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NUTRITIVE VALUE OF SEVERAL FORAGE SPECIES AS MEASURED BY IN VITRO AND IN VIVO METHODS

By

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ABSTRACT

Pure stands of alfalfa, birdsfoot trefoil, brome grass reed canary grass and timothy were harvested in 1961 and 1962. Three cuttings of each species were available for the 1961 crop and only first and second cuttings for the 1962 crop with the exception of timothy of which only first cutting was available for both years. The legumes contained up to 2-3 times more lignin than did the grasses. Lignin content of the forages was positively correlated with ad libitum dry matter intake by wethers.

Growing wethers were used to measure ad lib. dry matter intake, % digestible dry matter, digestible dry matter intake, dry matter nutritive value indices and body weight gains. Dry matter intake by the wethers ranked the 1961 forages in the order of birdsfoot trefoil, alfalfa, brome grass and reed canary grass while the 1962 forages were ranked in the order of alfalfa, birdsfoot trefoil, brome grass and reed canary grass. Dry matter intake of first and second cut forages were similar. Dry matter digestion coefficients were different for specific forages but when all cuttings and both years were considered, there was no difference in dry matter digestion coefficients for the different forage species. Digestible dry matter intake and nutritive value indiced followed a trend similar to that of dry matter intake for the different forage species. Weight gain was positively correlated to dry matter intake/cwt, digestible dry matter intake/cwt,

dry matter nutritive value indices and nutritive value indices while dry matter digestibility was not related to dry matter intake/cwt or body weight gain. However, the product of dry matter digestibility and dry matter intake resulted in a larger correlation coefficient with weight gain than did either individually.

Regression equations for nutritive value indices, dry matter nutritive value indices and digestible dry matter intake on body weight gain were about equal in precision of predicting weight gain. The standard error of estimate were such that only large differences in forage nutritive value could be differentiated.

Dry matter digestion coefficients, dry matter intake, digestible dry matter intake, dry matter nutritive value indices and weight gains by rabbits were not related to similar values determined by sheep. However, dry matter intake, digestible dry matter intake and dry matter nutritive value indices determined by sheep and rabbits were positively related to similar values determined by heifers.

Dry matter disappearance of the forages was measured by use of an in vitro fermentation method over several time intervals. Initial in vitro dry matter disappearnce was slower for the grasses than for the legumes. Dry matter disappearance after a six hour fermentation period was correlated to dry matter intake, digestible dry matter intake, dry matter nutritive value indices, nutritive value indices and body weight gains while

36 hour dry matter disappearance was correlated to in vivo digestion coefficients of dry matter and energy. Dry matter disappearance after a 6 hour fermentation period was effective in predicting the nutritive value of forages when the forages had a large range in nutritive values.

Wethers receiving experimental forages were slaughtered and their rumen contents examined to ascertain the relationship between rumen contents of dry matter, fiber or lignin and intake. Rumen digesta from sheep receiving the legumes contained larger amounts and a larger percentage of fiber, and lignin than those receiving brome grass or reed canary grass. With the specific forages studied, lignin content of the forages or total intake of fiber and lignin did not appear to limit consumption. The relation between amount of dry matter in the rumen and ad lib. intake appeared complex and indicated there probably were other factors playing a role in controlling ad lib. intake.

Rumen retention time of dry matter was about 0.6 days for the legumes and one day for the grasses. Rumen retention time of lignin was greater than that of fiber, which was greater than that of dry matter. As dry matter, fiber and lignin intake increased, retention time of each constituent decreased. Further studies will be necessary on the above relation to separate cause and effect.

Digesta from sheep fed legumes vs grasses contained a higher concentration of butyrate with no significant differences in acetate or propionate concentrations.

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BIOGRAPHY

Jesse R. Ingalls was born in Randolph, Vermont on April 4, 1936. He received his first four years of elementary education in Tilton, New Hampshire; the fifth year in Canaan, New Hampshire, and the last three years at East Haven, Vermont. He graduated from Lyndon Institute at Lyndonville, Vermont in 1954 and entered The University of Vermont from which he graduated in June 1958, receiving the degree of Bachelor of Science with a major in Animal and Dairy Husbandry. In July, 1958 he re-entered The University of Vermont as a graduate research assistant in the Animal and Dairy Husbandry Department, majoring in Animal Nutrition and received his Master of Science degree in June, 1960. In August, 1960 he entered Michigan State University as a graduate research assistant in the Dairy Nutrition Department as a candidate for the degree of Doctor of Philosophy.

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INTRODUCTION

Forage is an important feed source, more so in some countries and certain areas of countries than others. According to Crampton *et al.* (66), in North America, forage makes up 65%, 55% and 90% of the feed requirements for beef, dairy cattle and sheep, respectively. In Holland over 50% of the crop land is in grass and over 70% of the grass is harvested by direct grazing. Hardison (112) stated that 75% of feed for ruminants came from forage. In corn growing areas of the U.S., corn is replacing more and more of the grass in livestock rations. This will probably be true as long as this country has an excess of food for human consumption. But as the United States becomes more populated, grass may become a more important source of animal feed and grain may be used predominantly for human consumption.

Nutritionists have worked for many years on forage quality in relation to its productive energy value when fed to livestock. Of all the 4000 or so feeds studied, forages are still the most difficult to describe or evaluate as to their nutritive value. Throughout this thesis the term nutritive value will be used in reference to animal response in weight gain or milk production resulting from feeding an individual forage.

A great deal of interest has developed in the study of forage species and varieties in relation to animal response. Reid *et al.*(214,230) reported there was little difference in digestibility of first cut forage species harvested on the same calendar date and that the legume: grass ratio had little effect on animal response. However, Minson et al. (179) reported a difference in digestibility of forage species and varieties.

Many methods such as federal grades, visual examination, leaf content, date of harvest and many chemical analyses including lignin and fiber have been studied and used for evaluating forages as a source of energy. None of these methods has been entirely successful. A recently developed in vitro fermentation method was highly correlated with in vivo digestion data. However, digestibility of a forage without intake is of little value in predicting animal performance. Plant breeders are in need of a method to evaluate forages that requires only small samples and one that will indicate small differences in animal response.

Recently Crampton and coworkers (67) have proposed Nutritive Value Index (NVI) as a method of expressing the nutritive value of a forage. Since this is the only method proposed that takes into account forage intake as well as digestibility, the present study was undertaken to further investigate this method. Growth of laboratory animals on forages has been encouraging enough to warrant further study; however the relationship between laboratory animal response, large animal response and NVI values are not known.

Plant breeders at present have to work by trial and error in the development of forages that will be consumed in large quantities by ruminants. One of the reasons for this has been that the factors controlling forage intake have not been defined or delineated. There are several theories pertaining to the control of forage consumption by ruminants. The rumen load theory presented by Crampton *et al.* (67) appeared to have a logical basis to explain and relate intake of defined forages. Animal nutritionists and plant breeders would make more progress in selecting desirable forages for ruminants if factors controlling forage intake were known. Economical animal production on high roughage rations requires large dry matter (DM) yields of forage per acre, forage with high energy concentration and a forage that will be consumed in large quantities.

REVIEW OF LITERATURE

Nutritive Value of Different Forage Species

A great deal of work has been done on chemical composition and digestibility of forages and different forage species. This work is of limited value unless it is also related to intake of forage and the resulting animal production. Acceptable work studying intake and animal production on some of the more common forage species is not available. The work that has been reported is in disagreement as to the effects of forage species on digestibility, intake and production.

Reid et al. (214,230) reported that digestibility of a forage was highly correlated to date of harvest. He found little difference in digestibility of 8 different forage species and many mixtures harvested on similar calander dates. Newlander et al. (189) found little difference in digestibility of early cut alfalfa and timothy hays. Other workers have reported little difference in the gross energy value of different forage species (1,7,8,94,269).

Swift et al. (245,246) reported that Kentucky bluegrass, orchard grass, brome grass, and timothy had TDN values of 71.4, 68.6, 69.4 and 60.6, respectively, when harvested at the same physiological stage of maturity (head emerged from the boot but not expanded). When these forages were compared on the basis of calander date at harvest, a much smaller difference in digestibility between species was evident. Other workers have indicated differences in digestibility of the five forage species that were used in the present study (22, 25,60,122,164,174,178,179,245,246).

Minson _et_ _al_. (178,179) reported that digestibility is more related to stage of maturity than calendar date of cutting which is in agreement with Spahr et al. (236) and Baumgardt (25), but in disagreement with others (58,114,230,245). When cut at the same stage of physiological maturity there still appear to be differences in digestibility of the different forage species (25,164,174,178,179).

Explanations vary for the observed differences in _ad_ _lib_. consumption of alfalfa, birdsfoot trefoil, brome grass and reed canary grass. In some cases the differences in consumption may be due to lack of a common basis such as calendar cutting date or stage of maturity when harvested. However Spahr _et_ _al_. (236) found a higher intake of mixed hay (alfalfa-clover-timothy) than of orchard grass whether compared on calendar date of harvest or on stage of maturity. The difference in digestibility and milk production disappeared when based on stage of maturity rather than date of harvest (223). Gordon _et_ _al_. (101) reported no difference in consumption when alfalfa containing 10% timothy was fed in comparison to pure alfalfa. Also, Meigs and Converse (171) reported that alfalfa plus timothy hay was consumed at a rate 30% greater than alfalfa alone. Pratt et al. (206) allowed heifers free access to alfalfa and timothy. During the first half hour after feeding, heifers spent 23% of their time eating timothy and 77% eating alfalfa and at the end of a week the heifers had consumed 82% alfalfa and 18% timothy. However, the timothy hay was of low quality.

McCall et al. (164) compared several forage species harvested at the same stage of maturity. Brome grass appeared to be unpalatable but had dry matter (DM) digestion coefficients of about 45% while the other forages had values of 50-60%.

Reed canary grass is generally considered rather low in palatability. Arny (9) reported that the consumption rate of this grass was lower than alfalfa, equal to timothy and more than a wild hay. These workers found dairy cows required more time to become accustomed to canary grass than the other species studied. When switched from alfalfa to canary grass their consumption dropped 50% and then increased, but never to the previous level when on alfalfa. Fuelleman and Burlison (98) reported that brome grass was very palatable and that a canary grass pasture was unpalatable. Garrigus and Rusk (99) compared brome grass and canary grass pastures and found that steers would eat the canary grass only if forced to do so. Fillies consumed 26.7 lbs. of prairie hay and only 19.3 lbs. of canary grass (114).

