

BULLETIN 405
OCTOBER 1970

# Some Relationships between Chemical Composition and Nutritive Qualities of Coastal Bermudagrass Hays for Dairy Cows

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First Printing 4M, October 1970

# Some Relationships between Chemical Composition and Nutritive Qualities of Coastal Bermudagrass Hays for Dairy Cows

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COASTAL BERMUDAGRASS HAY is an important forage in the feeding program of Alabama dairymen. Nutritive quality of this grass hay varies widely from lot to lot. Thus, to effectively formulate a ration that will maintain milk production, dairymen need to know the nutritional qualities of each lot of Coastal bermudagrass hay. This requires that the relationship be known between total nutritive value and some easily measurable property of the hays. To meet this need a study was conducted to determine the variation in nutritive value of Coastal bermudagrass hay and to determine the value of certain chemical entities in characterizing total nutritive value of these hays.

## GENERAL EXPERIMENTAL PROCEDURES

### Description of Hays

Fifteen lots of Coastal bermudagrass hay representing a wide range in nutritional qualities were used in a series of digestion trials and hay intake and milk production experiments. Hays 11 and 12 were first cuttings harvested June 3 and June 30, respectively. Hays 1 and 13 were second cuttings and hays 2 and 3 were third cuttings. The other lots were purchased on the open market without knowledge or regard to time of cutting.

### Chemical Methodology

A core sample was taken from 20 or more bales of each of the 15 Coastal bermudagrass hays and composited for chemical analyses. The moisture, crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), ash, starch, calcium

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(Ca), manganese (Mn), sulfur (S), chlorine (Cl), and iodine (I) contents of the hays were determined by official methods *(3)*. The method described by Crampton and Maynard *(12)* was used to determine cellulose, and lignin was determined by the sulfuric acid method *(13)*. Sugars, phosphorous (P), and magnesium (Mg) were determined colorimetrically, sodium (Na) and potassium (K) by flame photometry, and copper (Cu), iron (FE), and zinc (Zn) by x-ray spectrography. Cold water extractables were determined by measuring the loss in dry matter after steeping 24 hours at room temperature. Hot water extractables were determined by refluxing a sample of the hay in distilled water for 1 hour, and measuring the loss in dry matter. The proximate composition *(3)* and lignin *(13)* of fecal matter were determined by the methods used for analyzing the hays. Volatile fatty acids (VFA) in rumen fluid were determined by gas chromatography. Fat content of milk was determined by the Babcock method and energy content of milk by oxygen bomb calorimetry.

### Digestibility Methodology

Digestible dry matter (DDM) of hays 1 to 7 was determined initially by the chromogen method *(28)*. This method gave low digestibility values. Therefore, DDM of hays 1 to 7 subsequently was determined by a combination of lignin ratio and total collection methods with four dairy animals per hay. The total collection method with three steers per hay was employed to determine digestibilities of hays 8 through 15. All total collections were made during 7-day periods following 7-day preliminary feeding periods. Total digestible nutrients (TDN) were determined in the usual manner, i.e., TDN $=$ digestible protein $+$ (digestible EE $\times$ 2.25) $+$ digestible CF $+$ digestible NFE. The ENE values of the hays were calculated from TDN contents as described by Moore, et al. *(25)*.

### Milk Production Experiments

Three continuous-design lactation experiments were carried out with the Coastal bermudagrass hays during different years to evaluate the relationships between indicators of hay quality and milk production. In Lactation Experiment I, hays 1 to 7 were the test forages; because of limited quantities of the hays, only two cows were fed each of these during a 38-day period. In Lactation Experiment II, hays 8 to 10 were the test forages and each was fed to five lactating cows during 42-day intervals. Hays 11 to 15 were the test forages for Lactation Experiment III and each was fed to five cows during a 35-day period. Feed allowances of the cows provided 110 per cent of Morrison's recommended TDN allowances in which half of the air-dry ration was hay and the other half was a concentrate mixture containing 16 per cent crude protein. The cows were individually fed twice daily and amounts fed and refused were recorded. The ratio of hay to concentrates consumed was variable because of some refusal of hays.

During the experiments all cows were housed in individual stalls in a barn bedded with wood shavings. The cows were milked twice daily and the amount produced by each cow at each milking was recorded. Water was available at all times.

Rumen fluid samples were collected approximately 2 hours after the morning feeding, from cows fed hays 8 through 15, to evaluate relationships among hay quality, rumen fluid VFA ratios, and milk production.

To obtain an overall evaluation of feed energy utilization in the lactation experiments, the energy content of milk produced was determined and body weight changes were converted to energy equivalent by using the factor of 1,900 kcal. per pound of gain *(14)*. Body weight changes were determined by differences in 3-day average weights taken at beginning and end of each experiment.

### Hay Intake Data

Amounts of hays eaten daily by cows on the lactation experiments were used to evaluate relationships between intakes and chemical composition of the 15 Coastal bermudagrass hays. Additionally, the relationships between intake of hays 11 through 15 and chemical entities were evaluated by feeding the hays as the exclusive diet of steers. Each steer was fed each hay in one of the five 2-week experimental periods. To ensure that quantity of hay available would not limit intake, the steers were fed an excess of the hays.

## RESULTS AND DISCUSSION

### Composition of Coastal Bermudagrass Hays

The proximate composition, cellulose, lignin, starch, cold and hot water solubles, and total sugar contents of the 15 Coastal bermudagrass hays are presented in Table 1 and mineral composition is recorded in Table 2.

