot X \text{ in feces}}{B \cdot X \text{ in forage}}$$

In this formula A = units of chromogen per gm. of forage, B = units of chromogen per gm. of feces, and X = per cent of the specific nutrient.

Also, these workers show that when the total amount of feces produced is known the dry matter intake can be determined by the equation:

$$\text{DM intake (gm./day)} = \frac{(\text{units of chromogen/gm. dry feces}) \times (\text{gm. of DM in feces/day})}{\text{units of chromogen/gm. DM in forage}}$$

Digestion coefficients obtained by these methods were in agreement with those obtained simultaneously by conventional methods. Dry matter digestion coefficients obtained by conventional and chromogen methods, respectively were: 72.9 and 73.3% for pasture grass at the vegetative stage, 66.3 and 67.2% for boot to early head stage, and 58.0 and 58.2% for the full bloom stage.

Reid et al. (1952) suggested a modification of the method for calibrating the spectrophotometer reported earlier. They concluded that the use of Na_2CrO_4 as a standard might be a source of error if the chromogen extracts studied did not conform to the Beer-Lambert law in precisely the same manner as the solutions of Na_2CrO_4. Therefore, a concentrated extract of mixed forages and feces resulting therefrom was made with 85 per cent acetone as the solvent. Chromogen concentration values were assigned to this extract and to each

successive dilution based upon a reference concentration of Na_2CrO_4. The amount of light absorbed by a reference solution containing 5.05 mg. per cent Na_2CrO_4 was said to be equivalent to that absorbed by an extract containing 10 units of chromogen per 100 ml.

Since the introduction of the chromogen method, several workers have used it for digestion studies with both sheep and cattle. Cook and Harris (1951) used the method in studies with sheep. They obtained excellent results when alfalfa hay was the ration but observed incomplete recoveries of chromogen when desert forage such as big sage brush and black sage were grazed. These workers attributed this incomplete recovery to possible error involved in sampling the forage grazed or more probably to the high content of essential oils in these forages which might have carried a portion of the chromogen with them through the intestinal wall after which it was eliminated in the urine. This latter possibility is supported by the fact that urine from sheep grazing these plants high in essential oils was about 16 times higher in chromogen than was the urine from sheep grazing grass.

Hardison et al. (1951) used the chromogen method in grazing selectivity studies. These workers compared the digestibility of 15 pasture forage mixtures and the coefficients determined on the whole plant were 91.6 per cent of the forage selected by grazing animals.

Woolfolk (1950) observed a quantitative relationship between the chromogen content of consumed forage and that of

the feces voided which indicated that the feces could be used to establish the nature of the pasture actually consumed. In similar work Reid et al. (1952) established definite mathematical relationships between the composition of the feces and that of the consumed grass so that more accurate estimates of the value of pasture could be made. These workers expressed this relationship by the equation:

$Y = 0.0925\ X \pm 137.3 \log X - 242.12$ where Y = units of chromogen/gm. of forage DM and X = units of chromogen/gm. of feces DM. The coefficient of correlation between the computed chromogen concentration of the forages and those predicted from this equation was 0.995 ± 0.001. Determining chromogen by this equation, digestion coefficients can then be calculated by the equation:

$$\% \text{ digestibility of DM} = 100 - 100 \frac{\text{units of chromogen/gm. forage DM.}}{\text{units of chromogen/gm. feces DM.}}$$

Kane et al. (1953) compared the digestion coefficients obtained by the chromogen method with those by the conventional procedure. These workers used dairy cattle and observed excellent agreement between the two methods when orchard grass hay was fed with a uniform amount of grain. Likewise, Brisson et al. (1954) also used the chromogen method for the evaluation of pasture for both cattle and sheep and concluded that these plant pigments were useful as indicators of the dry matter digestibility of pasture.

A Combination of Cr_2O_3 and Chromogen in Digestion Studies

As stated earlier in this review, in order to use Cr_2O_3 as an "indicator" we must know the quantity and composition of the feed consumed and in grazing studies this is accomplished by feeding known amounts of clipped forage. It has been shown that clipped herbage is not identical with that selected by grazing animals which introduces error. When chromogen is employed we avoid the necessity of clipping forage and feeding it indoors in weighed amounts by estimating forage intake using the chromogen content of a plucked sample of forage being grazed and the total amount of chromogen in the feces. This requires quantitative collection of feces; therefore, the Cr_2O_3 method and the chromogen method can be combined to eliminate both the necessity of clipping and weighing forage and the collection of total feces produced. This allows the evaluation of pastures under actual grazing conditions and avoids the probable decrease in intake caused by harnesses and collection bags. The Cr_2O_3 is fed daily to grazing animals and from the concentration of this substance in the feces an estimate is made of total fecal production. Simultaneously the content of chromogen in the forage grazed and feces resulting therefrom is determined. From the total amount of chromogen excreted the amount of herbage consumed is calculated by the following formula where all values are on a dry matter basis.

Daily DM Consumption (gm.) =

$$\frac{\text{gm. } Cr_2O_3 \text{ intake/day}}{\text{mg. } Cr_2O_3 \text{ /gm. DM in feces}} \times \frac{\text{units of chromogen/gm. in feces}}{\text{units of chromogen/gm. in forage}}$$

The simultaneous use of chromogen and Cr_2O_3 was reported by Kane et al. (1953) in a study of the digestibility of orchard grass fed to dairy cows. Digestion coefficients obtained on grazing animals by this method were compared with those determined by feeding clipped forage from the same field using conventional methods. Excellent agreement was observed on all nutrients except protein, the digestibility of which was higher in the case of the grazing animals thus indicating a different forage selected than that obtained by clipping.

Brannon et al. (1954) also measured the accuracy of the chromogen-chromic oxide method for determining dry matter intake by comparing it with the method of total fecal collection. The results were highly satisfactory. Mc Cullough (1953) also obtained reliable results when the chromogen-chromic oxide method was used to study the contribution of two pasture forages to the total ration of dairy cows. Noller et al. (1951) also used the method with dairy cows and reported digestibility figures thus obtained. No check by use of conventional procedures was made.

The evidence presented in the literature herein reviewed seems to be of sufficient extent and agreement to establish the indicator methods described as useful tools in digestion studies. In view of this, Experiment II of

this thesis is concerned with a study of the efficiency of absorption of pasture nutrients by performance tested bulls using chromic oxide to determine fecal output and naturally occurring plant pigments as an indicator of forage consumption.

EXPERIMENTAL PROCEDURE

Experiment I (Trials 1 and 2)

Five Hereford bulls weighing from 825 to 965 pounds were used in a study designed to compare their ability to digest feed nutrients. These bulls had previously been fed a fattening ration for a 154-day period to determine differences in performance as measured by rate and efficiency of gain.

The bulls were confined to 8 feet by 10 feet concrete-floored, metal-fenced pens throughout the experiment. They were fed in wooden, sheet metal-lined, stanchion-type feeders so constructed as to prevent waste of feed. Fresh water was available at all times. The only mineral feed was iodized salt at the rate of 30 gms. per head per day placed on top of each feed allotment.

The ration was fed at 7:00 a.m. and 6:00 p.m. in amounts sufficient to supply 2 lbs. of feed per 100 lbs. of body weight per head daily in the case of bulls 2, 4, 5, and 6. There were no orts. Bull 1 refused to consume this amount and received 1.75 lbs. of feed per 100 lbs. of body weight. This should be considered in any comparison of data from bull 1 with the other bulls. The data from this bull are recorded but interpretation of data is based on bulls 2, 4, 5, and 6 only, except where specific reference to bull 1 is made.

A 10-day preliminary and two consecutive 7-day collection periods (Trials 1 and 2) were used, during which time the bulls were consuming constant amounts of feed daily. The feed mixture used was identical with that fed during the performance testing period and contained the following ingredients:

Ground whole ear corn	35%
Cotton seed hulls	20%
Wheat Bran	10%
Cottonseed meal	10%
Chopped alfalfa hay	10%
Whole oats	10%
Blackstrap molasses	5%

This mixture contained 90.46% dry matter and its composition as determined by chemical analysis expressed on a dry matter basis was 95.28% organic matter, 14.69% protein, 4.12% ether extract, 17.97% fiber and 58.50% nitrogen free extract.

During the collection periods the feces were collected by means of canvas bags held in place by canvas and leather harness. The bags were emptied into metal containers, with tight-fitting lids in the morning and evening, and the contents of the containers were weighed and sampled each evening. These samples (a 2% aliquot of the feces produced over a 24 hour period) were placed in glass jars and after the addition of small amounts of thymol to aid in preservation, were refrigerated at approximately 36° F.

All analyses of feed and feces were in triplicate and handled according to the recommended AOAC (1950) procedures. The data so obtained were used to calculate coefficients of apparent digestibility for the various nutrients.

