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Summary

The purpose of this study was to determine how well various laboratory methods estimate **in vivo** digestibility, Voluntary Intake (VI), and performance (average daily gains) of beef cattle fed mixed rations. The relationships among and/or between **in vivo** digestibility, VI, Nutritive Value Indexes (NVI), total digestible nutrient (TDN) intake above maintenance, laboratory evaluations (in vitro DDM, acid insoluble lignin and dry matter solubility), and average daily gains (ADG) also were determined. In contrast to other studies of this type, which used forages alone, the present study was conducted with mixed rations. All the data were based on results from 43 different rations.

ADG were used as the standard to which results from other methods were compared. In the present study, VI of the 43 rations was determined from long-term feedlot trials rather than from short-term studies used by most other workers. VI was expressed as dry matter intake per unit of body weight, dry matter intake per unit of body weight$^{.75}$, and dry matter intake per unit of body weight$^{.84}$.

Total collection digestion trials, using Hereford steers of similar breeding, type, and condition, had been used to determine the digestibility of the 43 rations. Four measures of **in vivo** digestibility —digestible dry matter (DDM), digestible organic matter (DOM), TDN, and digestible energy (DE)—had been determined.

Unequal distribution of sexes, types, conditions, and body weights among rations resulted in considerable confounding of these effects in the feedlot data. Hence, where variables from feedlot data were involved, the above-mentioned variables were held constant and partial correlations were calculated. Simple correlations were calculated between the **in vivo** measures of digestibility and laboratory evaluations since there was no confounding involved. Multiple regression equations for ADG and the expressions of VI were developed from a multiple regression analysis.

Results of this study are as follows:

1. There was a high correlation between the **in vivo** expressions of digestibility which indicates that it is feasible to calculate one from another.

2. Acid insoluble lignin and **in vitro** DDM were significantly ($P < .05$) correlated with **in vivo** DDM, DOM, and TDN. However, dry matter solubility showed little relationship to any of the expressions of **in vivo** digestibility.

3. Little relationship between VI and the above-mentioned laboratory evaluations of mixed rations was found.

4. Results from both **in vitro** DDM and acid insoluble lignin show these laboratory methods to be useful estimators of NVI. However, dry matter solubility probably should not be used to estimate NVI when mixed rations are used.

5. Partial correlations between the four expressions of **in vivo** digestibility and ADG were small and nonsignificant; however, both DDM and DOM were more highly correlated with ADG than was TDN or DE.

6. Relationships between VI and ADG were small and not significant.

7. Small nonsignificant partial correlations were obtained between NVI or TDN intake above maintenance and ADG.

8. A highly significant ($P < .01$) partial correlation between ADG and **in vitro** DDM and a significant ($P < .05$) negative partial correlation between ADG and acid insoluble lignin were obtained, suggesting that results from these methods may be used to estimate ADG. However, the partial correlation between ADG and dry matter solubility was low and not significant.

9. The inclusion of several other variables—percent concentrate in the ration, length of feeding, percent crude protein in the ration and $(\text{length of feeding})^2$—in multiple regression equations, in addition to results from one of the laboratory evaluations, improved the VI coefficients of determination very little.

10. A multiple regression equation containing VI (dry matter intake per body weight$^{.75}$), **in vivo** DDM, percent concentrate in the ration, length of feeding, acid insoluble lignin content, $(\text{length of feeding})^2$, and percent crude protein explained approximately 50% of the variation in ADG.

11. Based on the results of this study, the equation which seems to be the most useful estimator of ADG is:

$$Y = 0.721 + 0.0194 X_1 - 0.0134 X_2 + 0.0001 X_3.$$

Where $\hat{Y}$ = predicted value of ADG.

X_1 = **in vitro** DDM.

X_2 = length of feeding.

X_3 = $(\text{length of feeding})^2$.

This equation explained 45.6% of the variation in ADG. It is even more useful than equations containing VI, **in vivo** digestibility, and other variables, since this equation contains variables, the measurement of which is simple, relatively accurate and inexpensive, time-saving, and does not involve feeding animals.

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A Comparison of Various Methods of Estimating Digestibility, Voluntary Intake and Average Daily Gains for Beef Cattle Fed Mixed Rations

by

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Since feedlot trials are the most accurate method of determining the nutritive value of feeds, they are the standard to which all other methods are compared. Considerable time, labor, and expense are required to conduct feedlot trials; hence, the number of trials which can be conducted is limited. Therefore, accurate, simple, time-saving, and low-cost methods of estimating nutritive value of feeds should be available. These methods could be used to select the more desirable rations, which can then be fed in the feedlot for animal evaluation.

For many years, digestibility trials have been used to estimate nutritive value of feeds. However, it has recently been recognized that the amount of feed eaten by ruminants is also an important factor in assessing its nutritive value. In addition, numerous laboratory methods are being used to estimate **in vivo** digestibility and forage intake. Using forages, several investigators have shown high correlations between results from these laboratory evaluations and **in vivo** digestibility and/or feed intake. However, since forages are seldom fed alone, it would be advantageous to have a laboratory procedure to evaluate the total mixed ration rather than just the forage alone.

Therefore, the major objective of this study was to determine the relationship between various laboratory evaluations and **in vivo** digestibility, feed intake, and performance of beef cattle (average daily gains) when mixed rations are used. The second objective was to determine the relationships among and/or between **in vivo**

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digestibility, feed intake, total digestible nutrient intake above maintenance, laboratory evaluation data, and animal performance.

Review of Literature

Explanation of Terms

In order to better understand the material which is to follow, a few concepts should be explained:

Voluntary Intake (VI) is that amount of food which an animal voluntarily consumes. It is usually expressed on the basis of body weight or metabolic size.

Relative Intake (RI) was calculated by Crampton **et al.** (1960) as follows:

$$RI = \frac{\text{observed intake X } 100}{80\ (W_{kg.}^{.75})}$$

where W is body weight and observed intake is equal to VI.

Nutritive Value Index (NVI) was defined by Crampton **et al.** (1960) as the product of RI and percent energy digestibility. In contrast, Ingalls **et al.** (1965) and Mohammed (1966) also calculated NVI from RI and percent dry matter digestibility.

Animal Performance

The performance of beef cattle is influenced by many factors. For many years **in vivo** digestion data have been used almost exclusively in predicting average daily gains. However, the usefulness of digestion data alone is limited. One reason for this is the fact that digestibility measures do not include the voluntary consumption of feeds. Also, Morrison (1956) stated that, on the average, fully one-half the feed eaten by farm animals is used for maintenance, and only the remainder can be converted into useful products. Therefore, feed intake above the maintenance requirement should be a good predictor of animal performance.

In Vitro Digestibility Studies

Studies on the role of rumen microorganisms have led to the development of many artificial rumen techniques. These techniques vary widely in the purpose for which they were developed. One of the goals was to estimate **in vivo** digestibility of forages. Marston (1948), Louw **et al.** (1949) and Burroughs **et al.** (1950) first suggested the use of artificial rumen techniques for measuring feeding value. Since the development of these techniques, several workers (Kamstra **et al.**, 1955; Barnett, 1957; Hershberger **et al.**, 1959;

Quicke **et al.**, 1959; Reid **et al.**, 1960; Oh and Baumgardt, 1966; and Chalupa and Lee, 1966)—all using forages—have reported high correlations between various **in vivo** expressions of digestibility and **in vitro** cellulose digestion.

In vitro dry matter digestibility also has been used as an estimator of forage quality. Bowden and Church (1962) stated that the within-trial variation of **in vitro** digestible dry matter (DDM) of all substrates digested for 48 hours was generally small while **in vitro** cellulose digestibility showed a slightly higher variability within trials. Tilley and Terry (1963) developed a two-stage technique for the **in vitro** digestion of forage crops which resulted in a very high correlation with **in vivo** DDM. With the use of this technique, Oh and Baumgardt (1966) reported a correlation of 0.88 between **in vivo** DDM and **in vitro** DDM in forages. When other **in vitro** fermentation techniques were used, Smith **et al.** (1965) and Barth and Mohammed (1966) also obtained statistically significant correlation coefficients between **in vivo** digestibility and **in vitro** DDM.

Several investigators (Norman, 1935; Crampton and Maynard, 1938; Phillips and Loughlin, 1949; Meyer and Lofgreen, 1956; Sullivan, 1955 and 1964; Simkins and Baumgardt, 1963; and Baumgardt and Oh, 1965) have indicated that the digestibility of any normal plant material is inversely proportional to the degree of lignification. Also, attempts have been made to relate solubility of forages in various solvents with forage digestibility. Dehority and Johnson (1964) found that dry matter solubility of forages in normal sulfuric acid was significantly correlated with **in vivo** DDM and DE.

Voluntary Intake Studies

Since adequate feed intake is essential for good animal performance, the VI of feeds has received much attention in the past few years. It has been suggested that the VI of a forage has a greater influence on animal performance than its digestibility (Crampton **et al.**, 1960; Byers and Ormiston, 1962; and Ingalls **et al.**, 1965). Moore (1966) stated that VI may be the most important biological criterion of forage nutritive value except for actual animal performance.

In vitro fermentation studies are often used to predict VI. One would expect results from short fermentation periods to be more closely correlated with the level of intake since short fermentation periods measure differences in rate of digestion and they, in turn, influence rumen fill which is believed to contribute to the regulation of VI. Several workers (Donefer **et al.**, 1960; Bratzler, 1961; Johnson **et al.**, 1962; Karn **et al.**, 1964; Reid and Jung, 1965; and Chalupa and Lee, 1966), who used short fermentation periods of 4 to 18 hours with forages, have reported significant correlations between this **in vitro** digestibility and **in vivo** VI. Reid et al. (1960) in an earlier pubication, however, indicated that there was no consistent relationship between VI and the rate of **in vitro** cellulose digestion of eight hays, at intervals of 4, 8, 12, 20, 32, and 48 hours.