Early work indicated that timothy hay would not maintain milk production as well as alfalfa (170). This early difficulty with timothy hay was probably due to late harvesting and a lack of vitamin A. Salisbury and Morrison (224) fed grain, silage and 10 lb of either timothy or alfalfa hay to two groups of 19 cows and found no difference in milk production. Holdaway et al. (122) fed alfalfa or timothy in equal amounts with grain to dairy cows. The timothy was lower in digestibility than the alfalfa but milk production per lb of nutrient intake was equal. Huffman et al. (125) found that milk production remained the same when boot stage timothy replaced early-bud alfalfa hay in the ration. Archibald et al. (7) compared two second cutting hays harvested at the same stage of maturity (52% legumes and 45% grass or 5% legume and 79% grass). High yielding cows produced more milk on the mixed hay (52-45) where as the low producers yielded more milk on the grass hay. On the average the difference in production of cows fed the two forages was not shown to be significant. These workers concluded that the "cow's ability as a converter of feed to food was of more significance that the type of roughage she gets." Hodgson and Knott (121) found milk production was a little higher on alfalfa than on mixed hay. Canary grass was found inferior to alfalfa for maintaining milk production (8). Van Arsdell et al. (258) reported that steers on canary grass pasture did not make satisfactory gains and were dull in appearance. Spahr et al. (223) compared an alfalfa-clover-timothy mixture with orchardgrass that was harvested both at the same calendar date and at the same physiological stage of maturity. When both forages were harvested on the same calendar date milk production was greatest from cows receiving the alfalfa grass mixture. There were no differences shown in milk production when both forages were harvested at the same physiological stage of maturity. In both cases there was a difference in consumption of forage due to species.

Weight gains of heifers were the same when receiving pure alfalfa or an alfalfa mixture with 10% timothy (101). Keith et al. (137) compared alfalfa, alfalfa + 24% brome grass and alfalfa + 33% brome grass for growing and fattening of lambs. The forage was fed as a 50:50 mixture of hay and grain. There were no differences in weight gain. Blaxter and Wilson (31) stated that if one third of the ration was made up of grain any difference in response expected from an all forage ration would not be detectable.

Northeastern dairy farmers for some time have preferred second cutting forage over the first cutting. There are probably two major reasons for this preference: (1) good first cutting hay is more difficult to make with prevailing weather conditions, and (2) second cutting hay in the past has been harvested at an earlier stage of maturity. However, dairy farmers of New Mexico and Utah have thought that first cutting forage was higher in nutritive value than second cutting (53, 189). Second cutting in these areas has a more rank growth with more stems and a lower percentage of leaves (189).

Early cut first cutting forage has been reported to be higher in digestible dry matter than second cut forage (123, 217,230,269) while opposite results were noted by others (147,173). Reid et al.(230) and others (123, 269,272) have indicated that second cut forage decreased in digestibility with delayed harvesting but at a slower rate than first cutting forages. First cutting forage digestibility decreased at a rate of about 0.3 to 0.5 percentage points per day with delayed harvesting (62,126,172,187,230). With a single forage species this may not be a linear decrease from early May to early July (187) and the extent of decrease is not the same every year (25). Colovas <u>et</u> <u>al</u>.(60) reported that early first cutting timothy (64.5% dig. energy) was a better source of metabolizable energy than second cut clover (60.4% dig. energy). The ratios of steer weight gains were

100 to 75 to 110 for first, second and third cutting forages respectively (161).

Several trials have been conducted comparing milk production when different cuttings of forage were fed. Carroll (53) compared first, second and third cutting early bloom alfalfa for milk production. Average data for two years showed that consumption ranked the forages in the order of third, first, and second cutting respectively. Fat production ranked the forages in the order of first, second and third cutting. Efficiency of fat production was highest for second cutting forage. The authors concluded that second cutting forage was at least equal to first and third cutting forages for milk production. Porter et al. (202,203) found that differences in consumption of first, second and fifth cuttings of early bloom alfalfa were not significantly different. However, cows consumed on the average of 0.5 to 1 lb more per day of first cutting forage and produced 0.18 to 1 lb more milk per day. The ranker growing second cutting forage was equal to the more leafy first and fifth cuttings. Huffman et al. (125) indicated little difference in milk production when first cutting early bud alfalfa was replaced by second cutting early bud stage alfalfa. Milk production increased in one trial and decreased in four when second cutting alfalfa replaced first cutting alfalfa, harvested at the same maturity stage. In all cases production from first cutting alfalfa was slightly higher than second cutting, but not significantly so.

Loosli et al.(152) compared early first cutting timothy with early bloom second cutting alfalfa and pre bloom second cutting trefoil. Percent digestible, dry matter, intake (lb/day) and production of fat corrected milk (FCM) was 62.1, 64.3, 65.0% and 25.1 lb, 27.1, 23.7 and 34.3, 33.9, 34.0 lb for alfalfa trefoil and timothy respectively. The authors concluded there was no difference in animal performance when the animals received the above forages.

Nutritive Value Index (NVI)

Crampton and co-workers at McGill University recently suggested nutritive value index (NVI) as a method to evaluate forages (66,67,69). The expression of NVI is a quantitative numerical term made up of the mathematical product of digestible energy concentration and relative intake of a specific forage per unit of animal metabolic size or weight in kilograms raised to the 0.75 power ($Wt._{kg}{}^{.75}$). The idea of combining intake and energy concentration of a forage to indicate the forage's nutritive value was not new. Murry (188) in 1933 attempted to express nutritive value of feeding stuffs in a mathematical formula based on quality and quantity of intake. For some time other nutritionists have been aware of the importance of forage intake along with energy digestibility. McCullough *et al.* (164,166,167) indicated that both total intake and energy concentration must be considered in describing the nutritive value of forages. Energy intake on an all roughage ration was the most often limiting nutrient for maximum production. Crampton (69) calculated that only one out of eight forages were deficient in protein or calcium and one out of 40 were low in phosphorus. Reid *et al.*(230) proposed that the main purpose of forage was to provide energy. Assuming other dietary conditions are adequate, then the two following assumptions appear warrented:

a. Animal response is proportional to energy intake

b. Energy intake equals dry matter intake times the energy concentration.

Blaxter and co-workers (34) have shown that a 10% increase in energy concentration of a forage may produce a several fold increase in the energy available for production. McCullough (165) reported similar findings.

Crampton and co-workers attempted to elucidate their concept of nutritive value index (NVI) by feeding pure stands of early bloom alfalfa, red clover, birdsfoot trefoil, brome grass and timothy in a chopped and artificially dehydrated condition to ewes in a 5 x 5 latin square design and collecting animal performance data (1956). In 1957, early bloom and full bloom cuttings were made of both red clover and timothy and fed to ewes in a 4 x 4 latin square design. The feeding periods for both trials were 21 days long. Data from the last eleven days of each period were used to determine voluntary intake, weight gain and digestibility of the forages. Using the above data, the authors calculated the NVI values for each forage and related these to animal performance.

Relative intake is a term applied by Crampton _et al._ (67) to indicate intake of forage relative to a standard. Thus intake values of all forages could be expressed as a % of this standard value. Early cut, artificially dehydrated legume hays when fed to sheep resulted in maximum consumption of 80 $\pm$ 10.5 g per unit of metabolic size ($Wt._{kg}{}^{.75}$). This is equivalent to about 3 lb/100 lb of body weight (cwt). The equivalent for dairy cattle would be 140 g per unit of metabolic size (65,66). Metabolic size was used to minimize the size effect on intake (67,145,155,221). A variation of 22% (52 - 109 lb) between body weight of sheep resulted in a 20% variation in forage consumption (67). This variation was reduced to 14% when consumption was based on intake per cwt (67) or 13 to 14% when based on intake/$Wt._{kg}{}^{.75}$ (34,67). Dry matter intake and body weight were correlated (r = .75) while the correlation coefficient between body weight and intake/cwt was small (r = .21). Expressing intake per metabolic size eliminated the high correlation between body size and intake (r = .08).

Thus all relative intake values for sheep are relative to 80 grams of DM intake/$Wt._{kg}{}^{.75}$ which was assigned a numberical value of 100.

Relative intake (RI) was computed in the following manner:

1. Compute metabolic size as weight in $kg^{.75}$ for the sheep in question
2. Determine expected intake of standard forage (i.e. $Wt._{kg}{}^{.75}$ x 80)
3. The observed intake of test forage is divided by expected intake and multiplied by 100.

$$RI = \frac{\text{observed DM intake g}}{80(Wt._{kg}{}^{.75})} \times 100$$

Nutritive value index (NVI) was then calculated by obtaining the product of relative intake (RI) and % digestible energy of the forage. Forages with a RI of 100 were found to be about 70% digestible resulting in an NVI of 70 (100 x 0.70). Multiple correlation and partial regressions (67) indicated that intake and digestible energy contributed 70% and 30% respectively to the final NVI expression. Byers et al. (44) found similar results. Crampton and co-workers (66,67,149) reported that NVI and weight gain had a higher correlation coefficient than intake and weight gain (r's about .9 vs. .5). One pound of gain in 11 days (.09 lb/day) reflected a change in NVI of 7 to 8 units. McCullough (165) reported that NVI adequately described the nutritive value of 3 silages in relation to weight gains.

Nutritive value index as presented above requires data on animal intake and digestibility of the forage. This requires much time and expense, and is of use only as a quantitative value for intake and digestibility of a forage already investigated. In recent years laboratory methods have been developed to study forage digestibility. Many workers have shown significant correlations between in vitro fermentation or artificial rumen data and in vivo digestibility (10,21,24,26,28, 41,42,58,59,81,82,116,131,132,143,204,209,212,232,254). Some workers have used in vitro dry matter disappearance while others used in vitro cellulose digestion.

The rate and extent of forage digestion have been studied by placing forage samples in semipermeable containers and placing them, through a fistula, into the rumen. Porcelain test tubes, bottles with semipermeable tops, semipermeable membranes, etc. have been suspended in the rumen for a period of time to study the rate and extent of forage degradation (91, 92,249). Semipermeable cloth bags, such as nylon, containing forage samples have also been suspended in the rumen (154,216, 259,260,279). The rumen is used as the incubator rather than a warm water bath as used with other in vitro fermentation methods.

Dehority and Johnson (77) compared in vivo forage digestibility with the amount of forage cellulose dissolved by cupriethylene diamine (CED). Cellulose dissolved by CED was correlated with in vitro cellulose digestion. CED soluble cellulose of grasses was closely associated with in vivo cellulose digestion and effective nutritive value index. The solubility of alfalfa cellulose by CED did not follow a pattern similar to that of the grasses, indicating a possible difference in the chemical structure of grasses and legumes, however preextraction with water increased the resulting relationships.

Donefer et al. (79,80) used various enzymes and solutions to digest or dissolve forage dry matter. Dry matter dissolved by potassium hydrogen phthalate, cellulase, cellulase plus pepsin, hydrochloric acid plus pepsin, and distilled water was correlated with nutritive value indices (r's of approximately 0.9).