The 15 hays averaged 0.48 per cent calcium and 0.26 per cent phosphorus. This indicates that, when feeding Coastal bermudagrass hays as the only roughage, a supplement of calcium often will be needed for lactating cows and a supplement of phosphorous will be needed for normal growth of dairy heifers weigh-

TABLE 1. PROXIMATE COMPOSITION, CELLULOSE, STARCH, LIGNIN, COLD AND HOT WATER SOLUBLES, AND TOTAL SUGAR CONTENTS OF 15 COASTAL BERMUDAGRASS HAYS, DRY-MATTER BASIS

| Hay No. | Proximate composition | | | | | Cellulose | Starch | Lignin | CWS | HWS | Total sugar |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CP | CF | EE | Ash | NFE | | | | | | |
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* |
| 1 | 9.8 | 32.7 | 2.1 | 5.9 | 49.5 | 31.7 | ---- | 9.9 | ---- | ---- | 1.4 |
| 2 | 8.5 | 34.5 | 2.1 | 4.1 | 50.8 | 31.9 | ---- | 11.4 | 20.1 | 18.6 | 1.3 |
| 3 | 7.1 | 32.9 | 2.1 | 4.1 | 53.8 | 31.4 | 3.0 | 10.7 | 18.7 | 20.0 | 0.8 |
| 4 | 12.1 | 36.9 | 2.2 | 5.8 | 43.0 | 30.7 | 1.8 | 10.5 | 22.0 | 20.6 | 0.9 |
| 5 | 14.7 | 34.2 | 2.0 | 5.0 | 44.1 | 31.2 | ---- | 10.2 | 26.2 | 23.2 | 2.7 |
| 6 | 13.4 | 32.7 | 2.9 | 5.6 | 45.4 | 31.2 | ---- | 9.6 | 22.0 | 24.2 | 3.2 |
| 7 | 10.8 | 34.4 | 2.5 | 5.9 | 46.4 | 31.4 | ---- | 9.7 | ---- | ---- | 1.5 |
| 8 | 6.7 | 30.9 | 2.0 | 3.8 | 56.6 | 30.9 | 2.2 | 10.5 | 21.4 | 23.7 | 2.3 |
| 9 | 6.1 | 31.9 | 2.0 | 4.2 | 55.8 | 31.0 | 3.1 | 10.7 | 19.2 | 25.3 | 1.7 |
| 10 | 6.9 | 32.0 | 2.0 | 3.7 | 55.4 | 31.8 | 2.2 | 11.3 | 21.7 | 20.6 | 2.2 |
| 11 | 14.0 | 28.5 | 2.8 | 6.2 | 48.5 | 27.8 | 1.7 | 9.3 | 28.6 | 30.1 | 3.9 |
| 12 | 11.8 | 32.0 | 2.1 | 5.9 | 48.2 | 30.3 | 1.0 | 10.5 | 25.0 | 23.4 | 1.6 |
| 13 | 10.5 | 31.4 | 2.3 | 5.3 | 50.5 | 30.6 | 1.1 | 10.1 | 26.4 | 25.9 | 3.4 |
| 14 | 9.6 | 31.6 | 2.0 | 5.4 | 51.4 | 31.3 | 1.9 | 9.6 | 25.7 | 25.9 | 3.4 |
| 15 | 7.0 | 32.6 | 1.7 | 5.3 | 53.4 | 32.4 | 2.2 | 10.1 | 22.4 | 22.9 | 2.6 |
| Mean | 9.9 | 32.6 | 2.2 | 5.1 | 50.2 | 31.0 | 2.0 | 10.3 | 23.1 | 23.4 | 2.2 |

TABLE 2. MINERAL COMPOSITION OF THE 15 COASTAL BERMUDAGRASS HAYS, DRY-MATTER BASIS

| Hay No. | Ca | P | Mg | Na | K | S | Cl | Mn | Fe | Zn | I |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *P.p.m.* | *P.p.m.* | *P.p.m.* | *P.p.m.* |
| 1 | 0.97 | 0.23 | 0.14 | ---- | ---- | 0.25 | ---- | ---- | ---- | ---- | ---- |
| 2 | .52 | .17 | .08 | 0.04 | 0.73 | .16 | 0.26 | ---- | 185 | 41 | ---- |
| 3 | .62 | .15 | .09 | ---- | .51 | .16 | .16 | 53 | 213 | 47 | ---- |
| 4 | .57 | .27 | .21 | .08 | 2.22 | .24 | .52 | 311 | 280 | 42 | ---- |
| 5 | .34 | .27 | .19 | .07 | 1.32 | .26 | .24 | 118 | 120 | 41 | 1.3 |
| 6 | .33 | .25 | .09 | .06 | 1.26 | .24 | .33 | 159 | 136 | 50 | .7 |
| 7 | .29 | .28 | .22 | .08 | .66 | .23 | .34 | 111 | 154 | 48 | 1.0 |
| 8 | .35 | .22 | .11 | .02 | .67 | .15 | .21 | 84 | 116 | 28 | 4.1 |
| 9 | .42 | .27 | .11 | .02 | .60 | .20 | .26 | 84 | 125 | 28 | 1.1 |
| 10 | .36 | .22 | .15 | .04 | .69 | .09 | .27 | 73 | 131 | 35 | 1.3 |
| 11 | .66 | .41 | .16 | .24 | 1.52 | .28 | .65 | 64 | 126 | 28 | 1.4 |
| 12 | .58 | .29 | .16 | .09 | 1.46 | .27 | .58 | 74 | 213 | 24 | .7 |
| 13 | .49 | .30 | .17 | .16 | .98 | .32 | .45 | 31 | 141 | 31 | 4.5 |
| 14 | .43 | .29 | .15 | .16 | .95 | .21 | .49 | 96 | 113 | 26 | 9.0 |
| 15 | .32 | .22 | .10 | .06 | 1.40 | .22 | .46 | 95 | 97 | 26 | .6 |
| Mean | .48 | .26 | .14 | .09 | 1.07 | .22 | .37 | 104 | 154 | 35 | 2.3 |

ing less than 400 pounds *(11)*. The magnesium content was relatively low in hays, 2, 3, 6, 8, 9, and 15, yet each of these would have met the minimum requirement (0.07 per cent air-dry basis) of this element for growing heifers *(7)*. As with most feed, average sodium content (0.09 per cent) of the hays was inadequate to meet the maintenance requirements of dairy cows *(11)* and, on the average, cows would need to eat 2 pounds of Coastal hay per 100 pounds of body weight to obtain adequate chlorine for maintenance *(11)*.