Various investigators have suggested the use of specific components in forages as predictors of VI. Lignin appears to be one of the most promising components. Van Soest (1964), Reid and Jung (1965), and Van Soest (1965), have reported positive relationships between lignin content and VI, when tall fescue was used. However, between species there was a significant negative relationship between lignin content and VI (Forbes and Garrigus, 1950; Van Soest, 1964; and Van Soest, 1965). Also, Dehority and Johnson (1964) found that the dry matter solubility of a forage in normal sulfuric acid was significantly correlated with RI and other factors.

Nutritive Value Index

Crampton **et al.** (1960) and Byers and Ormiston (1962) stated that the RI of a forage influenced NVI to a greater extent than digestible energy. Therefore, these workers proposed the best indicator of animal performance to be the product of RI and energy digestibility, which is NVI. They reported correlation coefficients of 0.88 to 0.94 between NVI and animal performance. Ingalls **et al.** (1965), however, reported a lower coefficient of 0.59 when individual animal values were used.

Several workers (Donefer **et al.**, 1960; Johnson **et al.**, 1964; Reid and Jung, 1965; and Chalupa and Lee, 1966) have indicated high correlations between **in vitro** fermentation studies and NVI. Dehority and Johnson (1964) found that dry matter solubility of forages in normal sulfuric acid was highly correlated with **in vivo** nutritive values.

Experimental Procedure

Various **in vivo** and **in vitro** feed evaluation methods were compared as to their accuracy in estimating animal performance. Average daily gains (ADG), obtained from feedlot trials, were used as the standard to which results from other methods were compared. Three laboratory evaluations were compared also as to their usefulness in estimating VI and digestibility. Feedlot trials and conventional **in vivo** digestion trials involving 43 rations had been previously conducted in other studies. The forages used in these studies were corn silage, alfalfa silage, alfalfa hay, and alfalfa-grass hay. The all-forage rations consisted of three qualities of alfalfa hay; the forage-concentrate mixed rations contained cracked or ground ear corn with either silage or a combination of one silage and one hay; the all-concentrate rations contained ground ear corn. Protein supplement was added to rations as needed and salt had been provided free-choice.

The feedlot trials using the 43 rations had been conducted by the following people: B. B. Wilson (1964), rations 1-9 and 40-42; Chamberlain **et al.** (1966), rations 10-25, 37-39 and 43; Corrick **et al.** (1966), rations 26 and 27; Clark and Barth (1966), rations 28 and 29; G. R. Wilson (1964), rations 30-33; and Mohammed **et al.** (1967), rations 34-36. Digestion trials using steers also had been conducted with these rations by the same individuals who conducted the feeding trials, with the exception of rations 10-25 conducted by McConnell **et al.** (1967) and rations 37-39 and 43 conducted by Barth and Prigge (1967).

Each ingredient in the 43 rations had been analyzed for proximate composition according to A.O.A.C. (1960) methods and for gross energy in a Parr (1960) oxygen bomb calorimeter. The nutrient composition and gross energy of these ingredients are shown in Table 1 of the Appendix.

Feedlot Trials

Description of Cattle. In the previously mentioned experiments, 317 Hereford, Angus, and crossbred heifers grading low Standard to low Good in initial condition, low Standard to low Choice in type, and averaging 388 to 741 pounds (176 to 336 kilograms) in initial weight had been fed 32 different rations. Also included in this study were 116 Hereford, Angus, and crossbred steers grading Standard to high Good in condition, Good to low Choice in type, and averaging 515 to 728 pounds (234 to 331 kilograms) in initial weight. These steers had been fed the other 11 rations.

Feeder calf sales or University of Tennessee herds had been the sources of cattle for rations 1-17, 26, 27, 30, 31, 34-39 and 40-43. Cattle fed rations 18-25, 28, 29, 32, and 33 had been fed high roughage rations before being switched to these finishing rations.

Experimental Procedure. The various rations had been fed to two replicate lots of animals, each lot consisting of 4 to 10 animals. Within each feedlot trial, the cattle had been assigned to their respective lots on the basis of weight, type, and condition. All cattle were graded for type and condition at the beginning and end of the experiment and were weighed at 14- or 28-day intervals. Averages of the two body weights determined on consecutive days were used as the beginning and ending experimental weights. ADG was calculated as the average change in body weight per day from the beginning to the end of each feedlot trial. The cattle were maintained on their respective rations from 42 to 141 days.

Voluntary Intake

VI was determined from the feedlot trials. Free-choice feeding of one of the ration ingredients had been practiced in these trials, while a constant amount of all other ingredients had been fed. In this study, VI was expressed as Voluntary Intake-Body Weight (VI-BW), Voluntary Intake-Body Weight$^{.75}$ (VI-BW$^{.75}$), and Voluntary Intake-Body Weight$^{.84}$ (VI-BW$^{.84}$). The average of the beginning and ending body weights was used in the calculation of VI. These measures were calculated as follows:

1. $\text{VI-BW} = \dfrac{\text{kg. dry matter}}{\text{100 kg. body weight}}$

2. $\text{VI-BW}^{.75} = \dfrac{\text{gm. dry matter}}{\text{body weight, }_{\text{kg.}}{}^{.75}}$ (Crampton **et al.**, 1960)

3. $\text{VI-BW}^{.84} = \dfrac{\text{gm. dry matter}}{\text{body weight, }_{\text{kg.}}{}^{.84}}$ (Reid, 1967).

Digestion Trials

Groups of either 3 or 4 Hereford steers of similar breeding, type, condition, and body weight had been used to determine the digestibility of the 43 rations. Metabolism stalls described by Hobbs **et al.** (1950) were used in these trials.

In each digestion trial, a 10-day preliminary period—during which the steers were accustomed to the metabolism stalls and necessary adjustments made—was followed by a 7-day total collection period. With rations 30-33 the collection period had been of a 5-day duration. The same ration ingredients as used in the feeding trials were fed twice daily. The ingredient which was fed free-choice in the feedlot was also fed free-choice in the digestion trial; however, its consumption was usually less in the digestion trial. The small amount of hay fed in the feedlot in rations 1-9, 30-33, and

40-42 was not offered in these trials. The animals had access to water twice daily at feeding time. Refusals had been determined before the morning feeding and fecal material had been collected and weighed once daily during the collection period. The feces had been thoroughly mixed, and a 5% aliquot had been stored under refrigeration. At the end of the collection period, two 500-gram representative fecal samples were taken, dried for 3 days at 70°C., and allowed to air equilibrate.

All ingredients in the rations and all fecal samples were then analyzed for nutrient composition according to A.O.A.C. (1960) methods and for gross energy in a Parr (1960) oxygen bomb calorimeter. Digestibility coefficients were calculated for each nutrient, and digestibility of the rations was expressed as DDM, digestible organic matter (DOM), total digestible nutrients (TDN), and digestible energy (DE).

Calculations of Nutritive Value Indexes and TDN Intake Above Maintenance

Crampton **et al.** (1960) proposed that the product of RI and percent energy digestibility of a forage be used as a NVI. In this study, NVI was calculated four ways as shown below:

NVI ($BW^{.75}$—energy) = RI x percent energy digestibility.

NVI ($BW^{.75}$—dry matter) = RI x percent dry matter digestibility.

NVI ($BW^{.84}$—energy) = RI x percent energy digestibility.

NVI ($BW^{.84}$—dry matter) = RI x percent dry matter digestibility.

The energy requirement in pounds of TDN for maintenance was calculated using the equation of Winchester and Hendricks (1953):

$$\text{Maintenance} = 0.0553 \text{ (pounds body weight}^{2/3}\text{)}.$$

The daily TDN maintenance requirement was subtracted from the daily TDN intake to arrive at TDN intake above maintenance.

Laboratory Evaluations

A two-stage **in vitro** fermentation technique reported by Tilley and Terry (1963) for estimating digestibility of forage crops was used to determine **in vitro** DDM. Three replicate trials were conducted. Acid solubility of the rations was obtained by using a chemical method based on the solubility of dry matter in normal sulfuric acid, which was developed by Dehority and Johnson (1964). Acid insoluble lignin content in the rations was determined according to the Van Soest (1963) procedure. In these three laboratory evaluations (conducted in duplicate), the ingredients of the 43 rations were used in the same proportions in which they had been consumed in the feedlot.

Correlation Coefficients

Either partial or simple correlations among ADG, NVI ($BW^{.75}$ energy), NVI ($BW^{.75}$ - dry matter), NVI ($BW^{.84}$ - energy), NVI ($BW^{.84}$ - dry matter), TDN intake above maintenance, VI-BW, VI-$BW^{.75}$, VI-$BW^{.84}$, **in vivo** expressions of digestibility (DDM, DOM, TDN and DE), **in vitro** DDM, acid insoluble lignin, and dry matter solubility were calculated.

Unequal distribution of sexes, types, conditions, and body weights among rations resulted in considerable confounding of these effects in the feedlot data. Hence, in cases where variables from feedlot data were involved, the above-mentioned variables were held constant and partial correlations were calculated. Simple correlations were calculated between the **in vivo** measures of digestibility and laboratory evaluations since there was no confounding involved.

Multiple Regression Equations

Multiple regression equations for ADG, VI-BW, VI-$BW^{.75}$, and VI-$BW^{.84}$ were developed from a multiple regression analysis using the following model:

$$\hat{Y}_i = a + \sum_j b_j X_j$$

where

$$i = 1, 2, 3 \text{ and } 4$$
$$j = 1, 2, \ldots, k$$
$$a = \bar{Y} + \sum_j b_j (O - \bar{X}_j).$$

The b_j's are the partial coefficients of regression of the dependent variables on the independent variables.