Several different in vitro fermentation methods have been reported in the literature with many variations of each method. Some of the methods are indicated below. 1) Semipermeable membranes containing rumen inoculum plus substrate surrounded by artificial saliva have been used (105,228). 2) Continuous type fermentations are used where it is necessary to keep the fermentation culture alive and growing over a period of several days (74,111,240). 3) Probably the simplest method is to add rumen microorganisms, a buffer solution and a small amount of substrate to a fermentation flask and then incubate the mixture for several hours. All the above methods have been used to study the degradation of forages by rumen microorganisms.

Microorganisms taken from the rumen may be prepared in several ways for use in in vitro fermentation studies of forages.

1. Strained rumen juice is obtained by taking rumen contents directly from the rumen and squeezing out the juice by hand. This liquid is then strained through cheesecloth and used as the inoculum.

2. Phosphate buffer extract is obtained by adding phosphate buffer to the pressed rumen pulp from above and then the pulp is repressed. This liquid extract is used as the inoculum.

3. (a) Resuspended ruminal microorganisms are obtained by centrifuging the inoculum obtained in the phosphate buffer extract above. The sediment is then resuspended in phosphate buffer and is used as the inoculum.

(b) Liquid as obtained in #1 above is centrifuged and the sediment resuspended in phosphate buffer.

Quicke et al. (209) indicated that it made little difference in forage degradation which of the above methods were used. Shelton and Reid (232) found little advantage of using the semipermeable membrane method over other in vitro fermentation methods to study degradation of forages. This is in agreement with work by El-Shazly <u>et</u> <u>al</u>. (86) and Baumgardt <u>et</u> <u>al</u>. (24). Quicke <u>et</u> <u>al</u>. (209) also indicated that filtered rumen fluid was as good as other types of culture preparations for studying the degradation of forages.

Some investigations have indicated that in vitro digestible dry matter determinations rather than digestible cellulose gave higher correlations with in vivo dry matter digestion (42,217) and smaller coefficients of variation (41,42). Ramaiak and Blosser (212) reported in vivo digestible dry matter was more highly correlated to in vitro cellulose digestion than to in vitro dry matter digestion. However, the literature as a whole indicates that both in vitro dry matter and cellulose digestion compare equally well with in vivo animal data.

Crampton and co-workers (81,82) utilized the in vitro fermentation method to study the relationship of in vitro digestion of experimental forages to animal performance when fed the same forages. Cellulose disappearance was measured at intervals of 3,6,12,24, and 48 hours, and disappearance curves obtained were similar to those of Hershberger <u>et</u> <u>al</u>.(116). A delay or lag period in cellulose digestion was indicated for some forage species, especially the grass hays. Forage consumption (relative intake) was related to the 12 hour in vitro cellulose digestion (r = .83). These data indicate that digestion occurring during the early portion of the in vitro fermentation might be useful in explaining differences in forage consumption. These authors reasoned that differences in early digestion occurring in the in vitro fermentation could relate to differences in forage consumption if the "rumen load" does control the level of forage intake (67). The relation of digestibility, rate of passage and rumen fill to intake are covered on pages 25-44.

The length of fermentation time that gave the highest correlation with in vivo data has varied in literature reports. In vivo digestible energy was correlated with 24 hour in vitro cellulose digestion (r = .87) (6). However, Reid, et al.(216) was not able to show a consistant relation between in vitro cellulose digestion and in vivo % digestible dry matter. Donefer et al. (82), Baumgardt et al. (24,26) and Reid et al. (216) found no advantage in fermenting 48 hour rather than 24 hour. Johnson et al. (131) found that correlations between both 12 hour and 24 hour in vitro cellulose digestibilities and in vivo % digestible dry matter were similar. Bowden and Church (41) reported 48 hour incubation periods rather than 24 reduced within treatment variation. Length of incubation period may change correlations between intake and % digestible dry matter because these different in vitro methods may have different coincidence times with *in vivo* rumen phenomena. *In vitro* methods do not necessarily have to duplicate *in vivo* digestibility and intake by the animal. However, to be useful, *in vitro* and *in vivo* values should be related so that *in vitro* values could be used to predict in vivo digestibility or nutritive value indices.

Donefer *et al.* (82) reported that either 12 hour cellulose digestion or the product of 12 and 24 hour cellulose digestion could be used to predict nutritive value index (NVI) (r = +.91 and + .89 respectively). The authors suggested that 24 hour in vitro cellulose digestion could be used to estimate in vivo dry matter digestibility and 12 hour in vitro cellulose digestion could be related to forage consumption. The product of cellulose disappearance at two different times during in vitro digestion may have advantages over using data from only one time, however present evidence to support this is not convincing.

The regression obtained between NVI and 12 hour in vitro cellulose digestion (82) is given as:

$$Y = 48.4 + 1.314\ (X - 42.8) \text{ where}$$

Y = predicted NVI; and X = 12 hour in vitro cellulose digestion.

The above regression was based on a limited number of forage species and observations. In later work (81) assuming homogeneity of regression coefficients, when ground and chopped forage data were combined, the regression equation given to predict NVI of chopped forage was:

$$Y = -3.5 + 1.23\ X \text{ where}$$

Y - NVI and X = 12 hour in vitro cellulose digestion.

Twelve hour in vitro cellulose digestion of ground forage resulted in predicted nutritive value indices (NVI) 10.9 units higher than chopped forage (81,149). There was a slight drop in digestibility, but this was more than offset by increased intake when the ground forage was fed to sheep. The following formula, compared to the one above, will allow one to compare the NVI of chopped hay with those of ground hay: $Y = -3.5 + 1.23\ X + 10.9$. There is no data comparing NVI for ground pelleted forage with other physical forms of forages.

Crampton _et al_. found that with advancing maturity in timothy hay, intake and digestibility decreased thus resulting in lower nutritive value indices (NVI) (148,149). Many workers have shown that as a forage matures, its productive potential decreases. When forages have a large variation in gross energy, concentration NVI may not give a good indication as to the energy consumed (177). If intake per unit metabolic size and % digestible energy of two forages are similar, the resulting NVI would be the same. Gross energy content of these two forages could be different and the resulting digesible energy intake very different. The usefulness of NVI would be extended if the gross caloric content of forage was known. Crampton et al. (65) found that gross caloric content of our common forages was 4.4 Kcal/g. According to the authors when estimating 24 hour energy intake, a one tenth Kcal variation from 4.4 Kcal/g of forage will result in only a 2% error. NVI values can be used to determine 24 hour digestible energy intake if all forages are assumed to contain 4.4 Kcal of gross energy. The outline in Table 1 presents Crampton's ideas on how NVI could be converted to digestible energy intake and how in vitro data can be used to predict forage digestible energy yield to the animal (65,82).

Rabbits as Pilot Animals in Forage Evaluation

The use of laboratory animals such as rabbits to evaluate forages could cut down time, expense and amount of feed necessary if the response of small animals could be related to that of the large animal. Although the digestive system of the rabbit is quite different from that of ruminants, there are certain similarities. Rabbits have a large stomach with microbial action and a comparatively large large intestine (2) where microbial products are produced and because of coproghagy, these products are made available for absorption (250). With the exception of crude fiber, rabbits have been reported to digest roughage nearly as well as other

TABLE 1. 24-hr Digestible Energy Intake From Forage.

$$NVI = \frac{100\ (\text{intake}/\text{Wt.}_{kg}{}^{.75}}{80} \cdot \%\ \text{dig. of energy}$$ (80 is replaced by 140 for cattle)

$$= 1.25\ (\text{intake}/\text{Wt.}_{kg}{}^{.75})(\%\ \text{dig. of energy})$$

$$\text{24-hr. dig. kcal intake}/\text{Wt.}_{kg}{}^{.75} = \text{Intake}/\text{Wt.}_{kg}{}^{.75}(\%\ \text{dig. of energy})(\text{gross kcal/g})$$

$$\text{24-hr dig. Kcal intake}/\text{Wt.}_{kg}{}^{.75}/NVI = \frac{\text{Intake}/\text{Wt.}_{kg}{}^{.75}(\%\ \text{dig. of energy})(\text{gross Kcal/g})}{1.25\ (\text{intake}/\text{Wt.}_{kg.}{}^{.75})(\%\ \text{dig. of energy})}$$

$$= \frac{\text{gross Kcal/g}}{1.25} = k$$

$$k = \frac{4.4}{1.25} = 3.5 \text{ for sheep; } \frac{4.4}{0.714} = 6.2 \text{ for cattle}$$

$$\text{24-hr dig. Kcal. intake from forage} = k(\text{Wt.}_{kg}{}^{.75})(NVI)$$

$$\text{24-hr. TDN intake from forage (lb)} = \frac{\text{24-hr dig. Kcal intake from forage}}{2000}$$

$$Y = k\ (\text{Wt.}_{kg}{}^{.75})\quad C_0 + b(X) + C_1$$

Y = 24 hr digestible Kcal. yield to animal from forage
X = 12 hr *in vitro* cellulose digestion
k = 3.5 for sheep; 6.2 for cattle
C_0 = 3.5 general constant in NVI prediction equation for chopped forage
b = 1.23 regression of Y on X
C_1 = 10.9, to adjust NVI for larger intake if ground forage was fed.

domestic animals (264). The net energy derived from a roughage was similar for rabbits and ruminants (68).

Richards et al. (218) in their review reported that Jarl (128) found a correlation between digestion by rabbits and bulls of -.65. He also reported that Watson et al. (270, 271) concluded that rabbits and sheep were too different for one specie to be an indicator for the other. However, Crampton et al. (7) reported that several workers found similar digestive abilities for steers and rabbits. Matrone et al. (160) successfully used the rabbit in studying phosphorus levels in soybean forage. Richards et al. (218,219) compared rabbit and sheep digestion coefficients of timothy, orchardgrass, brome grass, alfalfa- brome mixture, and alfalfa when harvested at three stages of maturity and fed at a rate 10% below maximum consumption. The correlation coefficients between sheep digestible dry matter and rabbit digestible dry matter for grasses, legumes, and all hays were .85**, .97** and .47* respectively. Rabbits showed larger reductions in digestibility with delayed harvesting than did the sheep.

Data comparing rabbit and ruminant growth when fed the same forage was limited. Crampton et al. (70) used steers and rabbits to compare pasture at different periods throughout the summer. Rabbits digested dry matter 71 to 85% as efficiently as did the steers. Trends in weight changes were similar for rabbits and steers. Work by Matrone et al. (160)

and the above work of Crampton et al. (70) indicate that rabbit growth might be used to estimate the nutritive value of forages.

Regulation of Forage Intake

Researchers have attempted for many years to explain the control mechanisms operative in regulating intake of forages. Many theories have been proposed but no single theory adequately explains all differences in consumption. A few of the more popular theories proposed are listed below.