Experiment II

One Hereford and three Polled Hereford bulls born within a 15-day period and approximately 20 months of age were used in this study. All the bulls had completed a 154-day performance test 3 months previously and had been on pasture since that time. The bulls were divided into two pairs. Bulls 1 and 2 composed one pair and made average daily gains on test of 2.90 pounds and 2.39 pounds respectively. The other pair, identified as numbers 3 and 4 gained 2.92 and 2.29 pounds during the test period.

At the initiation of the experiment the bulls were placed on a four-acre plot of birdsfoot trefoil. This was a very dense and almost pure stand.

After the bulls had grazed this forage for 3 weeks the administration of chromic oxide was begun. This material was given in gelatin capsules, by balling gun, at the rate of 14 grams per head daily. Daily dosage of bulls 1 and 2 consisted of a capsule containing 7 grams of Cr_2O_3 at 8:00 a.m. and one containing the same amount at 8:00 p.m. Bulls 3 and 4 received a capsule containing 14 grams at 8:00 a.m. daily.

Chromic oxide intakes were maintained at the levels listed above for a 20-day period. During the second 10-day interval fecal samples were collected. The fecal material was obtained by "grab" sample directly from the rectum beginning at 8:00 a.m. on the first day and every 3 hours thereafter for 10 days. The samples so collected were placed in 2-quart metal containers with tight-fitting, friction

type lids and taken directly to the nutrition laboratory where analyses for chromogen were conducted on the fresh feces. Chromogen concentration of this fresh material was obtained according to the method outlined by Reid et al. (1952). The samples were analyzed in order of their arrival at the laboratory and no sample was determined for chromogen later than 12 hours after collection, with the majority being handled within 3 or 4 hours after they left the field.

A sample of the herbage being grazed was taken daily by observing what the bulls were eating and duplicating this as nearly as possible. These forage samples were likewise analyzed for chromogen while fresh.

Following chromogen determination on the fresh material both forage and fecal samples were dried in the usual manner for later analysis.

Chromic oxide content of the feces was obtained after the method of Bolin et al. (1952), while protein percentage of both feces and forage was determined according to the A.O.A.C. (1950) recommended procedure.

Daily forage consumption was calculated by the chromogen content of the forage grazed and the resulting feces according to the equation:

$$\text{Daily DM Consumption (gms.)} = \frac{\text{units of chromogen/gm. feces} \times \text{gm. dry matter in feces}}{\text{units of chromogen/gm. dry matter in forage}}$$

The amount of feces produced daily was calculated on the basis of the Cr_2O_3 intake-excretion method according to the equation:

$$\text{Fecal Production (gm. DM/day)} = \frac{\text{gm. } Cr_2O_3 \text{ intake/day}}{\text{mg. } Cr_2O_3/\text{gm. DM in feces}}$$

Digestion coefficients were then calculated in the usual manner.

RESULTS AND DISCUSSION

Experiment I (Trials 1 and 2)

Data collected prior to and during the 154-day performance-testing period are presented in Table I. Feed intake during the digestion trial and coefficients of apparent digestibility are presented in Table II.

Dry matter and organic matter digestibility coefficients were quite uniform regardless of whether they are compared within trials, between trials, or as averages of Trials I and II. When expressed as averages, the range was 61.84 to 63.55% and 62.50 to 64.16% for dry matter and organic matter, respectively. There was apparently no pattern or association of digestibility of dry matter or organic matter with previous rate of gain. The same was true in the case of nitrogen-free extract coefficients which ranged from 69.08 to 71.91%

Ether extract digestibility coefficients vary considerably with average values from 75.45 to 84.41%. However, this nutrient makes up a very small portion of the total ration and since variation in the chemical determination itself is relatively great it seems of little importance. Here again there is no indication of association with previous rate of gain.

Crude protein coefficients were very uniform for bulls 2, 4, 5, and 6 at approximately 60%, but bull number 1 showed an increase of about 3% above this group during each trial.

TABLE I

Performance Data on Bulls Used in Experiment I

Bull No.	Birth wt. lbs.	Weaning* Wt. lbs.	Age at weaning days	Av. Daily gain, birth to weaning lbs.	Av. Daily gain on performance test of 154 days. Lbs.	Feed/cwt. of gain lbs.	Final wt. lbs.
I	69	485	218	1.91	1.82	930	765
II	75	505	230	1.87	2.44	837	880
IV	82	465	196	1.95	1.66	1062	720
V	74	500	204	2.09	2.18	874	835
VI	70	450	203	1.87	2.14	783	780

TABLE II

Coefficients of Apparent Digestibility, Experiment I

Bull No.	Av.daily gain on performance test, lbs.	Body wt. lbs.	Intake 100 lbs. body wt. lbs.	Trial No.	Digestion Coefficients %					
					Dry Matter	Organic Matter	Protein	Ether Extract	Crude Fiber	N-Free Extract
II	2.44	965	2.0	1	61.41	62.09	59.28	81.96	37.78	68.86
				2	62.26	62.91	58.76	86.24	40.17	69.29
				av.	61.84	62.50	59.02	84.10	38.98	69.08
V	2.18	885	2.0	1	61.19	62.04	59.55	78.26	37.90	68.93
				2	64.35	65.37	61.14	84.28	42.34	72.18
				av.	62.77	63.71	60.35	81.27	40.12	70.56
VI	2.14	825	2.0	1	62.41	63.52	60.30	72.04	35.71	72.28
				2	61.60	62.55	48.19	78.85	33.17	71.54
				av.	62.01	63.04	59.25	75.45	34.44	71.91
I	1.82	835	1.75	1	64.21	64.87	63.00	82.59	38.63	72.15
				2	62.89	63.45	63.00	86.23	36.12	70.35
				av.	63.55	64.16	63.00	84.41	37.38	71.25
IV	1.66	755	2.0	1	63.81	64.29	62.13	80.00	36.36	72.30
				2	58.91	59.44	58.29	84.31	30.07	67.01
				av.	61.36	61.87	60.21	82.16	33.22	69.66

This difference is logically explained by the fact that this bull consumed only 1.75 lbs. of feed 100 lbs. of body weight during the experiment whereas the others consumed 2.0 lbs. It is accepted (Maynard, 1956) that a reduction in total feed consumption increases the utilization of nutrients. Although the differences were greatest for protein digestibility, there was a tendency for the digestibility coefficients for all nutrients to be highest with bull 1.

In the case of crude fiber there is a definite tendency for the apparent digestibility coefficients to be highest for the high-gaining bulls. This is especially noticeable if data from bull 1 are omitted. The two high-gaining bulls (2 and 5) show coefficients of digestibility for crude fiber, expressed as the average of Trials 1 and 2, of 38.98 and 40.12%, respectively, while the values from the two low-gaining bulls are 34.44% for bull 6 and 33.22% for bull 4. However, statistical examination of these data by analysis of variance does not give significance and makes it impossible to conclude that there is a real difference in ability to digest crude fiber.

Similar analyses of the data for all nutrients do not show statistically significant differences. Mean squares from analysis of variance tables are quite small but the fact that they are larger for within bulls than within trials strongly suggests that the difference between trials might be expected biological variation.

It would appear on the basis of the data from Experiment I that the difference in efficiency of feed utilization among bulls with different previous gaining ability as measured in the 154-day performance period were not later reflected in differences in digestive capacity but were due perhaps to differences in efficiency of feed utilization after digestion.

Table III

Digestion Trial [a] Data from Experiment II

Item	Bull Number 1[b]	2[b]	3[c]	4[c]
Dry Matter				
Consumption, gms.	9591	9688	10043	9255
Fecal excretion, gms.	3111	3125	2935	2745
Digested, gms.	6480	6563	7108	6510
Digestibility, %	67.56	67.74	70.78	70.34
Protein				
Consumption, gms.	1437	1451	1504	1386
Fecal excretion, gms.	432	426	411	385
Digested, gms.	1005	1025	1093	1001
Digestibility, %	69.94	70.64	72.67	72.22

a. Chromogen-chromic oxide method.

b. Received chromic oxide twice daily.

c. Received chromic oxide once daily.

Experiment II

Practically no difficulty was encountered in the collection of "grab" samples during the trial. After the first 24 hours the bulls became sufficiently accustomed to the procedure to allow collection without restraint by halter. No digestive disturbances or abnormalities of any kind were observed.

The digestion coefficients obtained for birdsfoot trefoil pasture are shown in Table III. These values, averaging approximately 69%, are slightly higher than those reported in the literature for forage of this type as determined by clipping forage and feeding it in conventional digestion trials. However, it seems probable that grazing animals select portions of the herbage which are more completely digested than the forage obtained by clipping (Hardison et al., 1951).