The X_j's are the independent variables measured from the feedlot, digestion trials, and laboratory evaluations (specifically defined later).

The Y_i's are the dependent variables ADG and VI, defined above.

The $\hat{Y}_i$'s are the predicted value of the i^{th} dependent variable for specified values of the X_j's.

The $\bar{Y}_i$'s are the means of the i^{th} dependent variable.

The $\bar{X}_k$'s are the means of the k^{th} independent variable.

When predicting ADG and VI, the effects of sex, type, condition, and body weight were held constant, that is, the calculations were done on a within-subclass basis, the subclasses being those with respect to sex, type, condition, and body weight.

Results and Discussion

A description of the rations, the cattle and their performance in the feedlot trials, the **in vivo** digestibility of the rations, the VI of the rations, the NVI and TDN intake above maintenance of the rations, and the results of the three laboratory evaluations of the rations are shown in Appendix Tables 2 to 7. **In vitro** dry matter digestibility coefficients (Tilley and Terry, 1963) of the three individual trials are shown in Appendix Table 8.

Correlation Coefficients

Relationships Between Measures of In Vivo Digestibility. Simple correlations were calculated between the four **in vivo** measures of digestibility (DDM, DOM, TDN and DE), **using** the data obtained from the 43 previously mentioned mixed ration **trials.** These correlations are presented in Table 1. The correlation coefficients obtained between these measures of digestibility were highly significant ($P<.01$). The correlation (0.89) between TDN and DE was similar to those of Swift (1957), Markley (1958), Barth **et al.** (1959), Heaney and Pigden (1963), Stallcup and Davis (1965), and Barth and Mohammed (1966) who reported correlations of 0.97, 0.86, 0.95, 0.97, 0.89, and 0.89, respectively for ruminant animals. The correlations between DE and DDM (0.86), DE and DOM (0.86), TDN and DOM (0.96), and DDM and DOM (0.99) also are similar to those of Heaney and Pigden (1963), Stallcup and Davis (1965), and Barth and Mohammed (1966) who also reported highly significant relationships between these measures of digestibility. The correlation (0.95) between DDM and TDN was of about the same magnitude as the 0.87 and 0.98 simple correlations reported by Stallcup and Davis (1965) and Heaney and Pigden (1963), respectively. However, these correlations were considerably higher than the nonsignificant correlation (0.57) reported by Barth and Mohammed (1966). Therefore, there is a close relationship between these four measures of **in vivo** digestibility which indicates that it is feasible to calculate one from another.

Relationships Between In Vivo **Digestibility and Laboratory Evaluations.** Correlations of the four **in vivo** expressions of digestibility (DDM, DOM, TDN, and DE) with results from the three laboratory evaluations also are presented in Table 1. Using forages alone, other workers reported considerably higher correlations than were obtained in the present study. Two facts may account for this:

Table 1. Simple correlation coefficients[a] between **in vivo** and **in vitro** expressions of digestibility

	DDM	DOM	TDN	DE	In vitro DDM	Acid insoluble lignin
DOM	0.99					
TDN	0.95	0.96				
DE	0.86	0.86	0.89			
In vitro DDM	0.46	0.41	0.34	0.12		
Acid insoluble lignin	−.65	−.63	−.56	−.29	−.86	
Dry matter solubility	−.11	−.09	−.05	−.24	−.76	0.63

[a] Coefficients above 0.30 and below -.30 were significant (P<.05), and coefficients above 0.39 and below -.39 were highly significant (P<.01).

1) these laboratory techniques were developed to evaluate forages and not mixed rations, and 2) in the laboratory evaluations the ration constituents were used in the same ration as they had been consumed in the feedlot and not as consumed in the **in vivo** digestion trials. This was done because the major objective of this study was to estimate animal performance. It was therefore considered to be more important that the ratio of ration ingredients in the laboratory evaluations be the same as that in the feedlot and not that in the **in vivo** digestion trials. thus making possible a better estimate of animal performance.

Correlations between **in vitro** DDM and **in vivo** DDM and DOM were highly significant ($P<.01$). A significant ($P<.05$) relationship was shown to exist also between **in vitro** DDM and TDN; however, the correlation between **in vitro** DDM and DE was low and nonsignificant. The low magnitude of the latter correlation cannot be explained. Using this procedure on forages alone, Oh and Baumgardt (1966) reported a significant correlation of 0.88 between **in vitro** DDM and **in vivo** DDM. Trends in the present data indicate that the greater the proportion of concentrate in the ration, the more this method overestimates **in vivo** digestibility of the ration. In this study varying levels of concentrate were used. However, the exact influence of the level of concentrate on **in vivo** digestibility was not measured, since the ratio of ration ingredients used in the laboratory evaluation was not the same as had been consumed in the **in vivo** digestion trials. Therefore, a more meaningful determination of the effect of concentrate level and overestimation of **in vivo** digestibility could be made in a study where the ratio of ration ingredients is the same in the **in vivo** and **in vitro** digestion trials.

Using mixed rations, highly significant ($P<.01$) negative correlations (-.65, -.63, and -.56, respectively) were obtained between acid insoluble lignin and **in vivo** DDM, DOM, and TDN. The negative correlation (-.29) obtained between acid insoluble lignin and DE was approaching significance. The -.65 correlation between acid insoluble lignin and **in vivo** DDM from the present data is of a similar magnitude to the -.68 correlation reported by Simkins and Baumgardt (1963) between acid insoluble lignin and **in vivo** DDM when using forages alone; Oh and Baumgardt (1966) reported a lower correlation of -.46. These correlations are slightly lower than the -.79 reported by Van Soest (1963) between acid insoluble lignin and **in vivo** DDM of forages alone.

Correlation coefficients between dry matter solubility and the four measures of **in vivo** digestibility were generally low and not significant. Trends in the dry matter solubility data indicate that the use of concentrates in this laboratory evaluation could be the reason for the low correlations, especially since this method was developed to estimate the digestibility of forages only. Also, a different ratio of ration ingredients was used in the laboratory evaluation than was consumed in the **in vivo** digestion trials which could have contributed to the lower correlations.

In summary, it is evident from this study that some laboratory evaluations are significantly correlated with **in vivo** digestibility, even when mixed rations are used. Both acid insoluble lignin and **in vitro** DDM are significantly correlated with **in vivo** DDM, DOM, and TDN. However, dry matter solubility showed little relationship to any of the expressions of **in vivo** digestibility.

Relationships Between Voluntary Intake and Laboratory Evaluations. In this study, partial correlations between three measures of Voluntary Intake (VI-BW, $VI\text{-}BW^{.75}$ and $VI\text{-}BW^{.84}$) and three laboratory evaluations were calculated. These correlations are shown in Table 2. Correlations between the laboratory evaluations and the various measures of VI indicated that they were not significantly related. Various workers (Donefer **et al.**, 1960; Bratzler, 1961; Johnson **et al.**, 1962; Karn **et al.**, 1964; Reid and Jung, 1965; and Chalupa and Lee, 1966) have indicated that short-term **in vitro** digestion was highly correlated with VI. However, in this study the results of the longer term **in vitro** fermentation method of Tilley and Terry (1963) were correlated with VI, but this correlation only approached significance.

Using forages, Van Soest (1964 and 1965b), Reid and Jung (1965), and—using mixed rations—Barth and Mohammed (1966)

Table 2. Partial Correlation coefficients[a, b] between methods that evaluate ration quality

	ADG	TDN intake above maint.	NVI ($BW^{.75}$ energy)	NVI ($BW^{.75}$ dry matter)	NVI ($BW^{.[illegible]1}$ energy)	NVI ($BW^{.[illegible]1}$) dry matter	VI (BW)	VI ($BW^{.75}$)	VI ($BW^{.[illegible]1}$)
TDN intake above maint.	0.18								
NVI ($BW^{.75}$-energy)	0.18	0.67							
NVI ($BW^{.75}$-dry matter)	0.25	0.64	0.69						
NVI ($BW^{.[illegible]1}$-energy)	0.16	0.69	0.67	0.61					
NVI ($BW^{.[illegible]1}$-dry matter)	0.22	0.69	0.63	0.63	0.68				
VI (BW)	0.18	0.54	0.51	0.54	0.52	0.57			
VI ($BW^{.75}$)	0.20	0.47	0.46	0.50	.045	0.50	0.63		
VI ($BW^{.[illegible]1}$)	0.18	0.55	0.45	0.46	0.53	0.58	0.66	0.63	
DDM	0.27	0.62	0.62	0.59	0.61	0.60	0.20	0.18	0.23
DOM	0.21	0.60	0.60	0.55	0.60	0.57	0.15	0.18	**0.19**
TDN	0.16	0.62	0.60	0.55	0.59	0.56	0.19	0.17	0.21
DE	0.16	0.60	0.65	0.59	0.62	0.56	0.20	–.17	0.19
In vitro DDM	0.45	0.39	0.36	0.40	0.35	0.38	0.29	0.29	0.27
Acid insoluble lignin	–.37	–.33	–.34	–.33	–.31	–.31	–.07	–.08	–.08
Dry matter solubility	–.16	–.15	–.05	–.10	–.08	–.15	–.14	–.09	–.15

[a]Initial body weight, initial type and condition, and sex were held constant in calculating these correlations.
[b]Coefficients above 0.33 and below -.33 were significant ($P<.05$), and coefficients above 0.42 and below -.42 were highly significant ($P<.01$).

indicated that lignin content could be used to predict VI. Dry matter solubility was reported to be a good predictor of VI by Dehority and Johnson (1964) who used forages alone and by Mohammed (1966) who used mixed rations.