1. Thermostatic regulation
2. Lipostatic regulation
3. Other chemostatic regulation
4. Lipid glucostatic regulation
5. Central nervous control
6. Physical regulation due to gut capacity

Several reviews have recently been written on the subject of food intake regulation in mammals based on the previously stated theories (5,12,88,118,169,263). After reading the several reviews, the reader obtains the idea that not just one, but probably several of these mechanisms do have some control of feed intake. The inter-relations among these mechanisms are not understood at present. This review of feed intake will deal only with ruminants and the proposed physical regulation of dry forage consumption. The above reviews adequately cover the different theories of intake regulation in respect to both monogastric and ruminant animals.

Relation Between Gut Contents and Feed Intake of Ruminants.

For some time workers have suggested that bulk in the diet of ruminants might have some affect on voluntary consumption. Bulk alone cannot regulate rate of consumption but the interaction of bulk with rate of passage, rate of degradation and digestion of forages could be especially important in the consumption rate by ruminants. If the above is true, the size of gut would effect intake. Workers have attempted to measure volume (140) and swelling (208) of feeds in relation to the filling effects they might have.

According to Balch and Campling (12), Kruger and Muller (1955) indicated that cows fed different hays ad libitum would eat to similar rumen-reticulo fill. Blaxter et al. (35) by mathematical manipulation suggested that sheep ate to a "constant gut fill"; i.e. to a constant amount of dry matter in the gut after a meal. Crampton et al. (67) outlined the events in rumen digestion of animals maintained on an all forage ration as follows:

"1. Recurring hunger is closely associated with and probably primarily determined by some specific degree of reduction of the rumen ingesta load.

2. Rumen load is reduced at varying rates that presumably are correlated with the rate of the degradation of its cellulose and hemicullulose content.

3. The rumen ingesta load will reach the degree of reduction at which hunger recurrs after time periods characteristic of the specific forage involved."

With the above in mind these workers presented the theory of reticulo-rumen load and recurring hunger. Animals on a forage ration would eat to a certain rumen fill and hunger would reoccur at a time specific for the forage once the rumen load had been reduced to a certain level. Reticulo-rumen load is reduced by physical break down of particles, digestion, absorption and passage of the digesta to the omasum.

Many workers have tried to determine what effect bulk in the rumen has on consumption of forage (34,35,45,48,49, 96,157). Makela in 1956 (157) reviewed and studied the question of bulk in the diets of farm animals with special reference to ruminants. Physiological capacity or gut fill on ad lib. feeding as measured in slaughter tests was found to be lower than previously determined gut capacity as measured by adding water. Hay intake was reduced 4-6 kg during the final stages of pregnancy. This was presumably due to space limitation in the abdominal cavity due to space occupied by fetus and fat. Up to 51.9 kg of fat was found in the abdominal cavity of cattle. According to Balch and Campling (12) Heeselbarth (1954) also suggested a decrease in consumption during late pregnancy. Other workers (103,215) reported that late pregnancy in sheep might limit intake. However, Balch and Campling (12) reported that Broster (1960) found no depression of roughage intake during late pregnancy. Several workers (90,159,248) according to Balch and Campling (12) reported that size of the abdominal fat depots resulted in a lower intake, thus suggesting that space in the abdominal cavity of ruminants might limit intake.

Blaxter et al. (34) fed high, medium, and good quality forage to sheep. Gut "fill" was estimated by the method of Blaxter et al. (35) to be 99.7, 100.0 and 94.0 dry matter/ $Wt/_{kg}{}^{.73}$ for poor, medium, and good quality forage respectively. He concluded that the digestive tract contained about 100 g of dry matter/$Wt._{kg}{}^{.73}$ irrespective of forage given. Although much indirect evidence indicated that physical fill may have limited intake, the direct evidence was lacking (12).

Schalk and Amadon et al. (229) found that removing swallowed food at the cardia caused most animals to increase their intake of alfalfa hay. Consumption was increased by removing digesta from the reticulo-rumen and decreased when hay was placed directly in the rumen.

Campling and Balch (48) studied the effect of reticulo-rumen fill on intake of hay by cows in several experiments. The hay was offered ad lib. once per day for 3-4 hours. Swallowed hay was collected at the cardia for 3 hours. During collection the cows consumed 76-96% of their normal intake. Removing swallowed hay via a rumen fistula increased eating time from 3-4 hours to 6½-8 hours and total consumption increased 70-85%. When food was removed on experimental days, the cows did not cease to eat at the end of 3 hours as usual which indicates that the amount eaten was not due to habit but to a "full" rumen. This also would indicate that a cow does not stop eating due to fatigue of jaw muscles or exhaustion of saliva. In one trial rumen contents were added and removed immediately before, during and after a meal. Digesta (50 lb) was removed from the rumen of one cow and placed in the rumen of another cow just before feeding, just after feeding, one-half hour after feeding, 1½-2 hours after feeding and half way between feedings. On the average, 50 lb of digesta contained 7.1 lb of dry matter and to compensate for this amount of digesta, the animal would have to change hay consumption by 8.4 lb. Daily removal of digesta caused some increase in consumption but not equivalent to the amount removed. Removal of digesta just after a meal was more nearly compensated for by increased consumption than when the digesta was removed midway between meals. Adding digesta to the reticulo-rumen caused a decrease in consumption but not equivalent to the amount added. Again the compensation was greater when the digesta was added at or near the time of feeding.

Water-filled bladders were placed in the rumen of cows (0,85, and 100 lb). Voluntary intake decreased as the weight of water in bladders increased (.54 lb hay/10 lb water). Direct addition of 100 lb water to the rumen did not affect intake. This is in agreement with work of Moore _et al_. (181) and Hillman _et al_. (119). Veltman (263) reported that infusion into the rumen of up to 28 liters of silage juice per day caused a slight increase in consumption but infusion of 32 liters per day caused the cow to go off feed.

Campling _et al_. (49) fed straw and hay in ad lib. or in restricted amounts to cows and measured reticulo-rumen contents just previous to feeding. The reticulo-rumen contained 165 lb (14.4 lb DM) and 128 lb (13.6 lb DM) of digesta when fed hay or straw respectively. A dry matter content difference of only 6% digesta found in the reticulo-rumen just after ad lib. feeding of hay or straw was 250 lb (27.2 lb DM) and 184 lb (20.2 lb DM) respectively. The difference in dry weight contents was 35%. This would indicate that forage was consumed at a rate resulting in similar fill just before feeding. One should however keep in mind that one of the forages was very low in protein (2.9%) and that the animals were only fed once a day.

Freer and Campling (96) continued to study the effect of quantity of rumen digesta before feeding on intake of hay, dried grass or concentrate. The reticulo-rumen contained 40% more digesta and 84% more dry matter when fed hay rather than when fed dried grass. This difference was only 12 and 10%, respectively, after feeding. Thus roughage was consumed until the rumen reached about the same fill. When roughages were fed that had a disappearance rate from the rumen of greater than 18 lb/day, eating ceased when the reticulo-rumen contained 250 lb digesta or 35 lb of dry matter. Roughages with slower disappearance rates were eaten to a fill that left 19 lb of dry matter at the time of feeding. When concentrates rather than dried grasses were fed, the reticulo-rumen contained two thirds the amount of wet digesta and one half the amount of dry matter both before and after feeding. The authors found an increase in concentrate intake of 84% and an increase in forage intake of 20% when feed was offered over a period of 24 hours rather than for one 5 hour feeding period.

It seems obvious that reticulo-rumen fill in the above experiment was not limiting intake when concentrates were fed ad lib. However, in this experiment the cows were consuming only 18 lb of grain per day. One wonders what the reticulo-rumen fill would be when cows are consuming 75 lb of grain per day (43).

Campling <u>et al</u>. (45) studied the effect of ad lib. and limited intake of long and ground pelleted forage on reticulo-rumen fill. Intake was similar for both feeds. Just previous to feeding, the reticulo-rumen, of cows fed long and ground pelleted hay contained 193.7 lb (19.6 lb DM) and 160.1 lb (18.2 lb DM) of digesta respectively. After feeding, 266.0 lb (34.6 lb DM) and 214.9 lb (31.6 lb DM) of digesta was found in the reticulo-rumen of cows fed long and ground pelleted hay respectively. These workers suggested that ad lib. intake of ground pelleted forage was limited by rate of passage through the lower gut as restricted intake of the forages resulted in faster rate of passage with pelleted forage, than with long forage whereas with ad lib. feeding the rate of passage was similar for both forages. Other workers have indicated that food entering the intestine inhibits flow of digesta from the stomach (117,169,210,239).

Waldo _et al._ (265) studied rumen load as affected by level of intake and ration. Silage and companion hay were fed ad lib. and at a maintenance level. On ad lib. feeding, more hay than silage was consumed. Feeding hay resulted in more digesta and dry matter in the reticulo-rumen, which was in agreement with work by Thomas _et al._ (251). Both authors concluded that rumen capacity was not limiting the intake of silage. Water was limited to ½ normal by Waldo _et al._ (265) and no specific comparison was made between "fill" just after eating and "fill" just before eating.

Carr and Jacobson (52) studied the effect of adding inert bulk (polyethylene cubes and rubber containers of water) to the rumen and removing rumen digesta on ad lib. intake. The addition of 2,6, and 10% metabolic size of inert bulk did not significantly decrease intake. A significant increase in consumption was noted when 10% of metabolic size as digesta was removed from the rumen. Removing 2.75 lb of dry matter/ 1000 lb body weight resulted in an increased consumption of 1.0 lb/1000 lb body weight.

Veltman (263) studied the effect of stuffing hay into the rumen of two cows that were offered hay ad lib. Stuffing 10.3 lb of dry hay/day into the rumen of these cows via a fistula resulted in a decrease of 3.3 lb/day in voluntary intake of forage. Other feeds stuffed into the rumen caused varying degrees of decreased ad lib. consumption but there was always an increase in total dry matter consumption. Balch and Campling (12) concluded their review of "regulation of voluntary food intake in ruminants" by indicating that there is good reason to believe that the voluntary intake of roughages by ruminants is related to the amount of digesta in the reticulo-rumen at certain times. However, they also indicated a good deal more work is necessary to adequately integrate all factors concerned.

Factors Affecting Reduction of Rumen Fill

If rumen fill or physical capcity was controlling forage consumption, then rate of passage, rate of physical breakdown, and digestibility would affect intake and in turn may be affected by intake.