Chromic oxide excretions, as shown in Figures I, III, V, and VII, were within narrower limits for the bulls receiving chromic oxide twice daily than for the bulls capsuled only once each day. Standard deviations were 3.13 and 2.94 for the bulls capsuled twice daily as compared with 4.89 and 3.32 for the bulls receiving chromic oxide only once a day.

Standard deviations were also calculated on each bull's

chromic oxide excretion rate at each collection time. When these values were grouped by treatment (method of administration of chromic oxide) and compared by analysis of variance there was no significant difference between the bulls related to frequency of capsuling.

A definite diurnal variation of chromic oxide excretion was observed in all bulls, the pattern of which was very similar. High levels of excretion occurred in the morning and low rates occurred in the evening. This is in agreement with the work of Lancaster et al. (1954). In disagreement is the work of Hardison et al. (1953) and Mahaffey et al. (1954). These workers observed the lowest values in the morning and highest rates of excretion in the evening. The data reported here agree with all workers in that a composite of morning and evening samples closely approximates mean excretion rate. This indicates reliability of the method for calculation of fecal dry matter excretion, assuming no retention of the indicator.

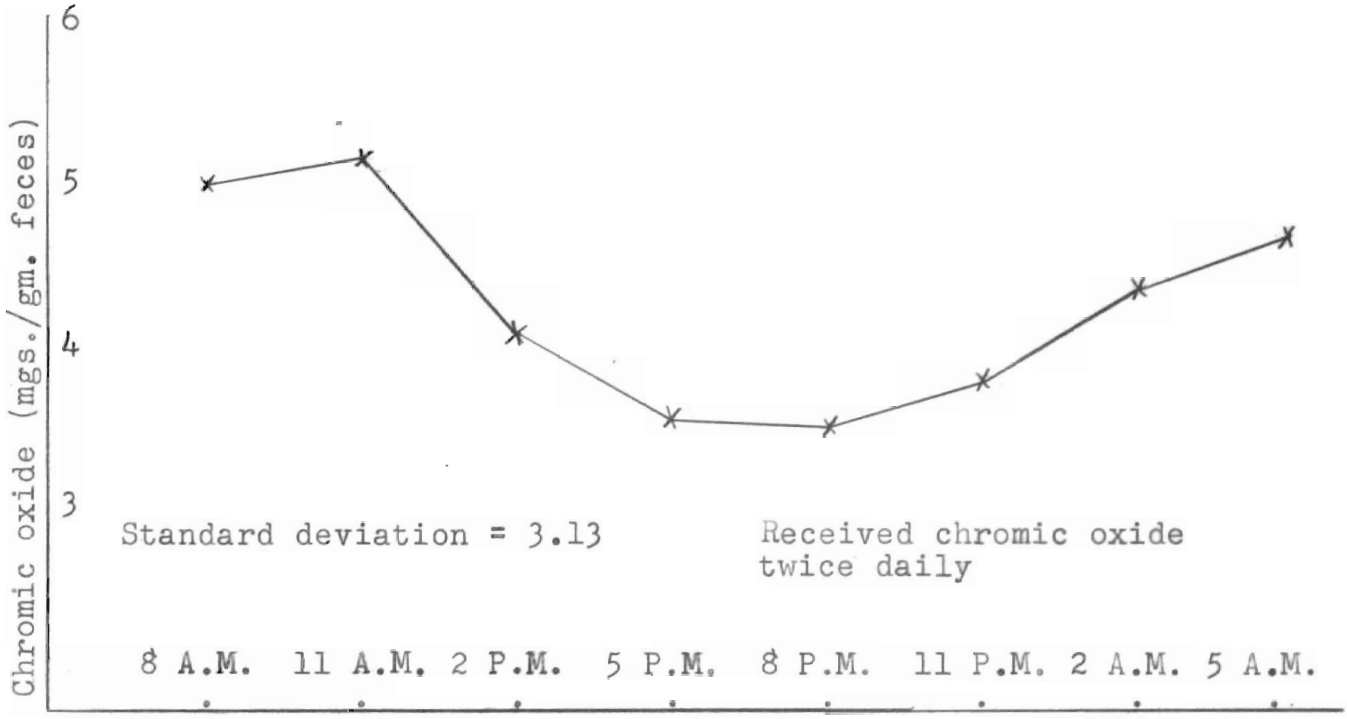

Figure I - Average chromic oxide excretion (Bull #1)

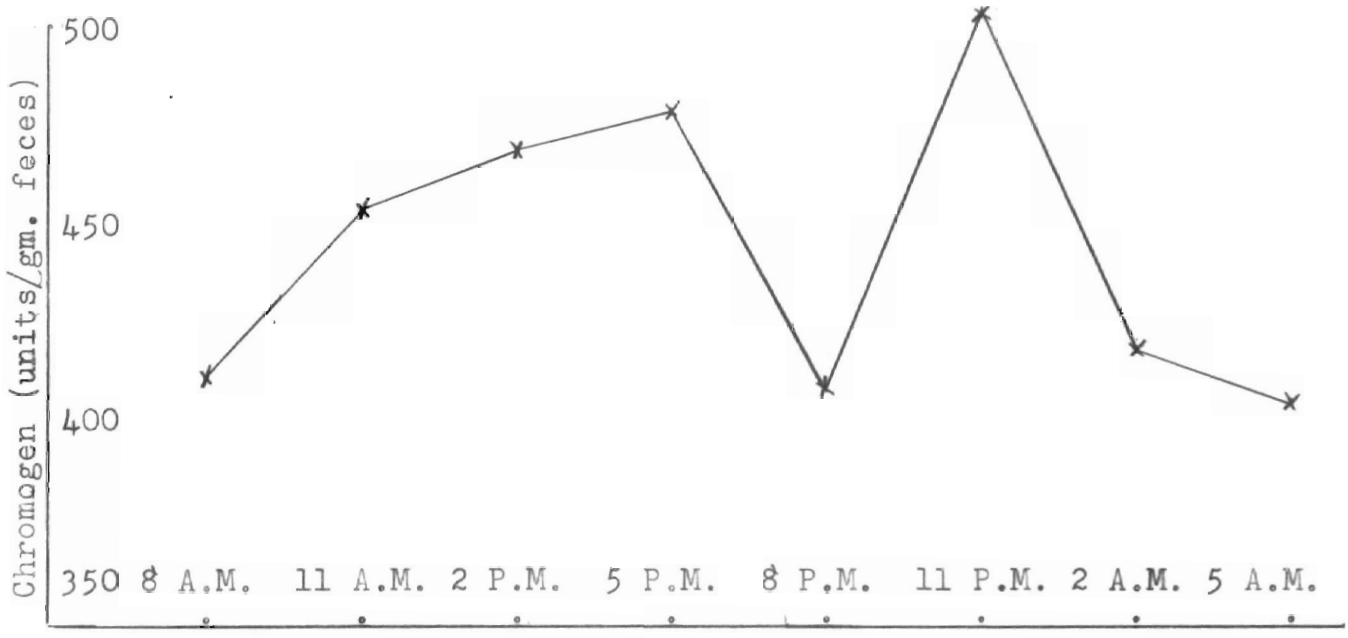

Figure II - Average chromogen excretion (Bull #1)