General conclusions from the present study are that there is little relationship between VI of mixed rations and results obtained from these laboratory procedures. However, of these laboratory evaluations, **in vitro** DDM (Tilley and Terry, 1963) is the best estimator of VI when mixed rations are used.

Relationships Between Nutritive Value Index and Laboratory Evaluations. The partial correlations between either NVI ($BW^{.75}$ energy), NVI ($BW^{.75}$-dry matter), NVI ($BW^{.84}$-energy), or NVI ($BW^{.84}$-dry matter) and the three laboratory evaluations (**in vitro** DDM, acid insoluble lignin, and dry matter solubility) also were determined in this investigation and these results are presented in Table 2. Essentially no difference was found in the correlations between the four expressions of NVI. Correlation coefficients between the four expressions of NVI and **in vitro** DDM were significant ($P < .05$), indicating **in vitro** DDM to be an estimator of NVI. Coefficients based on energy digestibility were slightly lower than those based on DDM, and coefficients where 0.75 was used as the exponent for body weight were slightly higher than those where 0.84 was used. Acid insoluble lignin also was significantly ($P < .05$) negatively correlated with NVI ($BW^{.75}$-energy) and NVI ($BW^{.75}$-dry matter), while negative correlations between acid insoluble lignin and NVI ($BW^{.84}$-energy), or NVI ($BW^{.84}$-dry matter) approached significance. Correlations between dry matter solubility and the four expressions of NVI were low and nonsignificant showing little or no relationship. This is in contrast with the results of Dehority and Johnson (1964) who stated that there was a high relationship between dry matter solubility and NVI when using forages alone.

In summary, these results show **in vitro** DDM to be a useful indicator of NVI when using mixed rations. Acid insoluble lignin can be used also to estimate NVI; however, **in vitro** DDM seems to be the preferred method for mixed rations. Dry matter solubility probably should not be used to estimate NVI when mixed rations are used.

Relationships Between Average Daily Gains and In Vivo Digestibility. Partial correlation coefficients between ADG and the four **in vivo** measures of digestibility (DDM, DOM, TDN, and DE) are presented in Table 2. It may be observed that these correlations are quite small and nonsignificant. Of special interest is the fact that both DDM and DOM were more highly correlated with ADG than was TDN or DE. This was especially surprising since, in the past, TDN and DE have been the major criteria for determining nutritive value of forages.

Relationships Between Average Daily Gains and Voluntary Intake. ADG was correlated also with three measures of VI (VI-BW, VI-$BW^{.75}$ and VI-$BW^{.84}$), and the coefficients are shown in Table 2. These partial correlations were small and nonsignificant. The partial correlation between VI-$BW^{.75}$ and ADG, however, was slightly larger (0.20 **vs.** 0.18) than the correlations between ADG and the two other measures of VI. In contrast, using forages, Crampton **et al.** (1960), Byers and Ormiston (1962), and Ingalls **et al.** (1965) have indicated a high relationship between ADG and VI.

Relationships Between Average Daily Gains and Nutritive Value Indexes or TDN Intake Above Maintenance. Crampton **et al.** (1960) and Byers and Ormiston (1962) have reported a high relationship between NVI and ADG. Therefore, partial correlation coefficients between NVI ($BW^{.75}$-dry matter), NVI ($BW^{.84}$-energy), and NVI ($BW^{.84}$-dry matter) and ADG were calculated. These partial correlations are presented in Table 2. Small, nonsignificant, partial correlations were obtained. NVI ($BW^{.75}$-dry matter) was the most highly correlated (0.25) with ADG, followed by NVI ($BW^{.84}$-dry matter), NVI ($BW^{.75}$-energy), and NVI ($BW^{.84}$-energy).

TDN intake above maintenance also was correlated with ADG (Table 2), since intake above maintenance is generally considered as that portion of the ration which determines production. However, the partial correlation obtained was low and not significant.

Relationships Between Average Daily Gains and Laboratory Evaluations. Partial correlations were calculated between ADG and the three laboratory evaluations, and the results are presented in Table 2. The highly significant ($P<.01$) partial correlation (0.45) between ADG and **in vitro** DDM indicated this laboratory procedure to be a useful estimator of ADG when mixed rations are fed. A somewhat lower but significant ($P<.05$) negative partial correlation was obtained between ADG and acid insoluble lignin, suggesting that this variable also may be used to estimate ADG. However, the partial correlation between ADG and dry matter solubility was low and not significant. Therefore, this procedure most probably should not be used to estimate ADG when mixed rations are to be used.

Multiple Regression Equations

Multiple regression equations were calculated for the three measures of VI (VI-BW, VI-$BW^{.75}$, and VI-$BW^{.84}$) and for ADG, using various combinations of independent variables. The purpose of these analyses was to determine combinations of variables which would be relatively easy to obtain and which would be useful in estimating VI and ADG.

The general form in which these equations are presented is:

$$\hat{Y} = a + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n.$$

Where "a" is a constant, calculated as follows:

$$a = \bar{Y} - b_1 \bar{X}_1 - b_2 \bar{X}_2 - \ldots - b_n \bar{X}_n.$$

The b's are partial regression coefficients. For example, in Table 3, equation two is the equation for estimating VI-BW from **in vitro** DDM, concentrate in the ration, and length of feeding; that is,

$$\hat{Y} = 1.147 + 0.0224 X_1 - 0.0056 X_2 - 0.0018 X_3.$$

Where $\hat{Y}$ = predicted value of VI-BW.
X_1 = **in vitro** DDM.
X_2 = percent concentrate in the ration.
X_3 = length of feeding in days.

Voluntary Intake Estimated from Laboratory Evaluations and Other Variables. Partial regression coefficients and constants for multiple regression equations calculated to estimate VI-BW, VI-$BW^{.75}$, and VI-$BW^{.84}$ of mixed rations appear in Tables 3, 4, and 5. The equations were calculated using either **in vitro** DDM, acid insoluble lignin, or dry matter solubility and one or more other variables, consisting of percent concentrate in the ration, length of feeding, percent crude protein in the ration, and length of feeding)^2. The quadratic "length of feeding" term was included to determine if a nonlinear reationship existed between length of feeding and these measures of VI.

Coefficients of determination for VI-BW, VI-$BW^{.75}$, and VI-$BW^{.84}$ obtained using the same combination of variables were of about the same magnitude. From these coefficients, it appears that any one of these three measures of VI can be estimated with about the same degree of success when using these multiple regression equations. The magnitude of these coefficients of determination obtained for VI-BW, VI-BW^{75}, and VI-BW^{84} were low and nonsignificant, suggesting that these multiple regression equations most probably

Table 3. Partial regression coefficients and constants used in multiple regression equations[a] for predicting VI-BW

	Equation number											
	1	2	3	4	5	6	7	8	9	10	11	12
Constant, (a)	1.071	1.147	0.883	0.237	2.266	2.265	2.289	2.481	2.429	2.408	2.178	2.087
In vitro DDM	0.0204	0.0224	0.0239	0.0241								
Acid insoluble lignin					–.0119	–.0118	–.0107	–.0119				
Dry matter solubility									–.0099	–.0098	–.0236	–.0238
Concentrate in ration, %	–.0048	–.0056	–.0058	–.0065	–.0003	–.0003	–.0003	–.0007	–.0016	–.0016	–.0034	–.0032
Length of feeding, days		–.0018	–.0017	0.0051		0.0000	0.0000	–.0019		0.0002	0.0007	0.0016
Crude protein in ration, %			0.0120	0.0131			–.0021	–.0012			0.0358	0.0358
(Length of feeding)^2, days				0.0000				0.0000				0.0000
$R^{2,b}$	.159	.171	.179	.181	.006	.006	.006	.007	.025	.025	.048	.048

[a]Initial body weight, initial type, initial condition, and sex were held constant in developing these equations.
[b]Coefficients of multiple determination.

Table 4. Partial regression coefficients and constants used in multiple regression equations[a] for predicting VI-BW[57]

	Equation number											
	1	2	3	4	5	6	7	8	9	10	11	12
Constant, (a)	42.185	44.872	30.590	43.574	95.205	94.068	93.097	105.985	99.285	97.101	88.386	94.781
In vitro DDM	0.8947	0.9702	1.0503	1.0711								
Acid insoluble lignin					–.6112	–.5846	–.6263	–.7886				
Dry matter solubility									–.3347	–.3288	–.8627	–.8461
Concentrate in ration, %	–.2368	–.2665	–.2767	–.3362	0.0429	0.0404	–.0407	–.0933	–.0791	–.0747	–.1447	–.1646
Length of feeding, days		–.0661	–.0606	–.3664		0.0093	0.0099	–.2585		0.0193	0.0381	–.0866
Crude protein in ration, %			0.6481	0.7408			0.0827	0.2082			1.3811	1.3834
(Length of feeding)^2, days				0.0016				0.0014				0.0006
$R^{2,b}$	.149	.158	.168	.176	.009	.009	.009	.015	.015	.016	.032	.034

[a]Initial body weight, initial type, initial condition, and sex were held constant in developing these equations.
[b]Coefficients of multiple determination.