The amounts of manganese, iron, zinc, and iodine found in the hays, although variable, would be expected to meet the minimum requirements of cattle *(30)*. Since the hay samples were ground through a brass screen prior to analysis, there was a chance for contamination with copper. For this reason the copper values are not reported. However, Anthony and Cunningham *(1)* found that Coastal bermudagrass from 67 Alabama counties averaged only 6 p.p.m. of copper and many Coastal samples from Alabama farms were deficient in both cobalt and copper *(2)*.

## Digestibility of Coastal Bermudagrass Hays

Digestibility data on the 15 Coastal bermudagrass hays fed in this series of digestion and lactation experiments are given in

TABLE 3. SOME MEASURES OF THE NUTRITIVE VALUE OF 15 COASTAL BERMUDAGRASS HAYS, DRY-MATTER BASIS

| Hay No. | DP | DDM | TDN | ETDN[1] | DE | ENE[2] |
|---|---|---|---|---|---|---|
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Mcal./100 lb.* |
| 1 | 4.8 | 55.8 | 54.1 | 54.7 | 52.9 | 40.7 |
| 2 | 4.6 | 53.2 | 52.8 | 52.5 | 49.3 | 38.9 |
| 3 | 3.0 | 51.9 | 52.6 | 53.7 | 48.3 | 38.6 |
| 4 | 7.5 | 52.9 | 52.3 | 51.2 | 48.4 | 38.2 |
| 5 | 9.4 | 57.5 | 54.2 | 54.8 | 55.9 | 40.9 |
| 6 | 8.5 | 57.6 | 55.6 | 55.9 | 53.7 | 42.8 |
| 7 | 5.8 | 56.0 | 53.9 | 53.4 | 52.4 | 40.5 |
| 8 | 3.2 | 54.8 | 54.9 | 55.6 | 52.7 | 41.8 |
| 9 | 2.5 | 53.6 | 54.0 | 54.4 | 50.8 | 40.6 |
| 10 | 3.2 | 54.4 | 55.6 | 54.6 | 53.1 | 42.8 |
| 11 | 9.3 | 63.7 | 62.2 | 60.5 | 58.8 | 52.0 |
| 12 | 6.8 | 57.5 | 55.9 | 56.1 | 55.5 | 43.2 |
| 13 | 6.5 | 57.1 | 56.3 | 56.4 | 53.8 | 43.8 |
| 14 | 5.6 | 58.0 | 56.7 | 55.9 | 55.5 | 44.4 |
| 15 | 3.1 | 54.3 | 52.8 | 53.9 | 51.8 | 38.9 |
| Mean | 5.6 | 55.9 | 54.9 | 54.9 | 52.9 | 41.9 |

[1] Estimated TDN % = [(3079 + % EDP × 14) − (% CF × 36.84)] ÷ 3563 × 100.

[2] Calculated by the equation, ENE (dry-matter basis) = 1.393 (% TDN) − 34.63, developed by Moore et al. *(25)*.

Table 3. Apparent digestible protein (DP), DDM, TDN, estimated total digestible nutrients (ETDN), digestible energy (DE), and estimated net energy (ENE) values show that quality of the hays varied. These measures indicated that most of the hays were relatively low in quality and that hay 11, an early first cutting hay, was superior to all others.

## Relationships Between Chemical Composition and Nutritive Quality

As shown by the correlations in Table 4, the DDM, TDN, DE, and ENE values for the Coastal hays increased as crude protein, total sugar, and cold and hot water extractables of the hays increased. The relatively high correlations between cold water extractables and both DDM and DE ($r = 0.87$) suggest this simple determination would be highly useful in evaluating nutritive quality of forages.

The DDM, TDN, DE, and ENE values for the Coastal hays decreased as the crude fiber, cellulose, and lignin contents increased. For each per cent increase in crude fiber there was a decrease of 0.95 per cent in DDM, 1.02 per cent in TDN, 1.01 per cent in DE, and 1.425 megacalories of ENE per 100 pounds of the Coastal hays.

As shown in Figure 1, digestible protein in the Coastal bermudagrass hays was linearly related to the crude protein content of the hays. From this relationship an equation was developed for determining estimated digestible protein (EDP) of Coastal hays from their crude protein contents (dry-matter basis), Figure 1.

TABLE 4. CORRELATIONS BETWEEN SOME COMPONENTS OF THE 15 COASTAL BERMUDAGRASS HAYS AND CERTAIN MEASURES OF THEIR NUTRITIVE VALUE

| Component | Correlation coefficients | | | |
|---|---|---|---|---|
| | DDM | TDN | DE | ENE |
| Crude protein | 0.68[1] | 0.44 | 0.56[2] | 0.43 |
| Crude fiber | — .63[1] | — .80[1] | — .66[1] | — .80[1] |
| Cellulose | — .75[1] | — .82[1] | — .71[1] | — .82[1] |
| Lignin | — .71[1] | — .50[2] | — .59[2] | — .53[2] |
| Total sugar | .78[1] | .75[1] | .78[1] | .76[1] |
| Cold water extractable | .87[1] | .73[1] | .87[1] | .73[1] |
| Hot water extractable | .84[1] | .83[1] | .78[1] | .84[1] |

[1] Correlation coefficients are significant, $P \leqq 0.01$.

[2] Correlation coefficients are significant, $P \leqq 0.05$.