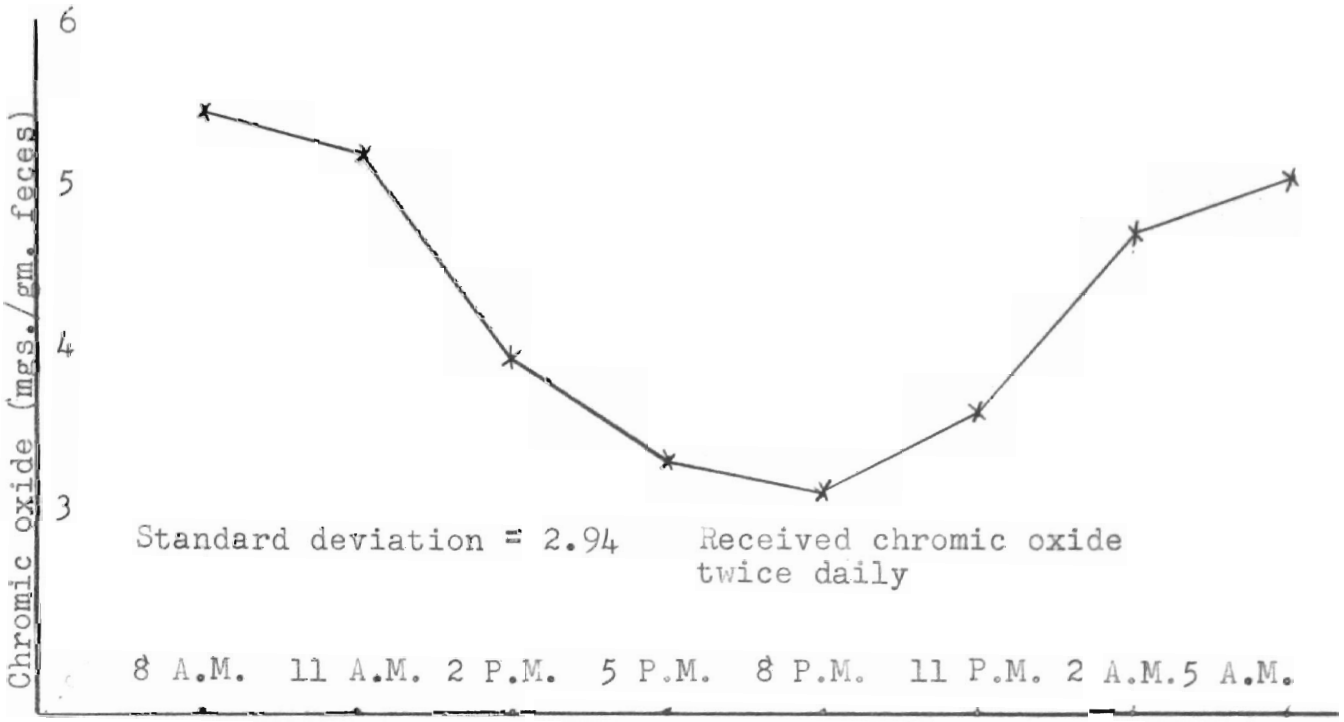

Figure III - Average chromic oxide excretion (Bull #2)

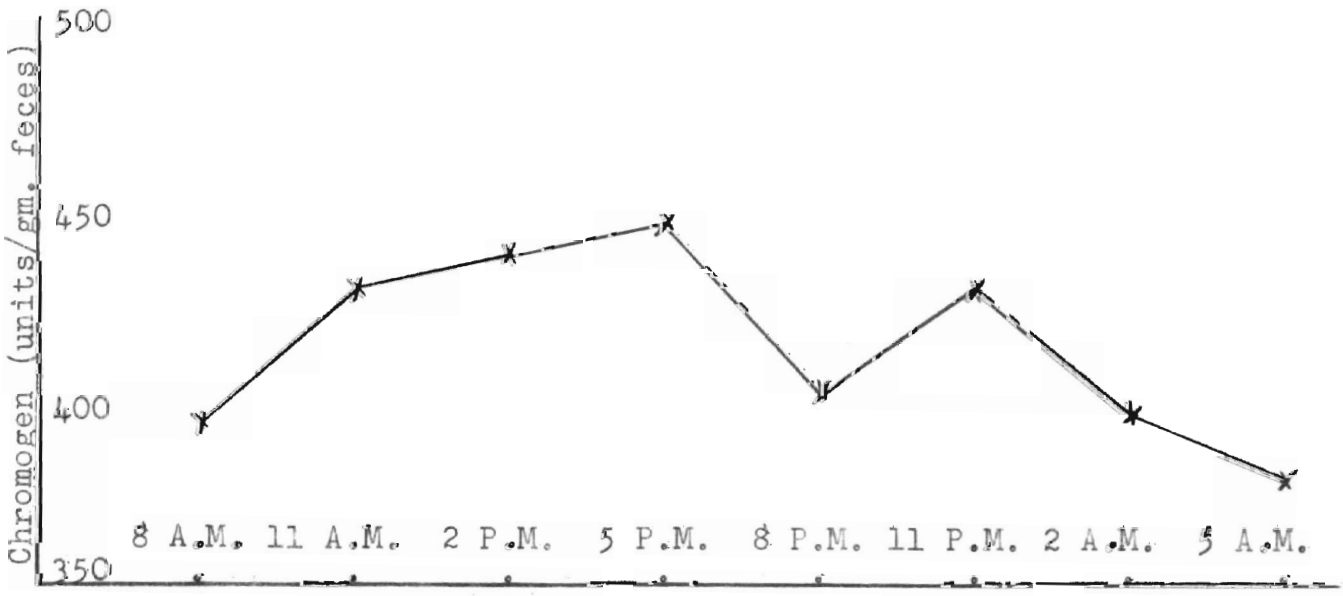

Figure IV - Average chromogen excretion (Bull #2)

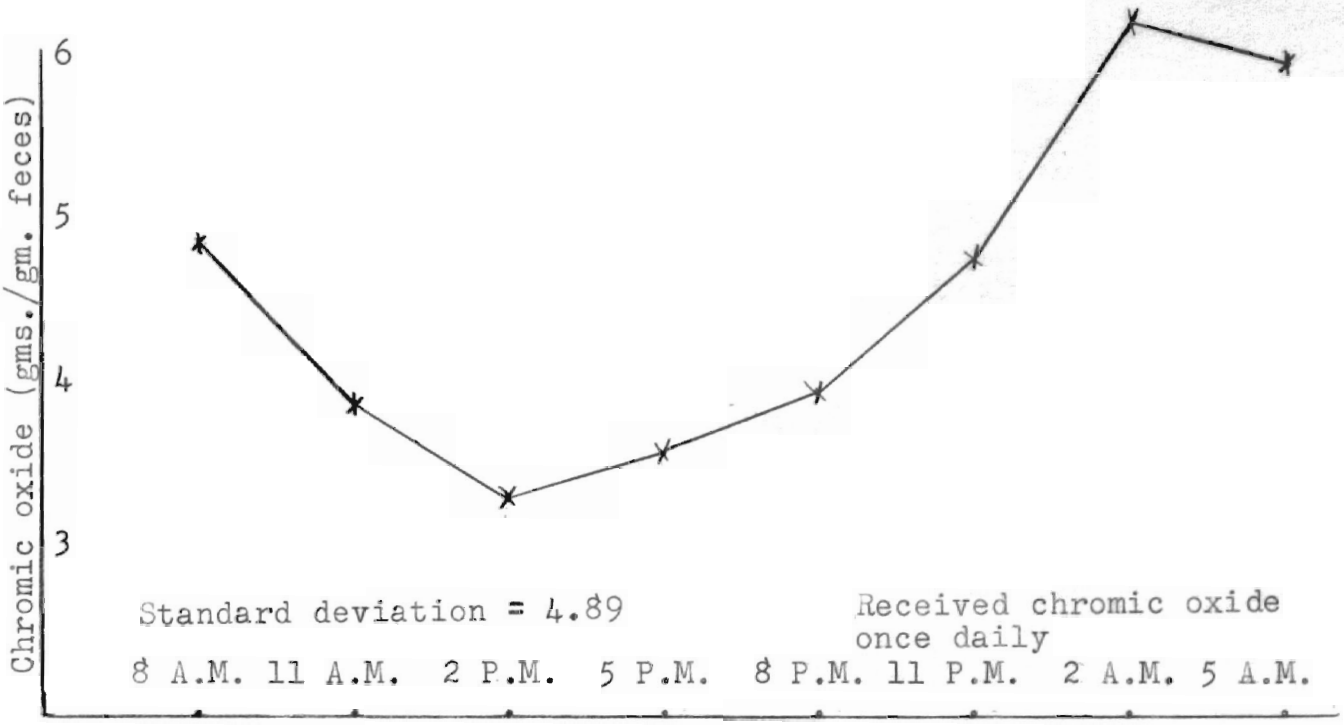

Figure V - Average chromic oxide excretion (Bull #3)