Rate of Passage

Rate of passage could play a large role in the amount of forage consumed if rumen fill limits intake. Rate of passage or retention time of forage has been studied by using many different reference substances. Such inert substances as rubber, tygon tubing, lucite, radioactive chromic oxide, iron oxide, chromic oxide, etc. have been used (47,50, 120,139,141,182,251). However, when such inert substances are used, one can question how the passage rate of inert particles compared with that of the feed being studied. Thomas et al. (251) found that small lucite particles had a faster excretion curve than larger pieces of tygon tubing, and Campling and Freer (47) reported that polystyrene particles passed through the G.I. tract faster than stained roughage particles. The most widely used technique to study rate of passage was introduced by Leukeit and Habeac (146). A small portion of straw or experimental feed was stained with a permanent stain. This technique was used by several workers in the 1930's and then not again until 1950. Since 1950 many workers have used stained particles to study passage rate of forages (15,16,34,35,36,45,46,49,54,55,56,96,97,191,196).

Rate of passage has been expressed in several different manners, one being the time between feeding the marker and its first or last appearance in the feces (29,158). The former is a measure of the maximum velocity that the material will pass through the gut. The last appearance of a marker is indistinct and of little value as a small amount of the marker tends to stay in the rumen. Excretion curves plotting time against percent of marker excreted have been used by Balch _et al_. (15,16,17,96),Blaxter _et al_. (34,35), Moore and Winter (182), Lambourne (141), Poijarvi (200), and Castle (54,55,56), to give a cumulative graph depicting rate of excretion. Data from different experiments expressed in terms of cumulative excretion curves are difficult and cumbersome to compare. It is possible to compare different points on the curves, such as time when 5% or 80% of the total marker is excreted or elapsed time from the 5 to the 80% point. However, this still doesn't give a good measure of the shape of the curve. Castle (54,55,56) proposed the value "R" which is directly related to the area below and to the left of the passage curve. The "R" value is determined by adding together the excretion times from 5% to 95% by intervals of 10% and dividing the sum by 10. This gives a value for mean retention time of residues in the alimentary tract. This method has been employed by several workers (45,46,49, 97,196) in the study of passage rate of digesta in ruminants.

Ewing and Smith (89) expressed retention time by making use of water content ratios in feed, digesta, and feces. Paloheimo et al.(156,192,193,194) proposed using "the mean time of retention of a dry matter point of the food" concept. Mean time of retention in the rumen was determined by dividing daily dry matter content in the rumen by the dry matter intake. Thomas et al. (251) and Waldo et al. (265) used this concept of retention time in studying the relation between rumen content and forage intake. This measurement must change with time after feeding, but should be comparative when observed under standard conditions.

Rate of passage of digesta in ruminants fed only roughages is probably primarily affected by level of intake. Mitchell et al.(180) in 1928 studied rate of passage and suggested a relation with intake. Many workers have since reported that increased forage intake resulted in a faster passage rate or a decreased mean reticulo-rumen retention time of digesta (17,34,36,45,49,54,55,56,96,97,157,191,192, 194,251,265). Blaxter et al. (35) fed three levels of dried grass to sheep and clearly showed an inverse relation between intake and rate of passage. Thomas (251) reported a curvilinear inverse relationship between dry matter consumption per cwt and rumen retention time. Campling et al. (49)

found similar results. With green chop the above relationship appeared to be linear (251). These data clearly showed that increasing intake below ad lib. consumption increased rate of passage. Data were not available to clearly demonstrate whether ad lib. intake determined or was a result of passage rate. Makela (6) reported a correlation of -.74 between dry matter retention time and dry matter intake when forage made up the entire ration for dairy cows. Other workers (251) reported correlation coefficients between retention time and dry matter intake of -.77.

Stallcup et al. (238) fed several lespedeza varities containing 33,27,20, 17 and 15% lignin to fistulated steers to study the effect of lignin content on rate of passage. By weighing and sampling rumen contents before feeding, 6 and 12 hours after feeding, these workers showed that as lignin content in the forage increased rate of digesta passage from the rumen decreased.

The main factor responsible for physical breakdown of the consumed long forage to the size found in the abomasum must be due to chewing during eating and rumination. Freer et al. (97) suggested the above relation when he found a direct relation between eating plus rumination time per pound of forage and rate of digesta passage from the reticulo-rumen. However, at present very little is known about the action of the omasum or the reticulum-omasal orifice as a filtering device for digesta ready to be passed on from the rumen (13). Only well broken down material passes through the omasum. This was illustrated by the fact that only very short pieces of forage were found in the abomasum of ruminants.

In general, more finely ground food passes through the digestive tract faster than the same food ground more coarsely or not ground. Balch (17) reported that ground hay residues when fed to a cow receiving a ration of long hay passed at a faster rate than residues of the long hay. Blaxer _et al._ (35) fed dried grass in three forms(long, medium ground-pelleted, and fine ground-pelleted) to sheep. Each feed was fed at the rate of 1500, 1200 and 600 g per day. Rate of passage increased with the fineness of grind. Campling _et al._ (45) fed ad lib. ground and long hay to cows. Mean retention time of stained hay on ad lib. feeding was slightly less for the ground hay. One cow had a faster passage rate of the ground material while the other 3 showed little difference or faster passage for the long hay. When only 8.7 lb of either ground or long hay were fed, the mean retention time of ground hay was less (56 hours vs. 85 hours for the long hay). Mean retention time of dry matter in the reticulo-rumen was least for ground pelleted, intermediate for ground and longest for baled costal Bermuda grass when fed to dairy heifers (191). In this trial, the difference in mean retention time may have been due to the differences in amount oonsumed and not to physical form. Daily consumption was highest for pelleted forage and lowest for ground forage. However, Rodrigue (222) reported that rate of passage was affected by degree of grinding and indicated all such experiments should state the fineness of grind.

Campling and Freer (47) studied the affect of size and specific gravity of inert particles on passage rate. At a specific gravity of 1.20, mean retention time was directly related to size (4.8, 4.0 and 3.2 mm in diameter of methyl methocrylate particles). King and Moore (139) reported a curvilinear relation between rate of passage and specific gravity with maximum passage rate when the particle size was 20 to 30 x 10^{-3} cm^3. The shortest mean time of retention through the gastro intestinal tract was found with particles having a specific gravity of 1.12 and the longest with particles having a specific gravity of 1.02. However, mean time of retention in the reticulo-rumen decreased as the specific gravity increased from 1.02 to 1.21, while the reverse was true in the lower gut, where the mean time of retention increased as the specific gravity increased. The mean time of retention of the inert particle was less with a diet of dried grass than with a more mature hay. King and

Moore (139) found that particles with a specific gravity of 1.20 gave minimum mean retention time with a ration of hay and concentrate.

Forage Digestibility

For many years great emphasis has been placed on forage digestibility as a measure of its nutritive value. It is well known that early cut forage will be consumed in greater quantities than a more mature forage (60,102,126, 151,152,172,207,211,214,234,236,256,275). Reid et al. (214) reported a high correlation between maturity and digestibility. He did not give the correlation between intake and digestibility but reported a trend of decreasing intake with lower digestibility and more maturity. Other workers (32, 33,34,35,69) have reported positive correlations between dry matter intake and percent digestibility of forages. The above relations were based on forages with a wide range in digestibilities (45 to 75%). The wide range in digestibility was obtained by using forages harvested at several stages of maturity. Thus the positive correlation between intake and digestibility was a consequence of both digestibility and maturity.

Blaxter (37) stated that "the amount of feed taken, measured in terms of dry matter, increases with increasing concentration of the ration (net energy/kg dry matter)". The reverse is true with most non-ruminant animals, as they will, within limits, eat more of a feed low in energy than of a feed with high nutrient density (38,39,138,162). Blaxter's above statement may be true with certain forages in the case of ruminants. Conrad et al. (63) determined voluntary intake of 82 different rations ranging in digestibility from 53 to 80%. Intake of rations (largely made up of roughages) between 53 and 67% digestible was directly related to digestibility. The differences in consumption could be accounted for by digestibility, indigestible residue, rate of passage and body weight. Intake of feeds decreased as digestibility increased from 66 to 80%. There was little tendency for consumption of forage to increase when digestibility increased above 70%. Intake was related to digestible energy and body weight to the .62 power, which was not significantly different from body weight to the .73 power. Blaxter et al. (34) reported that the consumption of poor quality hay was more related to body size than with hay of good quality (r= .8 vs. .5). This might indicate that rumen fill was more important in limiting intake of the poorer quality forage. Blaxter et al. (35) suggested that highly digestible forages resulted in a faster rate of passage and higher ad lib. intake than forages lower in digestibility. In a later experiment (34) poor, medium, and good quality hay were fed ad lib. to mature sheep. Intake of the better quality forage was greater and resulted in faster passage rates. Campling *et al.* (49) reported that passage rate of straw fed to cows was slower, when fed ad lib. or in restricted amounts, then passage rate of a good quality hay fed ad lib. or in restricted amounts. One wonders what affect the low protein in both the previous experiments had on rates of passage or degradation of forage dry matter. Freer and Campling (96) reported that ad lib. intake of dried grass was higher than that of hay and had a lower mean reticulo-rumen retention time. These experiments would suggest that forages of higher digestibility result in a faster rate of passage allowing for greater consumption.

Forage Degradation Rate

Forage degradation or breakdown rate could have a great deal of influence on level of intake assuming that forage intake is regulated by rumen fill. Balch and Johnson (18) studied factors affecting rate of cotton thread breakdown in the rumen and found breakdown to be faster in the ventral sac than in the dorsal sac. Cellulose breakdown was slower when ground hay rather than long hay was fed. A low dry matter content in the rumen favored rapid breakdown. Campling *et al.* (45) reported that feeding a ground forage diet reduced rate of cotton thread breakdown. Cotton thread was broken down six times faster when cows received hay as compared to straw. Cotton thread digestion decreased slightly as intake increased from 10 lb/day to ad lib. Later work (96) showed that in animals receiving hay 25% of the cotton thread was digested in 22 hours, whereas in animals receiving only concentrate 25% of the cotton thread was not digested in 240 hours.

Fiber and lignin content increases as forage matures (76,83,133,190,207,223,235,237,242,243,257). Rusoff (223) cited others as showing that as lignin content increased there was a decrease in digestibility of other plant constituents. Dehority and Johnson (78) showed that as lignin content increased with maturation the in vitro cellulose digestion rate was decreased. After this same material was ball milled the initial incubation or fermentation time necessary to observe cellulose digestion by rumen microorganisms was reduced. Also the authors observed further digestion of the forage after ball milling a digested sample. The authors concluded that this was direct evidence for the "incapsulating" effect of lignin on other plant constituents.