Table 5. Partial regression coefficients and constants used in multiple regression equations[a] for predicting $VI\text{-}BW^{.84}$

	Equation number											
	1	2	3	4	5	6	7	8	9	10	11	12
Constant, (a)	23.749	27.710	22.517	16.192	56.622	62.671	63.993	57.498	61.791	66.297	60.261	52.163
In vitro DDM	0.5524	0.6636	0.6927	0.6896								
Acid insoluble lignin					–.3975	–.5390	–.4823	–.4344				
Dry matter solubility									–.3205	–.3329	–.7011	–.7239
Concentrate in ration, %	–.1397	–.1834	–.1871	–.1783	–.0207	–.0340	–.0337	–.0181	–.0616	–.0708	.–1191	–.0917
Length of feeding, days		–.0974	–.0954	–.0502		–.0495	–.0503	–.0290		–.0408	–.0279	0.1442
Crude protein in ration, %			0.2357	0.2220			–.1123	–.1495			0.9524	0.9492
(Length of feeding)^2, days				–.0002				0.0004				–.0009
$R^{2,b}$	.141	.189	.192	.193	.008	.021	.022	.023	.032	.041	.061	.067

[a]Initial body weight, initial type, initial condition, and sex were held constant in developing these equations.
[b]Coefficients of multiple determination.

should not be used to estimate VI of mixed rations. On the basis of these results, evidently more work needs to be done concerning the estimation of VI of mixed rations from laboratory evaluations.

Coefficients of determination obtained with multiple regression equations in which **in vitro** DDM was used were larger than coefficients obtained with equations in which acid insoluble lignin or dry matter solubility was used. This indicates that even though these equations containing **in vitro** DDM are not acceptable for estimating VI of mixed rations, they are more useful than equations in which acid insoluble lignin or dry matter solubility were used. These data show also that percent concentrate in the ration, length of feeding, percent crude protein in the ration, and $(\text{length of feeding})^2$ contribute little to the estimation of VI, when either **in vitro** DDM, acid insoluble lignin, or dry matter solubility also has been included in the regression equation.

Average Daily Gains Estimated from Voluntary Intake and In Vivo **Digestibility.** Partial regression coefficients and constants for multiple regression equations and coefficients of determination were calculated for ADG (Table 6) by combining one of three measures of VI (VI-BW, VI-$BW^{.75}$ and VI-$BW^{.84}$) with 1 of 4 measures of **in vivo** digestibility (DDM, DOM, TDN, and DE) in regression equations, until all possible combinations of VI and **in vivo** digestibility were used. These coefficients of determination for ADG were low and nonsignificant, indicating that VI and **in vivo** digestibility explained only a very small amount of the variation in ADG.

Since equation five, consisting of VI-$BW^{.75}$ and **in vivo** DDM, explained more of the variation in ADG (11%) than did any of the other 11 regression equations, it was chosen to be expanded with other variables in order to establish the most accurate means of estimating ADG from several variables. In contrast to these results, it was indicated in the literature that VI and digestibility make a large contribution to animal performance. Therefore, this would indicate a need for additional work to determine the contribution of VI and digestibility on animal performance when mixed rations are fed.

Average Daily Gains Estimated from Several Variables. VI-$BW^{.75}$, **in vivo** DDM, and one or more other variables were used in calculating regression equations and coefficients of determination for ADG. These regression equations and coefficients of determination are presented in Table 7. Since several of the independent

Table 6. Partial regression coefficients and constants used in multiple regression equations[a] for predicting ADG from voluntary intake and **in vivo** digestibility

	Equation number											
	1	2	3	4	5	6	7	8	9	10	11	12
Constant, (a)	–.340	–.268	–.066	–.045	–.445	–.381	–.179	–.163	–.261	–.181	0.007	0.006
VI-BW	0.1872	0.2142	0.2181	0.2207								
$VI\text{-}BW^{.75}$					0.0060	0.0066	0.0067	0.0068				
$VI\text{-}BW^{.84}$									0.0064	0.0075	0.0078	0.0080
DDM	0.0097				0.0093				0.0095			
DOM		0.0076				0.0074				0.0073		
TDN			0.0045				0.0043				0.0043	
DE				0.0941				0.0899				0.0951
R^2 [b]	.096	.078	.061	.059	.113	.098	.080	.079	.093	.076	.060	.060

[a]Initial body weight, initial type, initial condition, and sex were held constant in developing these equations.
[b]Coefficients of multiple determination.

Table 7. Partial regression coefficients and constants used in multiple regression equations[a] for predicting ADG from several variables

	Equation number					
	1	2	3	4	5	6
Constant, (a)	−.445	−.683	−.539	0.496	1.121	1.356
$VI\text{-}BW^{.75}$	0.0060	0.0068	0.0069	0.0072	0.0063	0.0063
DDM	0.0093	0.0078	0.0100	−.0004	0.0010	−.0017
Concentrate in ration, %		0.0060	0.0055	0.0040	0.0010	0.0002
Length of feeding, days			−.0029	−.0035	−.0192	−.0221
Acid insoluble lignin				−.0480	−.0513	−.0713
$(\text{Length of feeding})^2$, days					0.0001	0.0001
Crude protein in ration, %						0.0260
$R^{2,b}$	.113	.293**	.343**	.408**	.462**	.498**

[a]Initial body weight, initial type, initial condition, and sex were held constant in developing these equations.
[b]Coefficients of multiple determination.
**P<.01.

variables included in the regression equations were highly correlated with one another, some of the variables included last possibly would have explained more of the variation had they been included earlier. Hence, when considering the percent of variation explained by regression on a particular independent variable in these regression equations, the above considerations as to order of incorporating variables should be kept in mind. The percent concentrate in the ration accounted for more of the variation in ADG (18%) than did any other variable in these regression equations. Each of the variables, length of feeding, lignin content, (length of feeding)^2, and crude protein in the ration explained from 3 to 6.5% of the variation in ADG when using these regression equations. These percentages were determined by subtracting the coefficient of determination for one equation from the coefficient of determination of another equation, when there was only one extra variable added to the last equation. For example, the coefficient of determination for equation 2 was subtracted from that of equation 3 yielding 5%. Since length of feeding was the only variable in equation 3, which was not in equation 2, its contribution to ADG in this regression equation is 5%.

The coefficients of determination for multiple regression equations 2-6 calculated using the above variables were significant, and when all variables were combined in one equation (Equation 6), they explained approximately 50% of the variation in ADG. These equations are useful in estimating ADG, when mixed rations are fed, since all the variables composing these equations can be easily determined.

Average Daily Gains Estimated from Laboratory Evaluations. Regression equations and coefficients of determination for estimating ADG from laboratory evaluations are presented in Table 8. Regression equations 1-4, containing **in vitro** DDM as the major laboratory evaluation, explained more of the variation in ADG than did similar equations containing either acid insoluble lignin or dry matter solubility as the laboratory evaluation. Coefficients of determination for multiple regression equations 1-4, containing **in vitro** DDM and combinations of the variables length of feeding, (length of feeding)^2, percent crude protein in the ration, and percent concentrate in the ration, were highly significant ($P<.01$). Equations 3 and 4 showed slightly higher coefficients of determination than did equations 1 and 2. However, equations 1 or 2 would most probably be used in estimating ADG when mixed rations are being fed, since the addition of percent crude protein in the ration and percent concentrate in the ration explained only 3% of the variation in ADG.

A considerable portion of the variation in ADG was explained when acid insoluble lignin was the laboratory evaluation. These coefficients also were highly significant ($P<.01$). In cases where **in vitro** DDM cannot be determined due to a lack of ruminant animals from which to obtain rumen microorganisms, or due to a lack of appropriate equipment, equations 6, 7, or 8 could be used to estimate ADG when mixed rations are fed. However, if these microorganisms are available, then **in vitro** DDM seems to be the variable of choice, since it gives a more accurate estimation of ADG and is an easier determination to conduct in the laboratory.

When dry matter solubility was used as the laboratory evaluation in regression equations, the coefficients of determination obtained were low. Since these coefficients were so low (the largest was 0.27), these equations probably should not be used to estimate ADG.

On the basis of the results of this study, regression equations 2-6 in Table 7 and regression equations 1-8 in Table 8 are useful in estimating ADG when mixed rations are fed. Regression equation 2, containing **in vivo** DDM, length of feeding, and (length of feeding)^2, in Table 8, seems to be the most useful estimator of ADG—even more useful than equations containing VI, **in vivo** digestibility and other variables—since this equation contains variables the measurement of which is simple, relatively accurate and inexpensive, time-saving, and does not involve feeding animals. This equation explains almost as much of the variation in ADG as does any other regression equation developed from these data (Tables 6, 7, and 8).

Table 8. Partial regression coefficients and constants used in multiple regression equations[a] for predicting ADG from laboratory evaluations

	Equation number											
	1	2	3	4	5	6	7	8	9	10	11	12
Constant, (a)	−.326	0.721	−.345	−.191	1.440	2.067	1.904	1.226	1.114	1.831	1.931	1.057
In vitro DDM	0.0220	0.0194	0.0207	0.0244								
lignin					−.0630	−.0588	−.0713	0.0722				
Acid insoluble												
Dry matter solubility									−.0081	0.0002	0.0020	0.0156
Length of feeding, days	−.0042	−.0134	−.0137	−.0190	−.0042	−.0216	−.0230	−.0237	−.0028	−.0224	−.0230	−.0154
(Length of feeding)^2, days		0.0001	0.0001	0.0001	0.0001		0.0001	0.0001		0.0001	0.0001	0.0001
Crude protein in ration, %			0.0147	0.0175			0.0261	0.0265			−.0053	−.0290
Concentration in ration, %				−.0030				−.0003				0.0056
$R^{2,b}$	.425**	.456**	.470**	.487**	.290**	.415**	.455**	.456**	.085	.211*	.212	.273

[a]Initial body weight, initial type, initial condition, and sex were held constant in developing these equations.
[b]Coefficients of multiple determination.
*P<.05.
**P<.01.