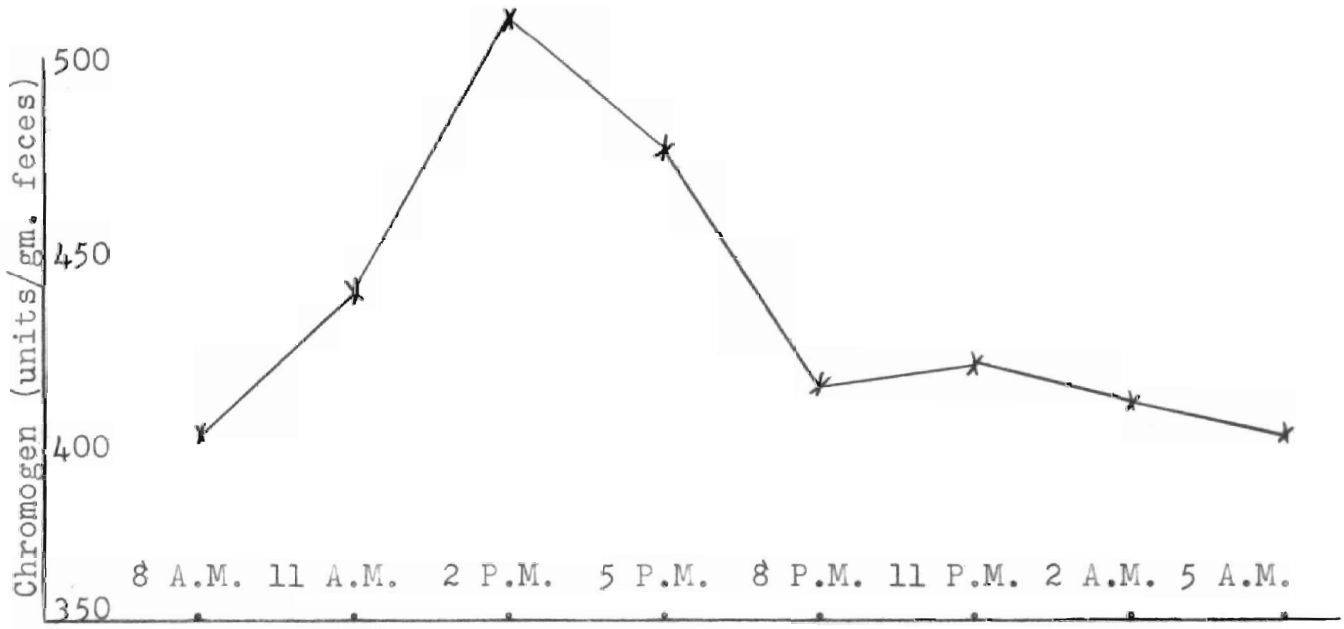

Figure VI - Average chromogen excretion (Bull #3)

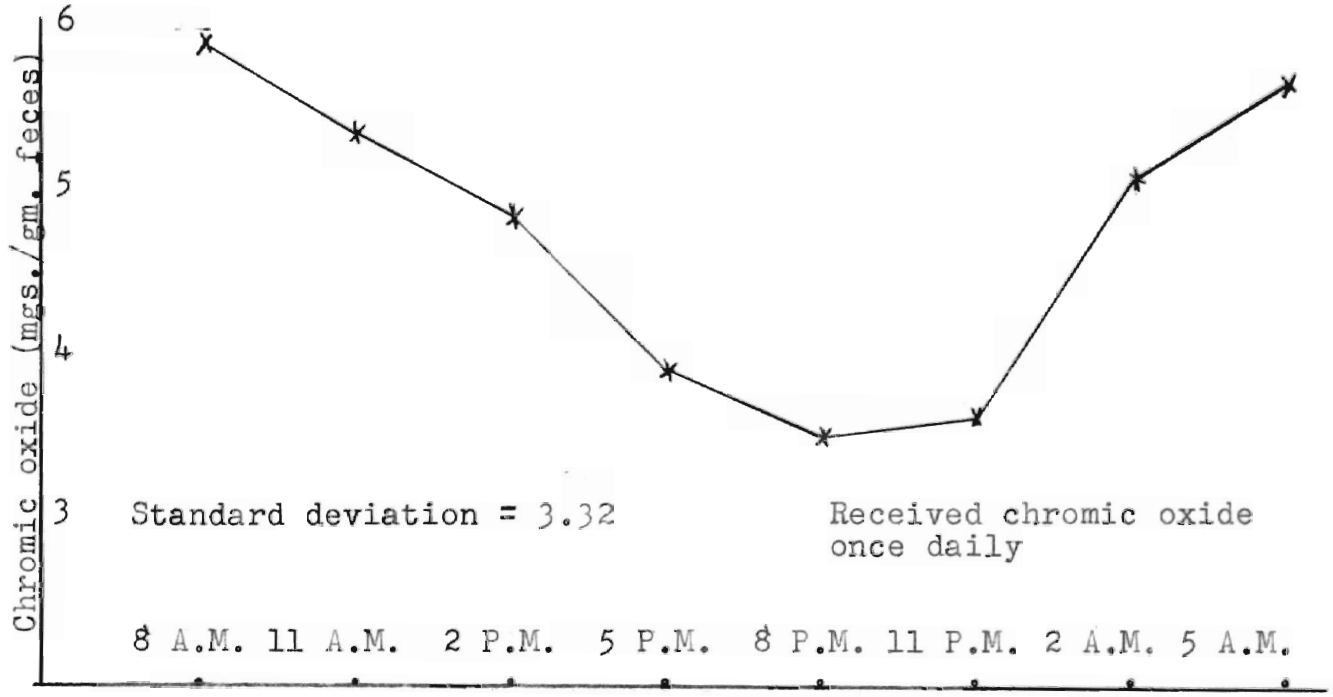

Figure VII - Average chromic oxide excretion (Bull #4)

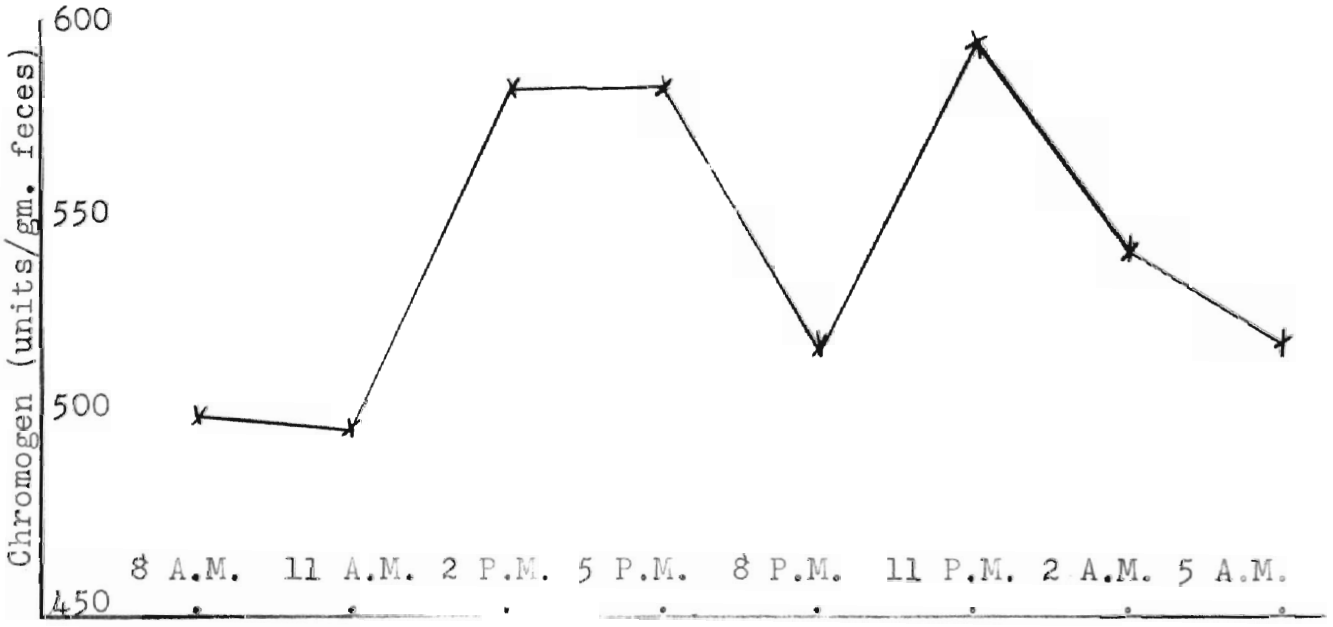

Figure VIII - Average chromogen excretion (Bull #4)

The excretion of chromogen in the feces is shown in Figures II, IV, VI, and VIII as averages for the various collection times throughout the trial. There is no apparent uniformity of pattern of chromogen excretion which strongly suggests inaccuracy in computation of forage consumption based on only one or two "grab" samples a day. Several "grab" samples might approximate mean excretion but of course greatly increases time and labor necessary.

These data indicate that chromic oxide can be used as a measure of fecal production or digestibility of nutrients by compositing morning and evening "grab" samples if intake of feed is known. However, chromogen excretion varies so greatly that consumption of forage based on so few samples might be greatly in error. The method is probably the best we have for evaluating pasture and can be used if sufficient number of samples of feces are taken.

As in Experiment I the digestion coefficients obtained are so similar, for both dry matter and protein, that any difference in performance of bulls seems due to variation in use of nutrients after absorption from the gut.

SUMMARY

The Hereford bulls used in this study had previously been fed a fattening ration for a 154-day period in drylot to determine differences in performance as measured by rate and efficiency of gain.

Four such performance-tested bulls were continued on the same feed mixture and allowed a ration of 2 lbs. of feed per hundred lbs. of body weight daily for 2 consecutive seven-day periods during which digestion coefficients for dry matter, organic matter, crude protein, ether extract, crude fiber, and nitrogen-free extract were determined by the conventional method.

Four similar bulls were placed on birdsfoot trefoil pasture and digestion coefficients for dry matter and crude protein were determined by the chromogen-chromic oxide technique based on samples collected over a ten-day period.