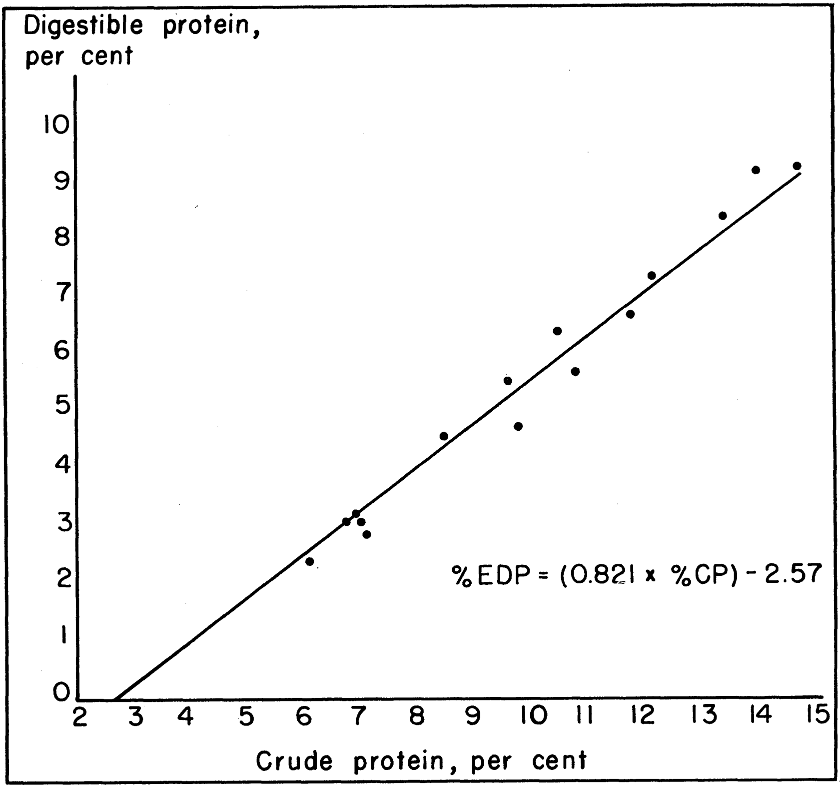


**FIG. 1. Digestible protein in Coastal bermudagrass hay was linearly related to the crude protein content. Estimated digestible protein (EDP) can be calculated by the equation, %EDP = (% CP × 0.821) − 2.57.**

The relationship between crude protein and digestible protein and between crude fiber and TDN in the 15 Coastal bermudagrass hays was used to develop an equation for estimating the TDN (ETDN) content. Using the equation from Figure 1 to determine EDP from CP the equation for % ETDN =

$$\frac{[3079 + (\%EDP \times 14) - (\%CF \times 36.84)]}{3563} \times 100.$$

The agreement between the ETDN and TDN values for the 15 hays was good, Figure 2. The maximum variation between these two values was 1.7 per cent (hay 11) and the standard deviation (S.D.) for the TDN-ETDN comparison for the 15 Coastal hays was 0.85 per cent. The foregoing equation gave a

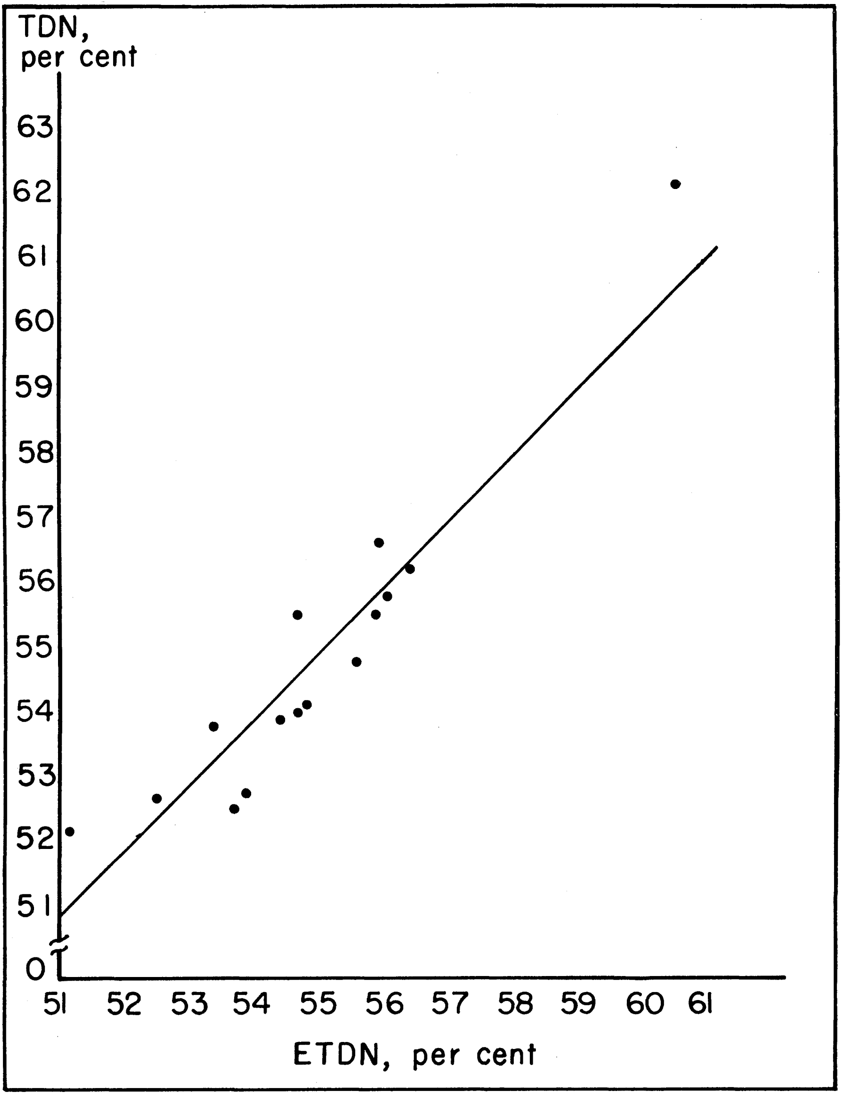


**FIG. 2. Estimated total digestible nutrients (ETDN) in relation to total digestible nutrients (TDN) in the 15 Coastal bermudagrass hays are shown.**

closer estimate of TDN values of these hays than was obtained by using a general equation *(6)*, usually referred to as the Pennsylvania State prediction equation. The general equation, which has been widely employed in forage testing, overestimated TDN of the hays by an average of 2.6 per cent. The proportion of chemically different compounds that make up the crude fiber fraction of different feeds *(27)* and of a single forage species at different stages of maturity *(4)* vary. Thus, it appears that the relationship between crude fiber and TDN in Coastal bermudagrass hays is more constant than that found across forage species and probably explains the increased accuracy obtained for ETDN by the equation developed from the 15 Coastal hays.