Workers at Ohio (77,124,129,255) have suggested a difference in rate of in vitro cellulose digestion of grasses and legumes due to differences in chemical make up of legumes and grasses. Donefer <u>et al</u>. (82) found that the 12 hour in vitro cellulose digestion was closely related to intake. He concluded that the early rate of digestion may, to a large extent, control intake. The evidence reported so far suggests that rumen fill, rate of passage, digestibility, and rate of forage breakdown are definitely related to intake. In many cases it is very difficult to separate cause from effect.

Effect of Urea, Thyroxine, or Limited Water on Digestion and Intake.

Urea added to low quality forage having a low crude protein content has been reported to increase intake (95,100, 113,183,185,276). Minson and Pigden (176) found urea added to poor quality forage decreased intake with little change in digestibility. Campling (220) administered urea via a fistula to cows receiving straw ad lib. The urea, infused to avoid any possible effect on straw palatability, markedly increased digestibility and intake. The rate of cotton thread breakdown in the rumen increased with added urea and mean retention time of hay in the reticulo-rumen decreased. In a later paper (97) these workers compared diets of hay, straw, and straw plus urea. They suggested that the amount of these forages eaten was dependent on the time necessary to physically and chemically break down the forages by chewing and microbial digestion respectively, to a size that could pass through the omasum.

Thyroxine has been shown to increase milk production, food intake and metabolic rate. Balch and co-workers (16) studied the effect of thyroxine on rate of passage and digestibility of a hay and concentrate ration fed just below appetite. A definite increase in metabolic rate was found with little difference in digestibility. However, crude fiber digestion was increased slightly though not significantly. The initial appearance of stained particles was not affected by thyroxine treatment. During thyroxine treatment 5% and 5 to 80% excretion times were less than those found previous to treatment with some cow differences. The authors suggested that if rate of passage did not increase during thyroxine treatment for an individual cow, then the fiber digestion increased. Water intake rose during thyroxine treatment.

In a later experiment Balch et al. (15) studied the effect of limiting water intake on digestibility. Any change would probably be due to change in rate of breakdown or rate of passage. Restricted water intake (60%) had little effect on digestion coefficients with the exception of producing a slight increase in crude fiber digestibility. The starch equivalent of the hays increased during water restriction, possibly due to increased flow of saliva. Passage rate showed a slight trend towards slower excretion. They suggested that rate of passage might slow down as the animals become accustomed to an all forage ration. Rate of breakdown of cotton thread in the dorsal sac of the rumen decreased during the second week of water restriction; however digestion rate increased throughout the experiment in the ventral sac.

Palatability

The term palatability (agreeable to the palate or pleasant to the taste) has been used with many meanings. Blaxter *et al.* (34) and Campling *et al.* (49) have indicated that voluntary intake of forage can be explained by physical regulation of appetite without using the concept of palatability. Blaxter *et al.* (34) feels the term palatability should not be used in reference to animal feeds. Thomas *et al.* (252) added several flavor compounds to silage to increase intake and concluded that reduced intake of silage in comparison to companion hay was due to metabolic end products and not palatability.

Experiments have shown that poultry have a sense of taste (136). The birds were able to detect and reject very low levels of certain flavors. Man's and bird's concept of taste differed. Baby pig rations containing saccharin were consumed at a rate 3.5 times the ration without saccharin (4). When 5 levels of saccharin were offered the results varied.

Miller *et al.* (175) showed in cafeteria type experiments that anise oil added to the calf ration decreased intake. Even the type of anise oil used made a difference in the amount of reduction in feed intake. Stubies and Kare (241) concluded that cows have a sense of taste that was relatively acute, but somewhat different from man's.

Ivins (127) reviewed the "palatability of herbage" and concluded that cattle showed a definite preference for some pasture plants over others. Only limited data are available as to the importance of these differences on animal production when no choice is offered.

Leigh (144) studied the relative palatability of several varieties of weeping love grass. Twenty varieties were planted in plots 20 x 40 ft which were further divided into 3 fertilizer treatments. Cattle were accustomed to the plot area, then allowed to graze. Time spent grazing and specific area grazed was recorded. There was a great difference in the acceptability of the different varieties. These results indicated that the variety presently used in most South Africa forage research was the least palatable. The level of fiber in these varieties was not important in influencing palatability.

Barnes _et al_. (19,20,186), by using cafeteria type grazing trials with sheep, selected two unpalatable and two palatable canary grass clones to study effects on in vivo digestibility and ad lib. intake. When sheep received the forages ad lib. there was a positive relation with digestibility, but not when intake was restricted. There seemed to be a positive relation between cafeteria palatability ratings and NVI or DM intake, which was more pronounced in the aftermath than in the first cuttings.

Hammes *et al.* (110) studied the palatability of coastal bermudagrass and alfalfa hays. Steers were allowed either alfalfa or bermudagrass for three days and then were reversed. After the second period all the animals were allowed a choice between the two hays. Alfalfa was consumed at the rate of 2.2 lb dry matter/cwt while only 1.55 lb of bermudagrass was consumed when no choice was allowed. When a choice was allowed, 2.2 lb of alfalfa and 0.4 lb of bermudagrass were consumed. At this time there is not sufficient data to eliminate the term palatability as a regulator of feed intake, nor is there sufficient data to indicate its importance in terms of animal production.

Lignin as a Marker

Inert or indigestible markers may be used to determine changes along the gastrointestinal tract of ruminants by the ratio technique. Hale (106,108,109) and Balch (14) suggested the use of lignin ratio to study chemical changes in the reticulo-rumen. The assumption was made that lignin is non-digestible. If no correction was made for rumen lignin digestion, the digestion values for the nutrients studied were slightly low. Total lignin digestion, however, averaged 21.5%. Several workers have reported no digestion of lignin (64,72,85,93,104,108,135), while others report some lignin digestion (40,71,73,75,84,87,107,134,153,163,195). Hale et al. (107) reported that 12 hour digestion coefficients in the rumen for lignin were small (3.1%). The probable reason for the above discrepancy is the fact that the chemical formula for lignin is not known. Lignin analysis is known to be difficult and inexact. Recently Van Soest (261) has shown that heating forage samples above 40°C increased the apparent lignin content. Therefore, many of the lignin values in the literature must be in error. At present the site of lignin digestion has not been determined, but has been assumed to be below the reticulo-rumen. This theory was supported with work by Hale et al. (107). With this assumption, lignin may be used to study chemical changes in the rumen. Below the rumen one may question the results obtained using the lignin ratio technique.

EXPERIMENTAL PROCEDURE

Objectives

The objectives of this experiment were (1) to determine and compare performance of animals when fed alfalfa, birdstrefoil, brome grass, reed canary grass or timothy, (2) to determine the correlation between animal gain and estimates of nutritive value (in vitro as well as in vivo) of the several forage species having reportedly, widely-varying potentials for animal performance, (3) to determine the effectiveness of rabbits in estimating large animal performance and nutritive value as determined by large animals, (4) to study the relationships between forage intake,rumen fill and rumen retention time of dry matter, fiber and lignin.

Forages - 1961 Crop

Three cuttings of pure stands of alfalfa (Vernal), birdsfoot trefoil (Viking), brome grass (Canadian) and reed canarygrass (Common) were harvested in 1961. Only one cutting of timothy (Commercial) was available due to the slow recovery of timothy. Forage cutting dates were June 17, August 3 and September 8 for first, second and third cuttings, respectively. All cuttings were from the same field and cut at the same time with the exception of alfalfa. Alfalfa first (Alf.I), second (Alf.2) and third (Alf.III) cutting were from the same field; however, Alfalfa-2 was harvested July 12 rather than August 3. Thus alfalfa III had a longer growing period than the other third-cutting forages. Alfalfa II was cut on August 3 from a different field than the above alfalfas and the first cutting had been removed about June 17. Thus, although the alfalfa II was from a different field than the other alfalfas, it had a regrowth period similar to that of the other second cut forages.

The grass forages were grown on Houghton muck soil while the legumes were grown on upland soil. The grasses received 100 lb nitrogen per acre on April 15. Forage yields (Table 2) were determined for the 1961 crop by the M.S.U. Crop Science Department. These data were not available for the 1962 crop.

TABLE 2. Dry Matter Yields of Pure Stand Forages - 1961 Crop.

Forage	Cutting 1st	2nd	3rd	Total
	tons/acre			
Birdsfoot trefoil	1.60	1.43	1.17	4.20
Alfalfa	1.67	1.72	0.74	4.13
Brome grass	1.42	0.91	0.85	3.18
Reed canary grass	1.66	1.38	1.15	4.19

The forages were harvested in a normal manner; partially field cured, baled and placed on a heated barn dryer to prevent weather damage. At the time of feeding the forages were chopped into about 1 inch lengths to facilitate weighing and prevent wastage when fed to sheep and heifers. A small portion of each forage was ground in a Letz chopper and pelleted into 3/8 inch pellets for feeding to rabbits.

Forages - 1962 Crop

The 1962 forages were handled in a manner similar to that of the 1961 forages. However, only two cuttings of each species were obtained due to dry weather. First cutting alfalfa I, canary grass I, brome I, timothy I and trefoil I were harvested May 28, May 31, May 31, June 4 and June 4, respectively. Trefoil I received a little rain soon after it was cut. Second cutting alfalfa II, brome II, canary grass II and trefoil II were harvested July 10, July 12, July 12 and July 16, respectively. Second cutting brome and canary grass received light rain the evening after cutting.

Standard methods, largely those of A.O.A.C. (11) with necessary modifications in accordance with equipment available, were used to determine forage protein (N x 6.25), ammonium, ether extract (E.E.), ash, phosphorus and sulfur.[1] Fiber and lignin content of hay and feces were determined by Van Soest's acid-detergent method (262). These values were used to determine fiber and lignin digestion coefficients for all forages. Gross energy of forages, orts and feces

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[1] These analyses were carried out by Dr. E.J. Benne, MSU, Biochemistry Department.

were determined by a Parr bomb calorimeter apparatus. Soluble carbohydrate content of the solute from Van Soest's fiber determinations were determined by the phenol-sulfuric acid method (Analytical Chemistry 28:350, 1956). Sub-samples of the 1961 forages were also sent to Van Soest's laboratory for analysis of lignin, fiber and cell wall constituents.

Sheep Trials - 1961 Crop

Twelve wethers weighing approximately 70 lb were used in three 4 x 4 latin squares to study intake, body weight gain and digestibility of the forages. To obtain data on alfalfa-2 and timothy, two wethers were alternated back and forth on the two forages. The three latin squares contained four different forage species of the same cutting and each period extended for 25 days. A weighed amount of forage was fed twice daily and refusals were weighed daily in the early afternoon to allow a period of about three hours when no feed was in the mangers. A scale graduated in ounces was used to weigh all feed and orts.