Differences between bulls in efficiency of digestion of various nutrients were not statistically significant. Thus, the results indicate that differences in previous performance, rate and efficiency of gain, were not due to differences in digestive capacity but were due perhaps to differences in efficiency of feed utilization after digestion.

Chromic oxide excretion apparently follows a definite daily pattern which permits its use as a measure of fecal

excretion of dry matter on the basis of composited morning and evening samples. Apparently chromic oxide can be administered either once or twice daily to provide an accurate estimate of its mean daily excretion from analysis of composited morning and evening samples of feces. Chromogen excretion was observed to be so variable as to prevent accurate estimates of mean daily chromogen excretion unless many samples were collected.

Chromogen values on both forage and feces were determined on strictly fresh material.

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APPENDIX

Fecal Analysis - Bull No. 1

Date	Time of Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
9-1-55	8 a.m.	3011	86.20	475	7.19	13.15	5.22
	11 a.m.	3013	83.39	646	6.68	14.14	4.72
	2 p.m.	3020	85.40	570	5.35	13.40	3.32
	5 p.m.	3021	87.39	513	5.62	13.30	4.89
	8 p.m.	3025	85.79	513	7.29	14.05	5.57
	11 p.m.	3029	83.71	536	4.95	13.15	5.34
9-2-55	2 a.m.	3033	85.59	467	7.54	12.79	4.26
	5 a.m.	3037	84.59	478	6.87	12.83	3.89
9-2-55	8 a.m.	3041	87.40	467	7.05	13.60	4.32
	11 a.m.	3045	84.45	502	8.08	14.90	4.42
	2 p.m.	3049	82.81	478	8.12	14.14	3.85
	5 p.m.	3053	86.87	455	7.32	14.00	2.77
	8 p.m.	3057	88.26	408	7.22	13.08	3.15
	11 p.m.	3061	86.74	478	5.31	13.76	3.77
9-3-55	2 a.m.	3065	86.97	455	4.99	13.94	4.66
	5 a.m.	3068	86.81	432	8.24	13.78	5.54
9-3-55	8 a.m.	3072	87.07	455	7.52	14.01	5.24
	11 a.m.	3076	86.57	443	7.62	12.09	3.15
	2 p.m.	3080	84.99	548	6.94	13.05	3.51
	5 p.m.	3084	84.88	560	7.78	12.08	2.42
	8 p.m.	3088	87.84	385	7.30	12.02	2.59
	11 p.m.	3092	84.53	525	7.43	13.57	3.14
9-4-55	2 a.m.	3096	88.98	315	7.85	11.99	4.27
	5 a.m.	3100	85.91	408	6.51	13.04	4.27
9-4-55	8 a.m.	3104	84.46	467	8.03	12.88	4.80
	11 a.m.	3108	85.62	455	7.64	12.70	4.64
	2 p.m.	3112	84.24	548	7.77	13.51	4.38
	5 p.m.	3116	84.81	502	5.34	13.67	3.13
	8 p.m.	3120	86.11	397	4.60	12.93	2.75
	11 p.m.	3124	84.08	432	9.23	12.79	3.49
9-5-55	2 a.m.	3128	85.15	408	7.96	13.23	4.28
	5 a.m.	3132	84.56	490	7.81	14.41	4.75
9-5-55	8 a.m.	3136	84.67	467	7.37	14.14	5.54
	11 a.m.	3140	84.10	478	7.62	12.70	5.28
	2 p.m.	3144	84.98	478	5.00	13.24	4.05

Fecal Analysis - Bull No. 1

Date	Time of Collection	Sample No.	Fresh Basis H_2O %	Fresh Basis Chromogen Units/gm. Feces	Air Dry Basis H_2O %	Air Dry Basis Prot. %	Air Dry Basis Cr_2O_3 mg/gm.
	5 p.m.	3148	85.00	583	5.10	15.23	4.23
	8 p.m.	3152	84.17	420	4.69	8.80*	3.54
	11 p.m.	3156		583			
9-6-55	2 a.m.	3160	84.30	420	4.72	12.93	4.63
	5 a.m.	3164	83.36	455	7.58	11.34	4.33
				*1/2 gm. - no duplicate			
9-6-55	8 a.m.	3168	83.84	397	4.66	13.11	5.62
	11 a.m.	3172	84.18	420	7.50	12.79	9.28
	2 p.m.	3176	83.13	478	8.15	13.15	4.38
	5 p.m.	3180	82.73	513			
	8 p.m.	3184	82.97	443			
	11 p.m.	3188	84.37	571			
9-7-55	2 a.m.	3192	83.43	502			
	5 a.m.	3196	81.48	373	5.20	12.65	5.11
	8 a.m.	3200	85.37	362	6.31	12.07	5.44
	11 a.m.	3204	84.30	397	7.76	11.89	5.96
	2 p.m.	3208	86.13	420	7.16	11.80	4.23
	5 p.m.	3212	84.01	467	7.61	12.34	3.77
	8 p.m.	3216	84.73	443	7.50	12.43	3.53
	11 p.m.	3220	81.15	513	6.97	12.25	3.33
9-8-55	2 a.m.	3224	83.88	420	6.99	12.43	4.90
	5 a.m.	3228	85.02	385	4.67	12.01	5.08
9-8-55	8 a.m.	3232	87.30	420	7.88	12.79	3.75
	11 a.m.	3236	84.83	443	8.00	13.05	4.82
	2 p.m.	3240	84.47	408	7.70	12.70	3.70
	5 p.m.	3244	84.57	385	7.27	11.84	3.00
	8 p.m.	3248	83.79	373	6.90	11.53	3.27
	11 p.m.	3252	83.75	420	6.47	11.71	3.57
9-9-55	2 a.m.	Missed this collection					
	5 a.m.	3256	84.78	327	8.30	13.45	4.22
9-9-55	8 a.m.	3260	84.07	350	7.29	12.34	5.02
	11 a.m.	3264	85.91	408	10.53	15.30	3.36
	2 p.m.	3268	83.84	455	8.02	13.29	4.30
	5 p.m.	3272	84.64	443	7.95	12.24	3.42
	8 p.m.	3276	85.47	373	7.07	12.88	3.19
	11 p.m.	3280	83.30	455	6.80	11.26	3.13
9-10-55	2 a.m.	3284	81.05	420	6.73	11.71	3.41
	5 a.m.	3288	74.08	362	7.11	11.71	4.25
	8 a.m.	3292	86.40	280	7.26	11.89	4.60
	11 a.m.	3296	84.06	350	7.20	11.98	4.90
	2 p.m.	3300	84.74	327	5.77	13.05	4.61
	5 p.m.	3304	85.86	350	6.60	13.06	3.38

Fecal Analysis - Bull No. 1

Date	Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
	8 p.m.	3308	86.38	338	6.34	12.06	3.16
	11 p.m.	3312	82.78	513	6.48	13.09	3.91
9-11-55	2 a.m.	3316	83.13	373			
	5 a.m.	3320	83.97	303	6.38	12.01	4.59

Fecal Analysis - Bull No. 2

Date	Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
9-1-55	8 a.m.	3009	87.58	466	5.91	11.07	5.15
	11 a.m.	3016	86.03	608	7.63	12.79	4.60
	2 p.m.	3019	86.80	532	6.84	13.00	3.75
	5 p.m.	3022	85.86	606	7.90	13.06	3.32
	8 p.m.	3026	87.35	490	7.08	13.56	3.04
	11 p.m.	3030	86.87	478	7.49	12.89	4.10
9-2-55	2 a.m.	3034	87.14	455	8.29	13.15	4.66
	5 a.m.	3038	86.11	536	6.91	12.02	4.10
9-2-55	8 a.m.	3042	86.16	513	4.62	14.40	5.13
	11 a.m.	3046	80.15	536	8.30	13.06	5.42
	2 p.m.	3050	85.75	443	7.32	13.09	4.15
	5 p.m.	3054	87.33	490	8.07	13.69	3.59
	8 p.m.	3058	85.31	502	5.57	13.94	3.67
	11 p.m.	3062	84.46	606	8.00	13.24	4.00
9-3-55	2 a.m.	3066	86.20	490	5.55	13.32	4.91
	5 a.m.	3069	87.43	443	8.17	14.02	5.50
9-3-55	8 a.m.	3073	86.94	420	8.46	12.43	6.06
	11 a.m.	3077	86.16	455	7.44	12.07	4.59
	2 p.m.	3081	87.38	420	7.10	12.06	3.24
	5 p.m.	3085	86.28	490	8.02	13.23	3.30
	8 p.m.	3089	87.12	432	8.22	11.71	2.85
	11 p.m.	3093	85.02	502	7.10	12.61	2.53
9-4-55	2 a.m.	3097	87.25	385	7.65	12.52	4.58
	5 a.m.	3101	86.49	397	6.57	12.06	5.57
	8 a.m.	3105	85.22	467	8.57	12.43	5.66
	11 a.m.	3109	85.73	443	7.95	13.06	5.34
	2 p.m.	3113	86.55	513	7.68	13.24	3.91
	5 p.m.	3117	82.96	490	8.33	12.79	3.47
	8 p.m.	3121	85.94	432	7.49	11.53	2.42
	11 p.m.	3125	83.77	432	7.56	12.68	3.02
9-5-55	2 a.m.	3129	85.29	408	4.33	12.74	4.10
	5 a.m.	3133	85.74	408	7.89	12.25	4.16
9-5-55	8 a.m.	3137	86.38	362	7.48	11.62	5.17
	11 a.m.	3141	84.81	432	4.94	12.00	5.41
	2 p.m.	3145	86.80	432	7.96	13.06	4.17
	5 p.m.	3149	86.28	432	4.98	13.39	3.24