## Relationship of Hay Intakes to Chemical Composition

The mean daily intake of hays 11 through 15 by dairy steers is given below:

| *Hay No.* | *Daily hay intake per 100 lb. body weight, lb.*[1] |
|---|---|
| 11 | 2.67[a] |
| 12 | 2.30[c] |
| 13 | 2.04[c] |
| 14 | 2.22[c] |
| 15 | 2.06[c] |

[1] Values followed by unlike superscripts differ significantly.

The steers received no other feed and consumed significantly more of hay 11 than of the other hays. Amounts consumed by steers were correlated significantly with the crude fiber (r = −0.87), cellulose (r = −0.89), crude protein (r = 0.84), and ash (r = 0.95) contents of the hays. Intakes of the hays per 100 pounds of body weight decreased 0.14 and 0.13 pound for each per cent increase in crude fiber and cellulose, respectively. The contrasting increase in intake (per 100 pounds of weight) for each per cent increase in protein and ash were 0.08 and 0.56 pound, respectively. These data indicate that hay 11 (an early first cutting) was superior to hay 12 (a late first cutting) and to hay 13 (a second cutting representing 53 days of regrowth). This observation is similar to that reported by others *(8,9,10,15,20,21,22, 23)* that the nutritive value of Coastal bermudagrass hay decreased as the forage matured.

## Milk Production Experiments

Composition of the concentrates, air-dry basis, fed in the three milk production experiments were as follows:

| *Experiment* | *CP, pct.* | *CF, pct.* | *Ash, pct.* | *ENE, Mcal.* |
|---|---|---|---|---|
| I | 15.9 | 3.8 | 3.1 | 73.1 |
| II | 16.4 | 4.1 | 3.5 | 71.6 |
| III | 17.0 | 7.0 | 3.1 | 71.6 |

TABLE 5. MEAN DAILY INTAKES OF TOTAL RATION IN WHICH EACH COASTAL BERMUDAGRASS HAY WAS FED

| Hay No. | Body weight | Intakes | | |
|---|---|---|---|---|
| | | Hay | Concentrates | Total |
| | *Lb.* | *Lb.* | *Lb.* | *Lb.* |
| **Experiment I** | | | | |
| 1 | 1,168 | 16.5 | 20.2 | 36.7 |
| 2 | 1,096 | 14.2 | 18.5 | 32.7 |
| 3 | 1,132 | 16.4 | 23.5 | 39.9 |
| 4 | 959 | 13.7 | 21.3 | 35.0 |
| 5 | 1,218 | 19.6 | 24.5 | 44.1 |
| 6 | 1,082 | 16.3 | 20.3 | 36.6 |
| 7 | 981 | 14.1 | 22.4 | 36.5 |
| **Experiment II** | | | | |
| 8 | 1,212 | 16.8 | 21.8 | 38.6 |
| 9 | 1,242 | 17.0 | 24.4 | 41.4 |
| 10 | 1,266 | 15.9 | 22.8 | 38.7 |
| **Experiment III** | | | | |
| 11 | 1,297 | 19.5 | 20.6 | 40.1 |
| 12 | 1,163 | 15.9 | 19.5 | 35.4 |
| 13 | 1,319 | 17.3 | 21.8 | 39.1 |
| 14 | 1,305 | 18.2 | 21.4 | 39.6 |
| 15 | 1,114 | 15.4 | 20.4 | 35.8 |

TABLE 6. RELATIONSHIP BETWEEN COASTAL BERMUDAGRASS HAY FED AND MEAN DAILY FCM PRODUCTION

| Hay No. | No. of cows | Mean daily FCM | | |
|---|---|---|---|---|
| | | Standardization[1] | Experimental | Experimental adjusted[2,3] |
| | | *Lb.* | *Lb.* | *Lb.* |
| **Experiment I** | | | | |
| 1 | 2 | 32.5 | 30.3 | 35.2 |
| 2 | 2 | 33.2 | 27.8 | 32.2[d] |
| 3 | 2 | 37.9 | 33.9 | 35.2 |
| 4 | 2 | 38.2 | 33.9 | 35.0 |
| 5 | 2 | 38.3 | 35.3 | 36.3 |
| 6 | 2 | 38.0 | 35.5 | 36.7[e] |
| 7 | 2 | 39.2 | 34.8 | 35.2 |
| **Experiment II** | | | | |
| 8 | 5 | 44.8 | 35.3 | 31.9 |
| 9 | 5 | 45.3 | 35.8 | 32.1 |
| 10 | 5 | 44.2 | 33.6 | 30.6 |
| **Experiment III** | | | | |
| 11 | 5 | 41.8 | 38.4 | 37.1 |
| 12 | 5 | 39.5 | 34.6 | 34.8 |
| 13 | 5 | 41.4 | 37.2 | 36.1 |
| 14 | 5 | 42.6 | 36.7 | 34.8 |
| 15 | 5 | 40.0 | 36.3 | 36.4 |

[1] Mean daily FCM production was 39.8 pounds per cow.

[2] FCM production adjusted to take into account the differences in average starting level.

[3] The value followed by superscript *d* differed ($P < 0.05$) from that followed by *e*.