Five grams of a 1:1 mixture of trace mineralized salt and dicalcium phosphate was fed daily. Water was offered ad libitum. At the beginning of each feeding period the forage was fed at the rate of 2 lb/cwt. and then adjusted rapidly the first few days. The portion offered was increased to 15% in excess of consumption. The amount offered was not decreased unless weight back was in excess of 15% for 2 or 3 days. The wethers were fed in individual pens for the first 12 days of the experiment then placed in conventional digestion stalls through the 20th day, after which they were returned to individual pens. Originally it was planned to keep the wethers in the collection stalls throughout the experiment; however, they became very weak in the hind legs from standing on a wire mesh support. Average daily voluntary dry matter intake was determined using consumption data for the last 19 days of each period. Dry matter was determined weekly on each forage. All dry matter samples unless otherwise stated were dried at 80°C for approximately 48 hours in a forced air oven.

The body weight changes were determined from day 7 through day 25 based on the average of consecutive weights over a 3 day period. All weighings were made at 4:00 p.m.

Sheep Trials - 1962 Crop

Feeding and collection trials using forages harvested in 1962 were similar to those of the 1961 crop. However, it was thought that a slightly longer feeding period was desirable and consequently each period was prolonged to 28 days. Timothy I was fed alternately to 2 sheep. Each period the wether not receiving timothy was fed a good mixed hay. Feed consumption was determined daily but that consumed from day

8 through 21 was used to determine daily intake average. This procedure was a more precise estimate of maximum intake than in the previous year's data which contained intake data collected during the slight drop in consumption found near the end of the collection period. Body weight changes were determined from day 6 through 28 based on the average of 3 consecutive daily weighings.

Sheep Digestion Trials

Digestion trials were conducted in collection crates allowing for separation of urine and feces. The wethers receiving the 1961 forages were placed in the collection crates on the 12th day of each period with actual feces collection from day 14 through 20. Feces were collected from day 20 through 26 from sheep receiving the 1962 forages. Total feces were collected daily and placed in a container kept at 2°C. At the end of each 7 day collection period the feces from each sheep were thoroughly mixed. Approximately 10% were dried at 80°C and ground for chemical analysis. At the same time another sample was obtained and dried at 40°C. for fiber and lignin determinations. During the collection trial a daily sample (approximately one hand full) of each hay was obtained. The 7 day composite sample was thoroughly mixed on a table and one-half dried for chemical analysis. The rest of the sample was saved for use as an in vitro fermentation substrate. All orts during each collection period were composited into a covered can. At the completion of each digestion trial these orts were mixed and sampled. The sample was dried at 80°C to determine % dry matter.

Digestible dry matter (dig.DM), digestible organic matter, digestible energy and estimated TDN were determined for all forages. Digestion coefficients were calculated by dividing retained nutrients by nutrients consumed which were based on total intake and fecal excretion during the 7 day collection period. TDN was estimated by the method of G.P. Lofgreen (150) as indicated in the following formula: Estimated TDN = M (.01 + .000125 E)· % dig. organic matter; where M = % organic matter and E = % ether extract. Dry matter nutritive value index (DM NVI)was determined by the following formula:

$$\text{DM NVI} = 100 \cdot \frac{\text{g observed DM intake}}{80\ (\text{wt.}_{\text{kg}}{}^{.75})} \times \%\ \text{digestible DM.}$$

Crampton's et al. (67) formula for NVI was similar except % digestible energy was used in place of % digestible dry matter. In vitro NVI was determined from the following formula:

$$\text{In vitro NVI} = \frac{\%\ 6\ \text{hr. DM disappearance} \cdot \%\ 36\ \text{hr. DM disappearance of substrate}}{100}$$

In vitro dry matter disappearance is discussed on pages 59 - 63.

Rabbit Trial - 1961 Crop

Growing Dutch belted rabbits weighing 600-1000 g were fed the fourteen 1961 forages in six replications for 4 weeks. The rabbits had been weaned and were receiving commercial rabbit pellets at the start of the experiment. Fourteen rabbits were started simultaneously with one rabbit on each hay. The average initial weights for all groups were approximately the same.

The rabbits were housed in stainless steel cages with wire mesh floors in a large temperature controlled room. Feed and water containers were hung on the door of each cage. A U-shaped strip of metal with bottom and sides was attached to the floor under each feed tray to help prevent wastage. Bedding was not used in the front half of the excreta tray to allow daily removal of wasted feed.

The pelleted forage under investigation was fed ad lib. as the sole ration except that salt blocks were available at all times. Feed intake was determined weekly for the last three weeks of the trial. The pelleted forage was sampled and % dry matter determined. A seven day total collection of excreta was made during the 3rd or 4th week of the trial to determine dry matter digestion coefficients. The feces were dried at 80°C for 48 hours and then weighed to determine total dry matter voided during the 7 day collection.

Weight gain was determined for the last three weeks of the trial from weighings made on 3 consecutive days each week.

Dairy Heifer Trial - 1961 Crop

The objective of this trial was to obtain data that could be used to compare responses when pure stand forages were fed. However, the amount of hay was limiting and resulted in a short trial with a small number of animals (3 to 4 per group). Two heifers in the brome I group and one in the reed II group developed coccidiosis and were removed from the experiment, which left two animals per group.

Dairy heifers weighing approximately 350-800 lb were fed ad lib. the chopped experimental forages twice daily (10% excess). Water was available at all times. Fifty grams of a 1:1 mixture of trace mineralized salt and dicalcium phosphate were fed daily . Orts were weighed back and recorded daily and dry matter was determined weekly on hay and ort samples. Digestion coefficients as determined by sheep were applied to the dry matter intake of the dairy heifers to determine dig. dry matter intake as several workers have shown that sheep and cattle give similar digestion coefficients for forages (3,245). The experimental hay was fed for 10 days previous to the start of the experiment.

All heifers were weighed for three consecutive days at the beginning of the experiment and thereafter every two weeks until the supply of that particular hay was exhausted.

In Vitro Fermentation - 1961 Forages

Strained rumen fluid was used to digest forage substrates. Digestion was measured by the amount of the added substrate that would pass through a sintered glass filtering crucible after a designated period of fermentation. This method was similar to that of Bowden and Church (41,42,58) and was selected because of simplicity and because the method measured dry matter disappearance. Oven dried composite samples taken from 4 samples of each forage collected during the digestion trials were ground through a 1 mm mesh Wiley mill screen, thoroughly mixed, and stored at 35°F.

Rumen inoculum was obtained from a fistulated Holstein cow maintained on 26 lb of timothy-brome hay containing 5-10% alfalfa. Water was available at all times and 50 g of a 1:1 mixture of salt and dicalcium phosphate was fed daily. On days of inoculum collection, the cow was fed at 7:00 a.m. Feed and water were removed at 8:00 a.m. and the rumen juice was collected at 9:00 a.m.

Rumen ingesta were obtained by hand from an area below the fistula and the juice expelled by squeezing. The juice was then strained through four layers of cheesecloth into a prewarmed thermos jug and transported to the laboratory. Carbon dioxide was bubbled through the rumen juice for two minutes.

The buffer solution for the in vitro fermentations was made up as follows. A 0.1M pH7 phosphate buffer was made from 2.04 g KH_2PO_4 plus 4.36 g Na_2HPO_4 and made to 500 ml with water. A urea stock solution was made from 8.00 g of urea diluted to 100 ml with water. A sodium carbonate stock solution was made from 18.4 g ($Na_2CO_3 \cdot H_2O$) and diluted to 100 ml with water. Two ml of the sodium carbonate stock solution and 2.5 ml of the stock urea solution were added to 100 ml of buffer. The fermentation mixture contained about .05% added urea which was the level suggested by Salsbury (228). Just before using, the buffer solution with added urea and sodium carbonate was warmed and CO_2 bubbled through it until a pH of 6.8 was reached.

An all glass fermentation system was used consisting of a 125 ml erlenmeyer flask fitted with a one-holed rubber stopper and bunsen valve made from rubber tubing. One gram ($\pm$ .003 g) of forage substrate was added to each flask.

Fermentations were carried out in a large temperature controlled circulating hot water bath maintained at 39°C. At 8:30 to 9:00 a.m. 20 ml of buffer solution was added to each flask containing the substrate. At 9:30 a.m. 60 ml of rumen inoculum was added to each flask. Similar amounts of rumen inoculum were added to four flasks without added substrate in order to determine residual non-filterable dry matter originating from the inoculum.

The flask was then flushed with CO_2, stoppered, and incubated in the hot water bath for 3,6,12,18,24,36 or 48 hours. Other work suggested that continued bubbling of the fermentation mixture with CO_2 was not necessary (337). At the end of the designated fermentation interval, one drop of 20% thymol solution was added to the mixture and the flask placed in a freezer (-10°C). Each fermentation trial (fermentations started the same day) consisted of 7 or 8 different forages all fermented for 7 different time intervals. Also with each fermentation trial, duplicate dry matter disappearance determinations were made on a standard alfalfa hay.

In Vitro Fermentation - 1962 Forages

The fermentation procedure was similar to that used for the 1961 forages with some slight changes. The donor cow received good quality alfalfa hay (5-10% mixed grass) throughout the experiment. After arriving at the laboratory, the rumen fluid was allowed to stand in large erlenmeyer flasks at 39°C for one half hour. This allowed the particulate matter to rise. The bottom, or more fluid portion was then siphoned off and bubbled with CO_2 for two minutes. Removing the particulate matter reduced the variation between replicates to a level similar to that obtained by other investigators (25,26,29). Non-filterable dry matter added to the fermentation mixture by 24 ml of rumen fluid for each trial conducted on the 1961 and 1962 forages is shown in appendix Table XXVI. The residual non-filterable dry matter contributed by settled rumen fluid was ¼ that contributed by non-settled fluid.

Dry matter disappearance was determined by filtering the fermented material through a tared coarse sintered glass filter (Corning Cat. #32940C). Frozen fermented samples were thawed in warm water (40°C) and quantitatively washed into filtering crucibles. However, when vacuum was applied, the sintered glass filters became plugged and very slow filtering occurred. To alleviate this, a solka flock paste (solka flock and H_2O mixed in a waring blender for 5 min) was placed in each filtering crucible to make a ¼" filtering plug or layer. Water was removed by applying a slight vacuum. The filtering layer was then rewashed with 50 ml of distilled H_2O. The filtering crucible with its filtering pad was then dried in a forced air oven at 80°C for 36 hours, placed in a desicator for 30 min and then weighed. The fermented sample was then washed into the tared crucible with distilled water and vacuum applied to remove the water. The non-filterable material was then rinsed by drawing through 50 ml of distilled water. The crucible was then dried, placed in a desiccator and re-weighed as previously described. The average non-filterable residual dry matter contributed by the rumen inoculum was subtracted from the total non-filterable dry matter. This allowed one to determine the portion of the added substrate that did not disappear during the fermentation process. (Total non-filterable DM - residual non-filterable rumen inoculum DM = "undigested" portion of substrate). The substrate "digested" or substrate disappearance was calculated by the following formula:

$$\%\ \text{DM disappearance} = \frac{\text{substrate added-non-filterable or "undigested" portion of substrate} \times 100}{\text{substrate added}}$$

By the nature of the above procedure some of the dry matter disappearance was due to loss of water-soluble portions of added substrate and part by microbial digestion. Therefore dry matter disappearance of each forage substrate was determined by incubating with only buffer solution for 3 hours. Extra buffer was added in place of the rumen inoculum. Dry matter disappearance due to rumen inoculum was determined by subtracting three hour buffer soluble dry matter from total dry matter disappearance at the different fermentation intervals.