Fecal Analysis - Bull No. 2

Date	Collection	Sample No.	Fresh Basis H_2O %	Fresh Basis Chromogen Units/gm. Feces	Air Dry Basis H_2O %	Air Dry Basis Prot. %	Air Dry Basis Cr_2O_3 mg/gm.
9-5-55	8 p.m.	3153	84.94	455	7.71	12.69	3.05
	11 p.m.	3157	83.85	455			
9-6-55	2 a.m.	3161	86.52	350	8.66	12.20	4.03
	5 a.m.	3165	84.57	397	8.19	12.43	4.06
	8 a.m.	3169	84.22	443	8.01	13.33	4.28
	11 a.m.	3173	85.47	397	8.39	12.79	4.12
	2 a.m.	3177	84.06	513	6.25	13.15	3.53
	5 a.m.	3181	84.79	420			
	8 p.m.	3185	86.41	385			
	11 p.m.	3189	84.75	420			
9-7-55	2 a.m.	3193	83.43	443			
	5 a.m.	3197	83.10	292	8.18	12.89	4.01
9-7-55	8 a.m.	3201	89.30	292	4.70	12.47	5.06
	11 a.m.	3205	84.56	373	4.21	13.48	5.47
	2 p.m.	3209	85.50	478	7.24	12.34	4.64
	5 p.m.	3213	85.30	432	5.07	12.36	3.69
	8 p.m.	3217	84.66	373	7.31	11.71	3.75
	11 p.m.	3221	83.40	362	5.09	12.56	4.71
9-8-55	2 a.m.	3225	86.96	327	6.92	12.07	4.90
	5 a.m.	3229	84.59	385	7.45	12.52	4.95
9-8-55	8 a.m.	3233	83.60	420	4.89	13.20	6.88
	11 a.m.	3237	84.98	350	4.85	12.60	5.06
	2 p.m.	3241	85.51	362	9.06	12.79	3.79
	5 p.m.	3245	86.57	373	7.56	11.44	3.37
	8 p.m.	3249	86.39	326	7.34	12.07	2.74
	11 p.m.	3253	85.76	362	7.33	11.80	2.94
9-9-55	2 a.m.	Missed this collection					
	5 a.m.	3257	85.12	315	7.17	11.53	4.23
	8 a.m.	3261	86.67	315	7.31	12.25	4.91
	11 a.m.	3265	85.30	432	7.60	12.87	4.72
	2 p.m.	3269	84.80	432	6.89	12.70	4.21
	5 p.m.	3273	87.20	350	7.31	12.07	2.79
	8 p.m.	3277	87.15	350	7.31	12.34	2.88
	11 p.m.	3281	87.19	338	8.00	18.85	3.38
9-10-55	2 a.m.	3285	84.96	385	7.32	12.88	3.85
	5 a.m.	3289	85.29	315	7.43	11.62	4.56
9-10-55	8 a.m.	3293	87.28	280	6.97	11.80	5.76
	11 a.m.	3297	85.42	327	8.19	11.35	6.23
	2 p.m.	3301	86.87	303	6.62	11.05	4.06
	5 p.m.	3305	87.64	303	6.66	14.90	3.32
	8 p.m.	3309	86.90	315	6.73	11.90	3.16
	11 p.m.	3313	86.54	315	6.35	11.50	3.75

Fecal Analysis - Bull No. 2

Date	Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
9-11-55	2 a.m.	3317	85.08	350			
	5 a.m.	3321	83.96	327	6.65	11.05	4.06

Fecal Analysis - Bull No. 3

Date	Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
9-1-55	8 a.m.	3010	94.46	494	7.64	12.24	4.32
	11 a.m.	3015	86.24	608	7.93	13.96	3.79
	2 p.m.	3017	83.56	751	82.1	13.24	2.56
	5 p.m.	3023	87.11	571	7.52	13.60	2.38
	8 p.m.	3027	89.36	432	8.02	13.33	3.44
	11 p.m.	3031	86.50	478	7.56	12.20	4.10
9-2-55	2 a.m.	3035	86.46	490	7.36	13.24	6.00
	5 a.m.	3039	87.58	513	5.01	13.57	6.48
9-2-55	8 a.m.	3043	85.18	536	7.38	12.80	5.60
	11 a.m.	3047	84.59	536			
	2 p.m.	3051	84.82	676	8.52	14.95	4.91
	5 p.m.	3055	85.64	548	8.19	13.60	3.77
	8 p.m.	3059	85.77	595	7.64	14.60	3.79
	11 p.m.	3063	86.59	548	7.80	14.50	4.59
9-3-55	2 a.m.	3066B	86.54	490	7.61	14.30	6.30
	5 a.m.	3070	86.47	467	8.42	12.88	6.59
9-3-55	8 a.m.	3074	86.05	536	8.77	13.51	5.66
	11 a.m.	3078	86.36	478	7.02	14.10	4.07
	2 p.m.	3082	86.24	560	8.11	13.97	3.12
	5 p.m.	3086	81.82	560	10.50	10.86	2.53
	8 p.m.	3090	87.60	490	7.30	14.10	2.62
	11 p.m.	3094	85.78	478	7.30	13.33	3.95
9-4-55	2 a.m.	3098	89.12	350	7.99	12.70	6.24
	5 a.m.	3102	86.39	443	6.40	13.00	6.44
	8 a.m.	3106	86.74	478	8.06	13.96	5.88
	11 a.m.	3110	86.40	443	7.90	12.52	4.42
	2 p.m.	3114	87.88	502	6.83	13.50	3.89
	5 p.m.	3118	85.51	525	5.40	14.96	3.01
	8 p.m.	3122	86.88	455	7.92	12.97	2.59
	11 p.m.	3126	85.29	455	8.91	13.42	3.02
9-5-55	2 a.m.	3130	87.56	397	7.85	13.33	6.38
	5 a.m.	3134	88.45	362	7.92	12.34	6.07
9-5-55	8 a.m.	3138	86.82	373	7.92	12.16	6.01
	11 a.m.	3142	85.75	408	4.48	13.76	5.13
	2 p.m.	3146	86.35	467	7.03	12.79	3.37
	5 p.m.	3150	87.26	432	5.16	13.76	3.08

Fecal Analysis - Bull No. 3

Date	Collection	Sample No.	Fresh Basis H_2O %	Fresh Basis Chromogen Units/gm. Feces	Air Dry Basis H_2O %	Air Dry Basis Prot. %	Air Dry Basis Cr_2O_3 mg/gm.
9-5-55	8 p.m.	3154	86.21	408	4.73	12.72	3.47
	11 p.m.	3158	86.43	420			
9-6-55	2 a.m.	3162	89.00	420	3.98	13.20	5.92
	5 a.m.	3166	86.33	397	5.23	12.46	6.37
9-6-55	8 a.m.	3170	86.66	362	5.23	12.46	4.86
	11 a.m.	3174	85.67	373	7.31	12.43	3.75
	2 p.m.	3178	85.86	536	6.96	15.58	3.09
	5 p.m.	3182	85.98	490			
	8 p.m.	3186	87.97	350			
	11 p.m.	3190	85.31	408			
9-7-55	2 a.m.	3194	85.30	397			
	5 a.m.	3198	86.74	420	4.52	12.01	5.55
	8 a.m.	3202	88.16	338	7.04	12.70	4.48
	11 a.m.	3206	84.63	443	8.01	13.60	4.35
	2 p.m.	3210	84.61	525	7.91	13.41	3.39
	5 p.m.	3214	84.52				
	8 p.m.	3218	86.01	408	7.17	11.80	2.80
	11 p.m.	3222	87.09	350	7.31	12.25	5.50
9-8-55	2 a.m.	3226	81.14	373	7.16	11.80	5.92
	5 a.m.	3230	86.04	408	7.52	11.98	5.28
9-8-55	8 a.m.	3234	87.75	327	8.55	12.60	4.86
	11 a.m.	3238	87.31	350	5.34	12.83	3.03
	2 p.m.	3242	38.89	408	9.51	12.25	2.28
	5 p.m.	3246	87.22	385	7.51	12.07	9.28
	8 p.m.	3250	89.12	268	6.89	12.07	9.02
	11 p.m.	3254	88.01	303	6.97	11.53	6.76
9-9-55	2 a.m.	Missed this collection					
	5 a.m.	3258	86.53	327	8.81	12.34	3.00
	8 a.m.	3262	87.16	315	6.25	12.40	2.20
	11 a.m.	3266	86.68	373	6.27	14.40	2.71
	2 p.m.	3270	87.74	478	6.24	12.30	2.05
	5 p.m.	3274	86.59	432	7.88	14.32	1.84
	8 p.m.	3278	86.40	362	7.50	12.97	3.13
	11 p.m.	3282	86.54	315	6.72	12.25	4.69
9-10-55	2 a.m.	3286	83.70	397	6.96	12.97	5.65
	5 a.m.	3290	87.18	315	8.22	12.25	5.43
9-10-55	8 a.m.	3294	87.21	315	7.29	12.07	3.90
	11 a.m.	3298	85.05	362	8.74	13.15	3.50
	2 p.m.	3302	84.84	408	6.97	13.50	3.63
	5 p.m.	3306	86.54	362	6.17	12.50	2.11
	8 p.m.	3310	85.95	397	6.25	14.10	3.12
	11 p.m.	3314	84.59	467	6.17	12.50	3.47