Mean body weights of cows assigned to each hay, and the mean daily intakes of hay, concentrate, and total ration for the three milk production experiments are given in Table 5. Cows on each ration refused some of their hay allowance. For this reason, hay intake as a percentage of the total ration was variable.

During Experiment I, the daily FCM production per cow fed hay 6 was greater than that of cows fed hay 2, Table 6. Within experiments the mean daily FCM production by cows fed the three hays in Experiment II and by those fed the five hays in Experiment III did not differ. Variations in FCM production among

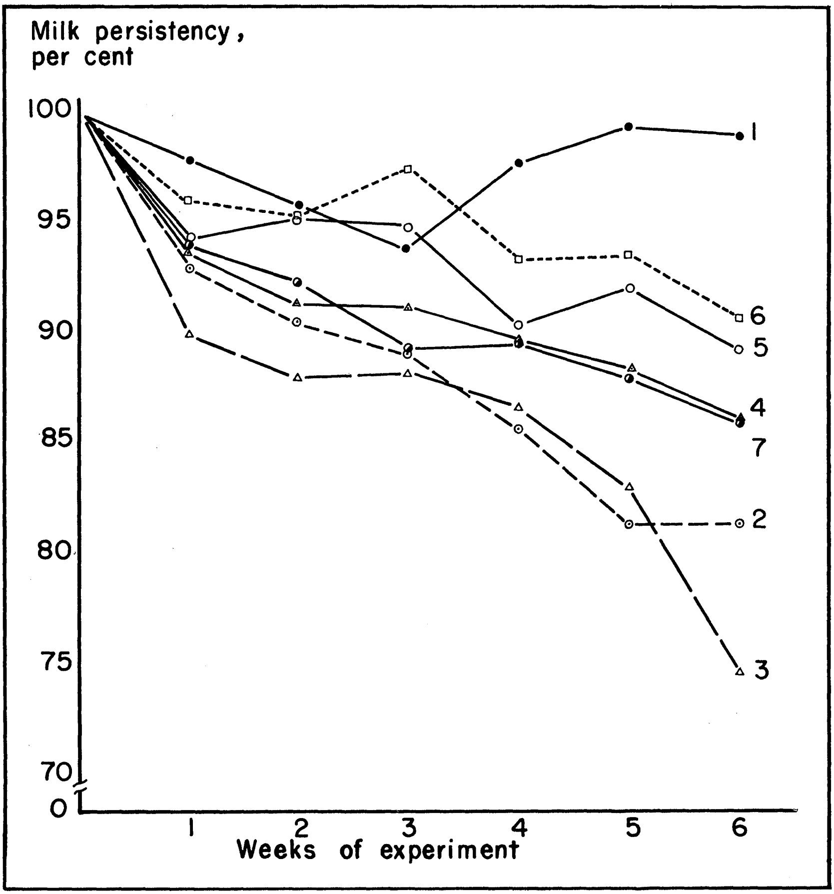


**FIG. 3. Mean persistency of actual milk production by cows fed Coastal bermudagrass hays 1 to 7 during Lactation Experiment I is illustrated here.**

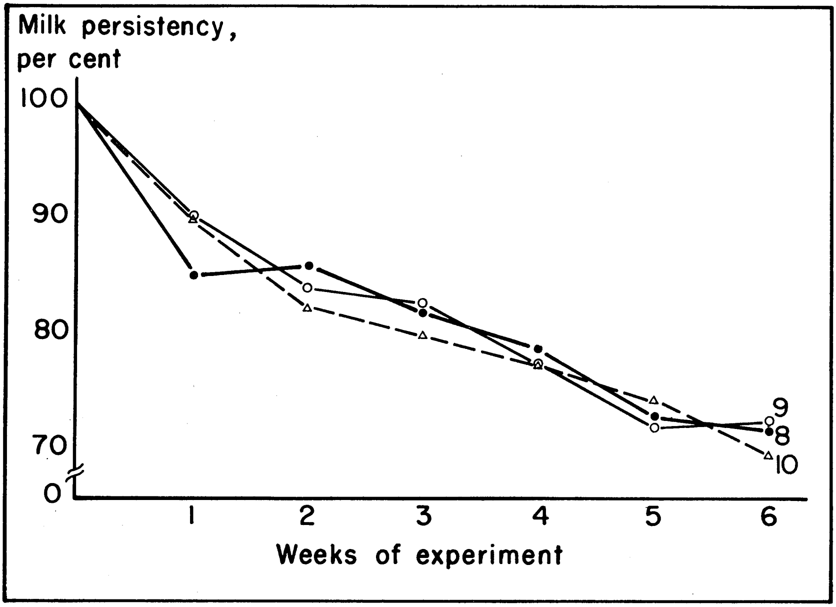


**FIG. 4. Mean persistency of actual milk production by cows fed Coastal bermudagrass hays 8, 9, and 10 during Lactation Experiment II is illustrated here.**

individual cows on the same hays were large, thus masking any differences among the hays.

Persistency of milk production is another measure of the nutritive adequacy of the rations containing Coastal hays. Persistencies of actual milk production each week as a percentage of that produced during the week preceding Experiments I, II, and III are shown in Figure 3, 4, and 5, respectively. In Experiment I cows fed hay 1 were the most persistent in production followed by those fed hays 6 and 5, with the lowest persistency occurring for cows fed hays 3 and 2, Figure 3. The rate of decline in milk production was unusually steep for cows fed all hays in Experiment II, Figure 4. In Experiment III, milk production of cows fed hays 11 and 15 persisted at higher levels than that of cows fed the other hays, Figure 5.