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Appendix Table 1. Ration ingredients and their nutrient composition

Ration number	Ingredient	Percent in ration[a]	Dry matter	Organic matter[b]	Crude protein[b]	Ether extract[b]	Crude fiber[b]	N-free extract[b]	Ash[b]	Gross energy[b]
			%	%	%	%	%	%	%	kcal./gm.
1[c]	Corn silage	45.9	22.4	18.3	8.4	2.5	28.7	56.0	4.1	4.29
	Alfalfa-grass hay[d]	14.3	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.85
	Concentrate mix[e]	39.8	87.7	85.2	16.5	3.6	4.1	73.4	2.5	4.46
2[c]	Alfalfa silage	44.5	24.3	16.3	9.3	2.1	37.5	43.1	8.0	4.26
	Alfalfa-grass hay[d]	15.3	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.85
	Concentrate mix[e]	40.2	89.5	85.7	16.8	3.9	4.6	70.9	3.8	4.46
3[c]	Corn silage	74.7	24.0	19.9	10.5	2.5	27.5	55.5	4.1	4.34
	Alfalfa-grass hay[d]	16.3	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Cottonseed meal	9.0	94.3	87.9	43.9	3.6	15.2	30.9	6.4	4.85
4[c]	Alfalfa silage	73.7	25.5	16.4	15.3	3.3	36.3	36.0	9.1	4.35
	Alfalfa-grass hay[d]	17.2	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Cottonseed meal	9.1	94.3	87.9	43.9	3.6	15.2	30.9	6.4	4.85
5[c]	Corn silage	45.9	24.9	20.8	8.5	3.2	24.4	59.9	4.1	4.60
	Alfalfa-grass hay[d]	15.4	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Concentrate mix[e]	38.7	89.5	85.7	16.8	3.9	4.6	70.9	3.8	4.45
6[c]	Alfalfa silage	46.6	23.2	12.6	18.8	4.7	31.3	34.6	10.6	4.84
	Alfalfa-grass hay[d]	15.2	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Concentrate mix[e]	38.2	89.5	85.7	16.8	3.9	4.6	70.9	3.8	4.45
7[c]	Corn silage	72.5	21.4	16.7	9.9	2.6	27.3	55.6	4.7	4.54
	Alfalfa-grass hay[f]	18.3	89.2	82.3	16.1	1.9	35.5	39.2	6.9	4.46
	Cottonseed meal	9.2	92.2	86.3	43.3	4.4	12.7	33.7	5.9	4.97
8[c]	Alfalfa silage	67.7	20.1	8.2	14.1	2.9	38.9	32.3	11.9	4.92
	Alfalfa-grass hay[f]	21.5	89.2	82.3	16.1	1.9	35.5	39.2	6.9	4.46
	Cottonseed meal	10.8	92.2	86.3	43.3	4.4	12.7	33.7	5.9	4.97

Appendix Table 1 (continued)

Ration number	Ingredient	Percent in ration[a]	Dry matter	Organic matter[b]	Crude protein[b]	Ether extract[b]	Crude fiber[b]	N-free extract[b]	Ash[b]	Gross energy[b]
			%	%	%	%	%	%	%	kcal./gm.
9[e]	Corn silage	38.2	23.7	19.5	9.0	2.3	26.2	58.3	4.2	4.38
	Alfalfa-grass hay[f]	16.7	89.2	82.3	16.1	1.9	35.5	39.2	6.9	4.46
	Concentrate mix[e]	45.1	87.9	85.3	20.0	4.3	3.9	69.2	2.6	4.79
10[g,h]	Alfalfa hay	10.0	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	85.0	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	5.0	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
11[g,h]	Ground ear corn	94.3	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	5.7	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
12[g,h]	Alfalfa hay	10.0	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	83.7	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	6.3	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88
13[g,h]	Ground ear corn	93.0	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	7.0	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88
14[g,h]	Alfalfa hay	11.3	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	83.0	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	5.7	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
15[g,h]	Ground ear corn	94.7	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	5.3	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
16[g,h]	Alfalfa hay	11.4	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	81.4	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	7.2	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88
17[g,h]	Ground ear corn	92.4	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	7.6	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88

Appendix Table 1 (continued)

Ration number	Ingredient	Percent in ration[a]	Dry matter	Organic matter[b]	Crude protein[b]	Ether extract[b]	Crude fiber[b]	N-free extract[b]	Ash[b]	Gross energy[b]
			%	%	%	%	%	%	%	kcal./gm.
18[g,h]	Corn silage	50.1	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Alfalfa hay	12.0	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	31.9	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	6.0	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
19[g,h]	Corn silage	59.2	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Ground ear corn	34.3	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	6.5	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
20[g,h]	Corn silage	49.1	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Alfalfa hay	12.4	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	32.3	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	6.2	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88
21[g,h]	Corn silage	58.9	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Ground ear corn	34.6	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	6.5	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88
22[g,h]	Corn silage	45.8	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Alfalfa hay	13.2	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	34.4	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	6.6	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
23[g,h]	Corn silage	55.3	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Ground ear corn	37.6	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Urea supplement	7.1	94.6	79.1	49.8	5.9	2.2	26.7	15.5	3.49
24[g,h]	Corn silage	44.7	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Alfalfa hay	13.3	92.7	83.6	20.0	2.2	27.0	41.7	9.1	4.43
	Ground ear corn	35.3	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	6.7	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88

Appendix Table 1 (continued)

Ration number	Ingredient	Percent in ration[a]	Dry matter	Organic matter[b]	Crude protein[b]	Ether extract[b]	Crude fiber[b]	N-free extract[b]	Ash[b]	Gross energy[b]
			%	%	%	%	%	%	%	kcal./gm.
25[k,h]	Corn silage	54.1	27.7	22.9	9.1	2.7	28.7	54.7	4.8	4.45
	Ground ear corn	38.5	92.2	90.8	7.9	3.8	10.3	76.6	1.4	4.37
	Cottonseed meal	7.4	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.88
26[i]	Corn silage	52.7	35.0	30.8	8.5	1.3	28.6	57.4	4.2	4.53
	Alfalfa hay	12.6	92.0	85.3	17.8	2.2	27.3	46.0	6.7	4.55
	Cracked corn	25.2	89.8	88.5	10.8	4.6	2.1	81.3	1.3	4.55
	Cottonseed meal	9.5	92.5	86.7	41.2	4.0	23.4	25.5	5.8	4.86
27[i]	Corn silage	45.6	30.0	24.8	8.7	1.1	25.7	59.3	5.2	4.30
	Alfalfa hay	13.6	92.0	85.3	17.8	2.2	27.3	46.0	6.7	4.55
	Cracked corn	34.0	89.8	88.5	10.8	4.6	2.1	81.3	1.3	4.55
	Cottonseed meal	6.8	92.5	86.7	41.2	4.0	23.4	25.5	5.8	4.86
28[j]	Alfalfa-grass hay	20.1	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Cracked corn	69.9	87.0	85.6	10.0	4.4	1.6	82.7	1.4	4.45
	Cottonseed meal	10.0	91.5	85.3	44.2	3.9	12.8	33.0	6.2	4.82
29[j]	Alfalfa-grass hay	73.8	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Cracked corn	15.7	87.0	85.6	10.0	4.4	1.6	82.7	1.4	4.45
	Cottonseed meal	10.5	91.5	85.3	44.2	3.9	12.8	33.0	6.2	4.82
30[k]	Corn silage	48.0	30.8	26.4	8.0	2.6	25.5	59.5	4.4	4.58
	Alfalfa hay[d]	14.8	89.3	82.9	15.9	1.5	35.4	40.1	6.4	4.61
	Concentrate mix[l]	37.2	89.2	86.7	17.9	4.0	4.5	71.1	2.5	4.65
31[k]	Corn silage	45.7	27.6	22.7	8.0	2.8	24.8	59.7	4.9	4.67
	Alfalfa hay[d]	15.5	89.3	82.9	15.9	1.5	35.4	40.1	6.4	4.61
	Concentrate mix[l]	38.8	89.2	86.7	17.9	4.0	4.5	71.1	2.5	4.65
32[k]	Alfalfa hay[d]	11.0	89.3	82.9	15.9	1.5	35.4	40.1	6.4	4.61
	Corn silage	1.9	30.8	26.4	8.0	2.6	25.5	59.5	4.4	4.58
	Concentrate mix[m]	87.1	89.2	86.7	17.9	4.0	4.5	71.1	2.5	4.65

Appendix Table 1 (continued)

Ration number	Ingredient	Percent in ration[a]	Dry matter	Organic matter[b]	Crude protein[b]	Ether extract[b]	Crude fiber[b]	N-free extract[b]	Ash[b]	Gross energy[b]
			%	%	%	%	%	%	%	kcal./gm.
33[k]	Alfalfa hay[d]	10.9	89.3	82.9	15.9	1.5	35.4	40.1	6.4	4.61
	Corn silage	1.7	27.6	22.7	8.0	2.8	24.8	59.7	4.9	4.67
	Concentrate mix[m]	87.4	89.2	86.7	17.9	4.0	4.5	71.1	2.5	4.65
34[n]	Good alfalfa hay	100.0	90.1	82.6	18.7	1.9	29.4	41.7	7.5	4.55
35[n]	Fair alfalfa hay	100.0	89.3	82.9	15.9	1.5	35.4	40.7	6.4	4.61
36[n]	Poor alfalfa hay	100.0	91.5	87.1	13.7	1.1	46.7	33.7	4.4	4.59
37[g,h]	1st cut corn silage	67.3	23.3	17.3	11.1	1.4	24.7	56.9	6.0	4.40
	Alfalfa hay	14.0	94.1	86.0	17.9	1.5	29.4	43.1	8.1	4.46
	Cottonseed meal	18.7	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.94
38[g,h]	2nd cut corn silage	68.5	25.9	19.8	11.1	1.6	23.7	57.7	6.1	4.43
	Alfalfa hay	13.5	94.1	86.0	17.9	1.5	29.4	43.1	8.1	4.46
	Cottonseed meal	18.0	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.94
39[g,h]	4th cut corn silage	65.4	32.7	25.0	9.7	1.2	27.7	53.7	7.7	4.27
	Alfalfa hay	14.9	94.1	86.0	17.9	1.5	29.4	43.1	8.1	4.46
	Cottonseed meal	19.8	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.94
40[c]	Corn silage	75.4	26.3	22.7	9.0	2.7	24.0	60.7	3.6	4.46
	Alfalfa-grass hay[d]	16.4	89.7	81.6	15.0	2.9	35 4	38.7	8.1	4.46
	Cottonseed meal	8.2	89.7	84.1	43.3	3.3	16.5	43.9	5.6	4.80
41[c]	Alfalfa silage	75.4	22.8	12.3	16.3	4.1	30.6	38.5	10.5	4.71
	Alfalfa-grass hay[d]	16.4	89.7	81.6	15.0	2.9	35.4	38.7	8.1	4.46
	Cottonseed meal	8.2	89.7	84.1	34.3	3.3	16.5	43.9	5.6	4.80