Fecal Analysis - Bull No. 3

Date	Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
9-11-55	2 a.m.	3318	85.16	397			
	5 a.m.	3322	83.51	385			

Fecal Analysis - Bull No. 4

Date	Collection	Sample No.	Fresh Basis H_2O %	Fresh Basis Chromogen Units/gm. Feces	Air Dry Basis H_2O %	Air Dry Basis Prot. %	Air Dry Basis Cr_2O_3 mg/gm.
9-1-55	8 a.m.	3012	85.30	656	7.73	12.93	6.31
	11 a.m.	3014	85.52	703	6.74	13.30	5.05
	2 p.m.	3018	83.82	684	5.20	15.14	4.20
	5 p.m.	3024	84.63	735	6.99	13.60	3.59
	8 p.m.	3028	85.33	618	7.13	14.50	3.53
	11 p.m.	3032	83.33	770	8.09	13.87	3.70
9-2-55	2 a.m.	3036	84.15	595	5.10	13.85	5.92
	5 a.m.	3040	83.64	583	6.52	13.40	6.89
9-2-55	8 a.m.	3044	82.87	548	7.20	13.37	6.36
	11 a.m.	3048	81.61	525	7.41	13.10	5.88
	2 p.m.	3052	80.43	653	7.88	13.67	4.91
	5 p.m.	3056	81.23	630	8.12	13.51	4.06
	8 p.m.	3060	82.89	606	5.31	14.19	3.01
	11 p.m.	3064	84.60	595	7.83	12.25	3.44
9-3-55	2 a.m.	3067	84.19	571	7.45	14.11	4.42
	5 a.m.	3071	82.40	618	8.13	13.06	5.60
9-3-55	8 a.m.	3075	84.91	536	7.92	12.07	5.90
	11 a.m.	3079	85.14	490	6.56	12.10	4.28
	2 p.m.	3083	86.09	571	6.93	12.80	3.76
	5 p.m.	3087	83.56	665	7.35	13.80	3.45
	8 p.m.	3091	84.79	536	6.98	12.40	2.84
	11 p.m.	3095	82.97	618	7.41	12.97	3.12
9-4-55	2 a.m.	3099	83.84	606	7.56	12.70	5.22
	5 a.m.	3103	83.77	513	6.56	12.00	5.99
	8 a.m.	3107	84.11	536	7.68	10.98	5.85
	11 a.m.	3111	84.22	467	7.93	12.25	5.28
	2 p.m.	3115	83.67	560	7.72	12.70	4.58
	5 p.m.	3119	84.75	513	4.93	13.57	3.33
	8 p.m.	3123	85.01	536	5.30	16.51	*3.49
	11 p.m.	3127	82.32	513	4.94	12.81	3.14
9-5-55	2 a.m.	3131	82.90	490	7.61	12.16	5.23
	5 a.m.	3135	83.17	490	4.96	12.72	5.36
				*10 grams of fresh used.			
9-5-55	8 a.m.	3139	82.10	502	7.56	12.61	6.01
	11 a.m.	3143	82.06	536	7.49	13.32	5.24
	2 p.m.	3147	80.43	676	4.78	13.40	5.26

Fecal Analysis - Bull No. 4

Date	Collection	Sample No.	Fresh Basis H_2O %	Fresh Basis Chromogen Units/gm. Feces	Air Dry Basis H_2O %	Air Dry Basis Prot. %	Air Dry Basis Cr_2O_3 mg/gm.
9-5-55	5 p.m.	3151	82.91	595	4.06	13.85	4.15
	8 p.m.	3155	81.49	536	4.93	12.83	3.39
	11 p.m.	3159	83.43	536			
9-6-55	2 a.m.	3163	78.80	513	7.64	13.33	5.69
	5 a.m.	3167	83.68	467	8.29	12.70	6.11
9-6-55	8 a.m.	3171	83.38	467	5.13	12.72	5.82
	11 a.m.	3175	82.59	478	7.47	12.16	5.38
	2 p.m.	3179	81.39	606	6.66	15.67	4.96
	5 p.m.	3183	81.24	583			
	8 p.m.	3187	85.55	443			
	11 p.m.	3191	81.09	711	10.54	32.6*	3.85
9-7-55	2 a.m.	3195	80.06	583			
	5 a.m.	3199	81.35	560	4.57		4.30
					*10 grams of fresh used.		
9-7-55	8 a.m.	3203	85.28	420	6.93	12.88	5.28
	11 a.m.	3207	84.71	397	5.02	12.89	5.67
	2 p.m.	3211	82.46	606	10.53	27.80*	5.87
	5 p.m.	3215	82.87	653	10.48	15.16	3.26
	8 p.m.	3219	82.08	478	4.64	12.93	4.31
	11 p.m.	3223	81.24	502	7.27	12.70	4.42
9-8-55	2 a.m.	3227	82.71	536	7.25	13.69	5.18
	5 a.m.	3231	82.79	490	7.77	12.70	6.08
					*10 grams of fresh used.		
9-8-55	8 a.m.	3235	83.28	455	7.64	11.53	5.44
	11 a.m.	3239	73.40	413	7.63	12.88	5.86
	2 p.m.	3243	83.75	502			
	5 p.m.	3247	80.61	513	7.63	12.88	4.91
	8 p.m.	3251	81.37	525	6.81	12.97	4.02
	11 p.m.	3255	81.14	618	6.74	13.15	3.98
9-9-55	2 a.m.	Missed this collection					
	5 a.m.	3259	79.61	583	7.10	12.43	5.02
	8 a.m.	3263	83.34	443	5.98	12.40	6.44
	11 a.m.	3267	82.06	443	6.80	13.10	5.61
	2 p.m.	3271	84.11	513	7.14	13.60	4.66
	5 p.m.	3275	86.33	467	7.05	12.88	3.97
	8 p.m.	3279	85.02	490	6.89	12.61	3.37
	11 p.m.	3283	82.39	502	7.36	12.25	3.45
9-10-55	2 a.m.	3287	82.99	467	7.23	12.88	4.13
	5 a.m.	3291	83.62	478	6.93	13.69	6.04
9-10-55	8 a.m.	3295	83.66	408	7.07	12.79	6.44
	11 a.m.	3299	81.96	455		12.52	6.24

Fecal Analysis - Bull No. 4

Date	Collection	Sample No.	Fresh Basis		Air Dry Basis		
			H_2O %	Chromogen Units/gm. Feces	H_2O %	Prot. %	Cr_2O_3 mg/gm.
9-10-55	2 p.m.	3303	83.82	420	6.71	11.70	5.05
	5 p.m.	3307	82.90	432	6.33	12.80	3.53
	8 p.m.	3311	82.55	443	6.63	13.00	3.44
	11 p.m.	3315	82.11	560	6.61	13.50	3.47
9-11-55	2 a.m.	3319	80.05	583			
	5 a.m.	3323	80.71	490			

VITA

Robert Allen Long

Candidate for the Degree of

Doctor of Philosophy

Thesis: A COMPARISON OF THE EFFICIENCY OF DIGESTION OF NUTRIENTS BY PERFORMANCE TESTED BULLS AS MEASURED BY CONVENTIONAL AND INDIRECT TECHNIQUES

Major Field: Animal Nutrition

Biographical:

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