Within experiments the milk energy produced by cows fed the Coastal hays did not differ significantly, Table 7. When ranked from highest to lowest, however, the milk energy produced by cows within experiments showed a close relationship to quality of the hay fed, with the highest quality hays supporting the high-

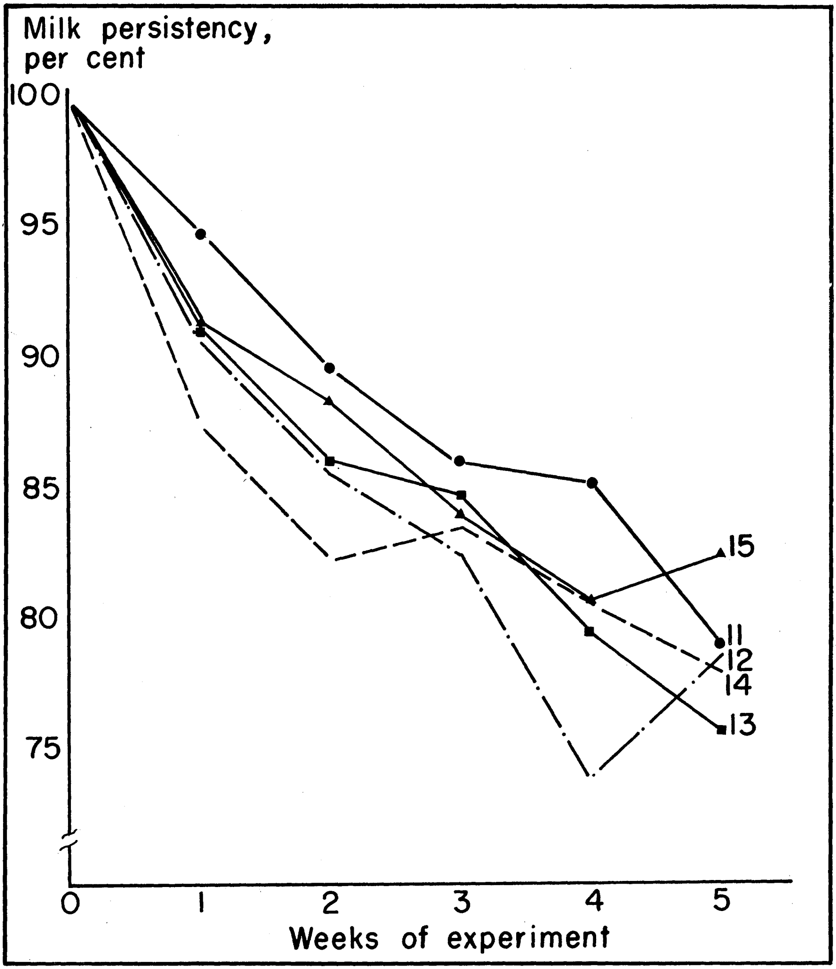


**FIG. 5. Mean persistency of actual milk production during Lactation Experiment III is illustrated here.**

est performance. In all experiments the cows gained some weight, Table 7.

The mean molar percentages of volatile fatty acids in rumen fluid from the cows varied among hays, Table 8, and within hay groups. As the percentage of concentrates in the total feed intake increased, molar percentages of acetic and butyric acids decreased and that of propionic acid increased.

The molar per cent of propionic acid in the rumen fluid of some cows increased and in other cows decreased from the standardi-

TABLE 7. MEAN DAILY MILK ENERGY PRODUCED AND MEAN DAILY BODY WEIGHT CHANGE BY COWS FED THE COASTAL BERMUDAGRASS HAY RATIONS

| Hay No. | Milk energy | | Body weight change |
|---|---|---|---|
| | Actual | Adjusted[1,2] | |
| | *Mcal.* | *Mcal.* | *Lb.* |
| **Experiment I** | | | |
| 1 | 9.844 | 11.178 | 2.29 |
| 2 | 9.203 | 10.371 | 1.25 |
| 3 | 11.018 | 10.559 | 0.84 |
| 4 | 11.070 | 10.761 | 1.09 |
| 5 | 11.608 | 11.316 | 3.45 |
| 6 | 11.659 | 11.216 | 1.82 |
| 7 | 11.840 | 10.838 | 1.09 |
| **Experiment II** | | | |
| 8 | 11.761 | 11.577 | 0.16 |
| 9 | 11.815 | 11.700 | 0.36 |
| 10 | 10.913 | 11.213 | 0.49 |
| **Experiment III** | | | |
| 11 | 12.808 | 12.778 | 0.98 |
| 12 | 12.120 | 12.564 | 0.18 |
| 13 | 12.696 | 12.463 | 0.31 |
| 14 | 12.249 | 11.722 | 0.98 |
| 15 | 12.699 | 13.048 | 0.94 |

[1] Adjusted by covariance within experiment to take into account the initial differences in levels of milk energy secreted by individual cows during the standardization period.

[2] Difference required for significance in Experiment I, II, and III is 1.265, 1.491, 1.475 Mcal., respectively.

TABLE 8. MEAN MOLAR PERCENTAGES OF VOLATILE FATTY ACIDS IN RUMEN LIQUOR FROM COWS FED COASTAL BERMUDAGRASS HAYS

| Hay No. | Feed intake as concentrates | VFA in rumen liquor | | | | |
|---|---|---|---|---|---|---|
| | | Acetic | Propionic | Butyric | Isovaleric | Valeric |
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* |
| **Experiment II** | | | | | | |
| 8 | 56.5 | 64.0 | 22.7 | 13.3[1] | ---- | ---- |
| 9 | 58.9 | 67.2 | 20.2 | 12.6[1] | ---- | ---- |
| 10 | 58.9 | 65.7 | 19.7 | 14.6[1] | ---- | ---- |
| **Experiment III** | | | | | | |
| 11 | 51.4 | 71.0 | 15.6 | 11.4 | 0.9 | 1.1 |
| 12 | 55.1 | 63.9 | 21.2[2] | 11.9 | 1.1 | 1.9 |
| 13 | 55.8 | 68.3 | 16.9[2] | 12.1 | 1.3 | 1.3 |
| 14 | 54.0 | 68.8 | 17.3 | 11.7 | 1.1 | 1.0 |
| 15 | 57.0 | 67.1 | 18.3 | 12.2 | 1.1 | 1.3 |

[1] Includes isovaleric and valeric acids.