Appendix Table 1 (continued)

Ration number	Ingredient	Percent in ration[a]	Dry matter	Organic matter[b]	Crude protein[b]	Ether extract[b]	Crude fiber[b]	N-free extract[b]	Ash[b]	Gross energy[b]
			%	%	%	%	%	%	%	kcal./gm.
42[c]	Alfalfa silage	33.6	15.8	4.3	14.0	3.0	40.0	31.4	11.5	4.86
	Alfalfa-grass hay[f]	17.9	89.2	82.3	16.1	1.9	35.4	39.2	6.9	4.46
	Concentrate mix[e]	48.5	87.9	85.3	20.0	4.3	3.9	69.2	2.6	4.79
43[k,n]	3rd cut corn silage	70.1	29.8	23.2	10.5	1.8	24.1	57.1	6.6	4.38
	Alfalfa hay	12.8	94.1	86.0	17.9	1.5	29.4	43.1	8.1	4.46
	Cottonseed meal	17.1	94.9	93.7	40.3	3.6	14.1	40.7	1.2	4.94

[a]Feedlot and laboratory evaluations, dry matter basis.

[b]Dry matter basis.

[c]B. B. Wilson, 1964.

[d]This hay was substituted in the laboratory evaluations. The nutrient composition of the hay used in the feedlot is not known.

[e]Four parts cracked corn and one part cottonseed meal.

[f]Nutrient composition applies to hay fed in the feedlot. In the laboratory evaluations, the hay as described in footnote [d] was substituted.

[g]Chamberlain *et al.*, 1966.

[h]McConnell *et al.*, 1967.

[i]Corrick *et al.*, 1966.

[j]Clark and Barth, 1966.

[k]G. R. Wilson, 1964.

[l]Four parts ground ear corn and one part cottonseed meal.

[m]Seven parts ground ear corn and one part cottonseed meal.

[n]Mohammed *et al.*, 1967.

[o]Barth and Prigge, 1966.

Appendix Table 2. Description of the rations

Ration number	Major forage[a]	Number of forages[b]	Dry matter in silage	Roughage in ration[c]	Concentrate in ration[c]	Crude protein in ration[c]
			%	%	%	%
1	11	2	22.4	60.2	39.8	12.3
2	12	2	24.3	59.8	40.2	13.1
3	11	2	24.0	91.0	9.0	14.2
4	12	2	25.5	90.9	9.1	17.8
5	11	2	24.9	61.3	38.7	12.6
6	12	2	23.2	61.8	38.2	17.5
7	11	2	21.4	90.8	9.2	14.1
8	12	2	20.1	89.3	10.7	17.8
9	11	2	23.7	54.9	45.1	14.9
10	22	1	——[e]	10.0	90.0	11.3
11	—[d]	0	——[e]	0.0	100.0	10.3
12	22	1	——[e]	10.0	90.0	11.2
13	—[d]	0	——[e]	0.0	100.0	10.2
14	22	1	——[e]	11.4	88.6	11.7
15	—[d]	0	——[e]	0.0	100.0	10.1
16	22	1	——[e]	11.4	88.6	11.6
17	—[d]	0	——[e]	0.0	100.0	10.4
18	11	2	27.7	62.1	37.9	12.4
19	11	1	27.7	59.2	40.8	11.3
20	11	2	27.7	61.5	38.5	11.9
21	11	1	27.7	58.9	41.1	10.7
22	11	2	27.7	59.0	41.0	12.7
23	11	1	27.7	55.3	44.7	11.5
24	11	2	27.7	58.0	42.0	12.2
25	11	1	27.7	54.1	45.9	11.0
26	11	2	35.0	65.3	34.7	13.3
27	11	2	30.0	59.2	40.8	12.8
28	23	1	——[e]	20.0	80.0	14.6
29	23	1	——[e]	73.8	26.2	17.4
30	11	2	30.8	62.8	37.2	12.5
31	11	2	27.6	61.2	38.8	12.8
32	22	2	30.8	12.9	87.1	17.5
33	22	2	27.6	12.6	87.4	17.5
34	22	1	——[e]	100.0	0.0	18.7
35	22	1	——[e]	100.0	0.0	15.9
36	22	1	——[e]	100.0	0.0	13.7
37	11	2	23.3	81.3	18.7	17.4
38	11	2	25.9	82.0	18.0	17.4
39	11	2	32.7	80.2	19.8	16.6
40	11	2	26.3	91.8	8.2	12.0
41	12	2	22.8	91.8	8.2	17.6
42	12	2	15.8	51.5	48.5	17.2
43	11	2	29.8	82.9	17.1	16.4

[a]Corn silage = 11, alfalfa silage = 12, legume hay = 22, alfalfa-grass hay = 23.
[b]Number of forages fed per ration.
[c]Dry matter basis.
[d]No forage fed.
[e]No silage fed.

Appendix Table 3. Description of animals and feedlot trials

Ration number	Sex[a]	Initial weight	Initial cond.[b]	Initial type[b]	Length of feeding	Av. daily gain
		kg.			days	kg.
1	1	230	8.0	11.8	113	0.61
2	1	231	8.0	12.1	113	0.51
3	2	234	7.4	10.6	113	0.60
4	2	236	7.3	10.4	113	0.36
5	1	209	8.2	11.0	112	0.64
6	1	207	8.0	11.2	112	0.65
7	2	241	8.1	10.6	141	0.68
8	2	239	8.1	11.1	141	0.39
9	1	176	7.4	10.5	141	0.73
10	1	330	6.3	8.4	48	1.06
11	1	315	6.6	8.0	48	0.96
12	1	336	6.6	8.4	48	1.04
13	1	324	6.7	8.2	48	0.83
14	1	280	5.6	7.0	48	1.13
15	1	295	6.3	7.7	48	0.94
16	1	285	6.0	7.7	48	0.90
17	1	281	5.4	6.3	48	0.99
18	1	266	6.3	8.4	112	0.55
19	1	258	6.6	8.0	112	0.52
20	1	266	6.6	8.4	112	0.63
21	1	262	6.7	8.2	112	0.55
22	1	207	5.6	7.0	112	0.65
23	1	217	6.3	7.7	112	0.69
24	1	208	6.0	7.7	112	0.69
25	1	202	5.4	6.3	112	0.71
26	1	205	8.4	10.6	140	0.75
27	1	207	8.3	10.3	140	0.93
28	2	325	10.4	12.0	42	1.16
29	2	331	10.6	11.7	42	0.59
30	1	213	7.8	11.0	113	0.80
31	1	213	7.5	11.0	113	0.79
32	1	305	8.5	11.0	80	0.73
33	1	302	8.5	11.0	80	0.74
34	2	258	7.7	10.2	71	0.84
35	2	262	7.6	10.1	71	0.68
36	2	257	7.9	10.1	71	0.00
37	1	212	8.4	10.7	98	0.70
38	1	213	8.5	10.6	98	0.76
39	1	212	8.5	10.6	98	0.56
40	2	248	8.6	12.1	112	0.58
41	2	250	9.1	12.2	112	0.49
42	1	177	7.6	10.5	141	0.66
43	1	212	8.4	10.7	98	0.72

[a] Heifer—1, steer—2.
[b] Low Standard—6, high Choice—14.

Appendix Table 4. **In vivo** expressions of digestibility of the rations

Ration number	DDM[a]	DOM[a]	TDN[a]	DE[a]
	%	%	%	kcal./gm.
1	69.4	70.9	71.2	3.02
2	54.4	56.1	53.7	2.34
3	69.4	71.0	70.8	3.04
4	54.7	56.0	53.5	2.41
5	72.5	73.6	79.4	3.25
6	67.3	68.0	72.0	3.10
7	62.3	64.1	65.6	2.84
8	53.0	52.8	49.2	2.65
9	77.1	77.9	78.5	3.48
10	69.3	70.2	65.0	2.91
11	68.4	79.1	65.6	2.85
12	60.3	60.8	57.4	2.25
13	63.6	64.3	61.7	2.38
14	69.3	70.2	65.0	2.91
15	68.4	69.1	65.6	2.85
16	60.3	60.8	57.4	2.25
17	63.6	64.3	61.7	2.38
18	74.2	75.6	74.4	3.28
19	72.9	74.5	74.4	3.11
20	68.4	69.6	69.5	2.99
21	65.9	67.4	68.8	2.93
22	74.2	75.6	74.4	3.28
23	72.9	74.5	74.4	3.11
24	68.4	69.6	69.5	2.99
25	65.9	67.4	68.8	2.93
26	69.8	68.1	69.7	2.99
27	67.5	66.0	68.2	2.92
28	63.2	63.5	64.2	2.73
29	63.1	63.9	62.5	2.70
30	68.2	68.8	70.7	3.11
31	69.4	71.3	71.8	3.20
32	68.2	68.8	70.7	3.11
33	69.4	71.3	71.8	3.20
34	59.5	60.1	56.6	2.63
35	59.5	59.6	56.7	2.67
36	45.0	46.8	44.9	1.97
37	68.9	70.8	68.9	3.11
38	68.0	69.2	68.0	3.01
39	66.7	68.1	66.5	2.90
40	71.1	71.8	70.6	3.15
41	59.0	60.0	57.1	2.84
42	66.0	66.9	65.8	3.19
43	66.4	67.5	66.7	2.91

[a]Dry matter basis.