[2] Molar per cent of propionic acid differed significantly after correction for per cent concentrate in the ration consumed.

zation period to end of the experimental period. Within Experiment III, the change in molar per cent of propionic acid during the experimental period was correlated (r = −0.66) significantly with the change in fat percentage of milk produced by individual cows.

### Milk Production and Hay Intakes and Composition Relationships

For all hays in the experiments there was a high degree of variability in milk production responses of cows fed the same hays. The results are similar to earlier findings when Coastal was fed *(16)*. Consequently for hays 1 to 7, each of which were fed to only two cows, variability was so great that the average response may not be indicative of hay quality. Nevertheless, it was found that across all 15 Coastal hays, the mean daily FCM and milk energy persistency increased significantly as hay intake per 100 pounds of body weight increased, r = 0.63 and 0.51, respectively.

Increase in lignin content of the hays was significantly negatively correlated with FCM persistency (r = −0.67). On the average, FCM persistency decreased 5.92 per cent for each per cent increase in lignin content of the hays. This was associated with a decrease in hay intake equal to 0.08 pound daily for 100 pounds of cow weight for each per cent increase in lignin content.

Hays 8 to 15 were each fed to five lactating cows, whereas hays 1 to 7 were each fed to only two cows. For this reason correlations were determined between some measures of quality for only hays 8 to 15 and the mean FCM persistency of cows to which they were fed. The cold water solubles per cent of the hays and FCM persistency were correlated (r = 0.83) significantly. Average persistency of FCM over the 5-week period increased 1.49 per cent for each percentage increase in cold water solubles in the hays. Although crude fiber contents of the 15 hays were not correlated significantly with FCM persistency (r = −0.31) of cows to which the hays were fed, the relationship was negative. On the average, FCM persistency decreased 1.4 per cent for each per cent increase in crude fiber. In a like manner, the persistency of FCM production by cows fed rations containing the 15 hays was not correlated significantly with crude fiber contents of the complete rations, which ranged from 14.2 per cent for the hay 9 ration to 16.8 for rations which included hays 12 and 14. The absence of a trend in FCM production in relation to total ration crude fiber percentage over the range of 14 to 17 per cent agrees with reports of others *(24,29)*. Nevertheless, there is some evidence *(26)* that 16 per cent crude fiber in the ration approaches the optimum level. Autrey *(5)* found that cows could consume approximately 0.6 pound of crude fiber per 100 pounds of body weight. However, it would appear that other factors limited the total feed intake of the Coastal bermudagrass hay rations before crude fiber level of the ration became a limiting factor. Crude fiber intakes ranged from 0.44 to 0.57 pound per 100 pounds of body weight.

Intake of DP by cows fed the rations containing the 15 Coastal bermudagrass hays exceeded the recommended allowances *(11)*. The utilization of ENE intakes for maintenance and milk production by cows fed rations including hays 11 to 15 was 97.3 to 101.9 per cent. In contrast, cows fed hays 1 to 10 used only 84.8 to 93.1 per cent of their ENE intake for body maintenance and milk energy production with most of the remainder being accounted for as stored body tissue.

## SUMMARY

The quality of the 15 Coastal bermudagrass hays fed in the digestibility and lactation studies reported herein was highly variable as measured by chemical composition, by digestibility of protein and of energy, and by animal performance.

Apparent digestible protein contents of the 15 Coastal bermudagrass hays was linearly related to level of crude protein in the hays and could be estimated with a high degree of precision by the equation, $\%\ EDP = (\%\ CP \times 0.821) - 2.57$.

The TDN content of the 15 hays decreased 1.02 per cent for each per cent increase in crude fiber over the range found in these hays (28.5 to 36.9 per cent). The correlation ($r = -0.80$) between crude fiber and TDN was highly significant.

The relationships between crude protein and digestible protein and between crude fiber and TDN were used to modify a prediction equation *(6)* for obtaining greater accuracy in estimating the TDN of Coastal bermudagrass hays. The modified prediction equation for estimated TDN of Coastal bermudagrass hays is

$$\%\ ETDN = \frac{[3079 + (\%EDP \times 14) - (\%CF \times 36.84)]}{3563} \times 100.$$

This equation is being used in the Alabama forage testing program to estimate TDN of Coastal bermudagrass hays.

The Ca, P, Mg, and Na contents of several of the hays were either too low to meet minimum requirements for growth or for lactation unless fed with a concentrate containing a supplement of these minerals. Also, copper and cobalt contents of Coastal hays often are below levels required by cattle *(2)*.

The highest quality Coastal bermudagrass hay was an acceptable forage as measured by ENE, by the amount consumed per cow daily, and by milk production persistency.

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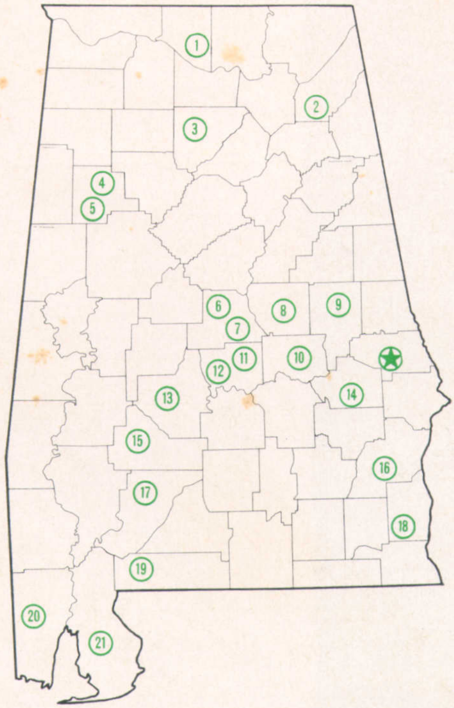
## AGRICULTURAL EXPERIMENT STATION SYSTEM OF ALABAMA'S LAND-GRANT UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.




### Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.