Appendix Table 5. Voluntary intake of the rations

ation mber	VI[a] (BW)	VI[b] ($BW^{.75}$)	VI[c] ($BW^{.84}$)
1	2.02	81.5	49.3
2	1.95	78.5	47.5
3	1.76	71.2	43.0
4	1.85	74.2	45.0
5	2.17	85.9	52.3
6	2.19	86.7	52.8
7	1.89	77.4	39.3
8	1.82	74.5	35.1
9	2.09	81.1	49.8
10	2.36	102.6	60.5
11	2.16	92.6	54.8
12	2.32	110.2	59.5
13	2.18	93.9	55.5
14	2.41	100.5	60.0
15	2.49	105.3	62.7
16	2.41	100.6	60.1
17	2.28	95.2	56.9
18	2.44	101.3	60.7
19	2.37	97.7	58.7
20	2.34	97.7	58.2
21	2.31	95.3	57.2
22	2.71	106.9	65.2
23	2.41	96.7	58.6
24	2.65	105.1	62.5
25	2.45	96.6	58.9
26	2.59	103.9	63.0
27	2.29	92.9	56.1
28	2.29	96.5	58.3
29	2.26	97.2	57.5
30	2.25	90.4	54.8
31	2.12	85.4	51.6
32	2.19	93.8	55.6
33	2.22	94.6	56.2
34	2.43	101.6	60.2
35	2.34	96.3	57.9
36	1.88	75.2	45.6
37	1.91	75.6	46.2
38	1.87	79.6	45.4
39	1.91	74.9	46.1
40	1.82	74.7	45.0
41	1.82	74.3	44.8
42	1.95	75.2	46.3
43	2.09	83.1	50.9

[a] $\frac{\text{Kg dry matter intake}}{\text{100 kg. body weight}}$

[b] $\frac{\text{Gm. dry matter intake}}{\text{body weight, kg}^{.75}}$

[c] $\frac{\text{Gm. dry matter intake}}{\text{body weight, kg}^{.84}}$

Appendix Table 6. Nutritive value indexes and TDN intake above maintenance of the rations

Ration number	NVI[a] ($BW^{.75}$-energy)	NVI[b] ($BW^{.75}$-dry matter	NVI[c] ($BW^{.84}$-energy)	NVI[d] ($BW^{.84}$-dry matter)	TDN intake above maint.
					Kg.
1	70.2	70.7	42.5	42.8	2.06
2	50.1	50.7	32.0	32.3	0.99
3	61.4	61.8	37.1	37.3	1.58
4	50.4	50.7	30.5	30.7	0.83
5	77.1	77.9	47.0	47.4	2.56
6	71.9	72.9	43.8	44.4	2.20
7	67.5	68.8	30.3	30.6	1.15
8	56.0	60.7	23.6	23.3	0.12
9	77.3	78.1	47.4	48.0	2.15
10	86.4	88.9	51.0	52.4	3.32
11	76.6	79.2	45.4	46.9	2.72
12	75.8	83.1	40.9	44.8	2.65
13	69.1	74.6	40.9	44.1	2.54
14	84.7	87.1	50.6	52.0	2.86
15	87.1	90.0	51.9	53.6	3.22
16	69.2	75.9	41.4	45.3	2.30
17	70.1	75.7	41.9	45.2	2.37
18	94.5	93.9	56.6	56.2	3.52
19	93.9	89.0	56.4	53.5	3.21
20	81.1	83.5	48.3	49.8	2.98
21	86.2	78.6	51.7	47.2	2.77
22	99.8	99.2	60.8	60.5	3.25
23	92.9	88.0	56.3	53.4	2.89
24	87.3	89.8	51.9	53.5	2.87
25	87.3	79.6	53.2	48.5	2.43
26	87.7	90.6	53.2	55.0	2.93
27	76.3	78.3	46.1	47.4	2.44
28	73.3	76.3	44.3	46.1	3.02
29	72.7	76.7	43.0	45.4	2.76
30	76.4	77.1	46.3	46.8	2.40
31	73.5	74.1	44.7	44.3	2.21
32	79.3	80.0	47.0	47.4	3.13
33	81.4	82.1	48.3	48.7	3.26
34	73.5	76.6	43.5	44.7	2.11
35	69.7	71.6	41.8	43.0	1.95
36	40.3	42.3	24.5	25.7	0.44
37	65.1	64.2	39.6	39.8	1.58
38	67.7	67.4	41.2	38.6	1.51
39	62.4	67.3	37.4	38.4	1.41
40	65.2	66.4	39.2	39.9	1.79
41	55.8	54.8	33.7	33.0	1.08
42	62.2	62.1	38.3	38.2	1.29
43	68.9	61.6	41.9	42.3	1.80

[a]Product of energy digestion coefficient and Relative Intake based on metabolic size $^{.75}$.
[b]Product of dry matter digestion coefficient and Relative Intake based on metabolic size $^{.75}$.
[c]Product of energy digestion coefficient and Relative Intake based on metabolic size $^{.84}$.
[d]Product of dry matter digestion coefficient and Relative Intake based on metabolic size $^{.84}$.

Appendix Table 7. Laboratory evaluations of the rations

Ration number	In vitro DDM[a]	Dry matter solubility[b]	Acid insoluble lignin[c]
	%	%	%
1	63.7	14.7	4.5
2	57.0	14.3	6.4
3	58.9	23.0	4.9
4	49.2	24.0	9.0
5	63.4	14.3	4.2
6	62.1	19.2	6.5
7	57.3	19.1	5.9
8	54.1	27.6	9.9
9	64.7	15.1	4.6
10	75.7	9.1	2.5
11	79.2	6.4	2.1
12	75.1	10.0	2.8
13	77.2	5.9	2.4
14	76.6	9.1	2.8
15	77.9	6.4	2.1
16	75.8	10.0	3.4
17	76.8	6.4	3.4
18	68.6	18.2	4.4
19	66.8	16.9	3.3
20	67.0	17.9	4.4
21	65.7	16.8	3.9
22	67.6	18.2	4.8
23	68.0	16.9	3.8
24	65.3	17.9	4.8
25	66.8	16.8	5.1
26	72.0	14.7	4.4
27	73.0	12.9	4.1
28	80.4	8.9	3.3
29	64.3	15.8	7.6
30	67.1	16.2	5.4
31	66.2	17.1	5.2
32	75.2	16.2	4.2
33	73.5	17.1	3.8
34	59.8	26.9	8.0
35	55.4	24.0	10.4
36	38.5	15.6	13.5
37	54.1	31.8	5.7
38	58.5	28.0	5.8
39	52.3	23.7	6.0
40	63.4[d]	14.3[d]	4.2[d]
41	62.1[d]	19.2[d]	6.5[d]
42	54.1[d]	27.6[d]	9.9[d]
43	55.4[e]	26.9	5.9[e]

[a]Tilley and Terry, 1963.
[b]Dehority and Johnson, 1964.
[c]Van Soest, 1963.
[d]Estimated from similar ration fed in the same year.
[e]Estimated -average of rations 38 and 39.

Appendix Table 8. **In vitro** dry matter digestion of the rations[a]

Ration number	Trial number 1	Trial number 2	Trial number 3
	%	%	%
1	64.7	62.5	63.8
2	58.6	56.8	55.7
3	59.9	61.5	55.3
4	52.6	47.8	47.1
5	64.7	62.9	62.6
6	65.5	59.7	61.1
7	61.1	56.1	54.7
8	57.4	50.8	54.0
9	66.2	65.0	62.8
10	77.4	74.1	75.5
11	78.5	77.0	82.0
12	75.8	74.0	75.5
13	77.1	77.7	76.8
14	75.5	77.5	76.9
15	77.8	78.1	77.9
16	75.1	77.9	74.3
17	75.6	79.0	75.8
18	68.7	71.5	65.7
19	70.7	64.8	64.9
20	69.0	67.8	64.1
21	68.4	63.6	65.2
22	70.2	66.2	66.4
23	72.5	65.6	65.9
24	68.5	64.8	62.7
25	68.4	67.1	65.0
26	73.2	71.7	71.0
27	75.5	73.0	70.4
28	81.1	81.2	79.0
29	65.4	65.0	62.6
30	69.9	66.0	65.5
31	64.6	68.8	65.1
32	74.2	77.1	74.2
33	72.6	74.5	73.5
34	59.9	59.8	59.8
35	55.0	56.5	54.7
36	37.5	39.4	38.6
37	55.0	56.3	51.1
38	60.6	60.9	54.1
39	52.5	53.3	51.0
40	—[b]	—[b]	—[b]
41	—[b]	—[b]	—[b]
42	—[b]	—[b]	—[b]
43	—[b]	—[b]	—[b]

[a]Tilley and Terry, 1963.
[b]*In vitro* digestible dry matter was not determined on these rations due to a lack of samples.

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