Slaughter Trials - 1961 Crop

Second cut trefoil, alfalfa, brome grass and canary grass were fed to 3 wethers for 14 days. These particular forages had the maximum intake range of all the 1961 forages and yet had similar dry matter digestion coefficients. Intake data for the slaughter trial were based on average consumption for days 11 through 13. The wethers were slaughtered on the 14th day 6 hours after feeding or halfway between feedings. Feed and water was available until about 2 hours before killing.

The wethers were killed, their hides quickly removed and the gastro-intestinal (G.I.) tract removed. The G.I. tract was then tied off between the reticulum and omasum, small intestine and large intestine and at the base of the cecum. The pH of fresh rumen contents was obtained immediately. Fiber and lignin contents of digesta in the rumen and lower large intestine were determined on dried (40°C) portions by the Van Soest acid-detergent method (262).

Slaughter Trial - 1962 Crop

The 1962 crop slaughter trials were carried out in a manner similar to that for the 1961 forages except for a few changes. First cut alfalfa, trefoil, timothy and canary grass were each fed individually to 4 sheep for 14 days. Intake was determined for the last three days of the period. Feed was offered ad lib. at 12 hour intervals. Orts from the last feeding were removed one hour after feeding. Two sheep from each forage group were killed six hours after feeding while the other two were killed 12 hours after feeding or just prior to the next feeding. Available facilities made it necessary to slaughter the sheep on two consecutive days.

The gastro-intestinal tract sections were tied off as in the previous trial with the exception that the large intestine was divided at a point where pelleted feces in the tract were obvious. Thus this organ was divided into upper large intestine (excluding cecum) and lower large intestine. Samples from the lower large intestine were considered to be similar to feces.

From each rumen sample 20 grams of digesta were placed in a large test tube with 20 ml of .6 N H_2SO_4 and frozen until analyzed for volatile fatty acids (C_2-C_4). At the time of analysis the samples were thawed and centrifuged at 2,000 rpm for 10 minutes. The supernatant was poured off into small sample bottles. To keep the recorded peaks on the recording chart, the samples were diluted 2 to 4 times with distilled water acidified to pH 2 with H_2SO_4.

Volatile fatty acids in the rumen contents were determined by using an aerograph model A-600-D "Hi'Fi" gas chromagraph with an hydrogen flame ionization detector coupled with a Sargent SRL recorder. The absorbing column was five feet long by 1/8" in diameter and contained 15% versamid 900, 5% isophthalic acid on 60/80 chromosorb W. A 135°C chamber temperature was maintained with the injection port at 190°C.

Nitrogen was used as a carrier gas.

Five tenths µl of the final sample solutions was injected into the apparatus. The amounts of acetic, propionic and butyric acids were calculated by measuring the recorded peak heights and comparing these to a standard curve. The standard curve was made by using known dilutions of barium acetate, sodium propionate and sodium butyrate to give peak heights in the range of those found in the samples being tested. The standard acetate, propionate and butyrate solutions were mixed and 0.5 ul injected. Peak height rather than area was used to determine concentrations because of sharp and very narrow peak widths. Measuring the peak width would probably induce more error rather than reduce error under these circumstances.

Rumen retention time was determined by a method similar to that of Paloheimo (194) as shown in the following formula:

$$\text{Rumen retention time of DM} = \frac{\text{DM contents in the rumen/cwt}}{\text{Daily DM intake/cwt}}$$

Rumen retention time of fiber and lignin was determined in a similar manner by substituting fiber or lignin for dry matter (DM).

Dry matter and fiber disappearance from the rumen and large intestine were determined by using the lignin ratio technique as proposed by Hale *et al.*, (106). The formula for determining "digestion" or disappearance from the rumen was as follows:

$$\% \text{ digestion} = 100 - \frac{\% \text{ lignin in hay}}{\% \text{ nutrient in hay}} \times \frac{\% \text{ nutrient in rumen}}{\% \text{ lignin in rumen}} \times 100$$

There was assumed to be no "digestion" of lignin in the rumen. Indigestible lignin in the hay was determined from the total collection trials.

RESULTS

Forages

Protein content of the experimental forages ranged from 14% for timothy to 32% for Brome III (Table 3). Although the protein content of brome grass was high, other workers (127) have reported up to 39% crude protein in young brome grass. Ammonia nitrogen was determined to ascertain how much of the crude protein (N x 6.25) was ammonia nitrogen. The maximum ammonia nitrogen found in the forages harvested in 1961 (Table 3) was equivalent to about ½ percent unit of crude protein. Fiber content of the forages varied from 27 to 40% with grasses containing slightly less fiber than the legumes when considering forages of the same year and cutting. Lignin content of the forages varied from 2.8 to 9.9%. Legumes in some cases contained 2 and 3 times as much lignin as did the grasses. Lignin analyses between our laboratory and Van Soest's were in reasonable agreement. Van Soest found that some of the isolated lignin from the forages contained nitrogen which he termed artifact nitrogen (Table 4).

When forages are heated over 40°C the lignin fraction as measured by this method contains protein (N·6.25). Heating the sample apparently may cause protein to bond with the lignin and cause an "elevated" lignin content. This artifact nitrogen can be compensated for by a correction factor (153). These forage samples were not oven dried.

TABLE 3. Chemical Analysis of Experimental Forages-
1961 and 1962 Crop.

Forage	NH_4^+	Protein[1]		E.E.		Ash		Phosphorus		Sulfur	
	% Expressed on Dry Matter Basis										
	1961	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962
Tre I	.03	16.2	16.1	2.63	3.23	6.03	6.99	.21	.17	.20	.26
Alf I	.03	19.2	18.1	1.97	2.02	7.86	8.54	.47	.31	.26	.31
Brome I	.06	22.1	24.1	3.13	3.68	8.40	8.65	.31	.36	.30	.32
Reed I	.04	22.2	21.2	3.95	3.12	8.67	7.20	.31	.21	.34	.40
Tim I	.01	14.2	15.6	3.57	3.76	6.22	5.07	.28	.24	.20	.21
Tre II	.05	17.8	17.8	2.89	2.55	6.91	6.59	.21	.21	.23	.26
Alf II	.05	17.6	20.6	1.79	2.06	7.72	7.49	.32	.32	.32	.33
Alf 2	.03	20.2	-	2.24	-	9.48	-	.29	-	.36	-
Brome II	.10	24.6	22.2	4.09	4.37	7.30	8.23	.26	.32	.32	.31
Reed II	.05	20.1	21.2	3.19	3.39	6.48	7.06	.24	.22	.34	.48
Tre III	.05	23.1		3.63		10.64		.30		.28	
Alf III	.07	18.8		1.85		9.94		.30		.27	
Brome III	.05	32.1		4.75		9.20		.37		.43	
Reed III	.08	29.6		3.53		10.11		.41		.55	
		Fiber[2]		Lignin[2]		Soluble CHO		K.Cal/g			
Tre I		37.5	32.7	9.93	8.73	30.	31.	4.65	4.58		
Alf I		36.6	33.2	7.46	6.24	24.	31.	4.45	4.47		
Brome I		31.7	30.3	4.12	3.78	34.	35.	4.41	4.62		
Reed I		27.4	29.6	2.72	3.43	37.	44.	4.58	4.66		
Tim I		34.0	33.2	4.60	4.37	43.	46.	4.42	4.74		

continued

TABLE 3 CONTINUED

Forage	% Expressed on Dry Matter Basis							
	Fiber[2]		Lignin[2]		Soluble CHO		K.Cal/g	
	1961	1962	1961	1962	1961	1962	1961	1962
Tre I	31.0	30.9	9.71	8.50	29.	31.	4.58	4.69
Alf II	38.4	32.9	8.77	7.08	26.	29.	4.51	5.11
Alf 2	30.1	-	6.57	-	28.	-	4.62	-
Brome II	33.3	29.8	7.03	3.85	33.	37.	5.08	4.71
Reed II	32.1	29.8	4.21	3.56	40.	42.	4.61	4.71
Tre III	29.2		7.43		24.		4.50	
Alf III	40.4		8.41		27.		4.47	
Brome III	27.0		5.23		27.		4.68	
Reed III	28.8		2.80		31.		4.60	

[1]Kjeldahl nitrogen x 6.25

[2]Acid-detergent fiber and lignin by method of Van Soest.

TABLE 4. Fiber and Lignin Content of 1961 Forages As Determined by Van Soest.

Sample	Cell Wall Constit.	Acid Deterg. Fiber	Lignin	Acid Deterg. Insol. N x 6.25	Corrected* Lignin
	% D.M.	% D.M.	% D.M.	% D.M.	% D.M.
Alf I	47.2	36.5	7.06		
Alf II	49.8	37.9	8.24		
Alf 2	42.2	31.3	5.74		
Alf III	59.1	41.1	8.18		
Tre I	49.0*	38.5*	9.53	1.52	9.31
Tre II	44.0*	31.4*	9.35	2.03	8.18
Tre III	36.9*	29.3*	8.05	1.77	7.07
Brome I	63.9	31.9	3.57		
Brome II	59.9*	29.5*	7.36	2.79	4.41
Brome III	53.8*	24.5*	4.97	2.31	2.36
Reed I	58.7	27.8	2.38		
Reed II	67.6	32.4	3.67		
Reed III	59.8	28.1	2.88		
Tim.I	62.4	34.1	3.90		

* Corrected for artifact lignin.

Possibly the nitrogen contamination in the lignin could have occurred because of heating in the bales during curing.

Cell wall constituents which includes lignin, holocellulose and cell wall proteins as determined by Van Soest (Table 4) were compared with intake and % dry matter digestion of the experimental forages for different animal species. Cell wall constituents had little effect on sheep dry matter digestion coefficients but were negatively related to dry matter intake by sheep and heifers ($r = -.70^{**}$ and $-.66^{*}$ respectively, Table 5). Dry matter intake by rabbits was not significantly ($P > .05$) related to cell wall constituents. However, rabbit digestion coefficients were negatively related to forage cell wall constituents ($r = -.74^{**}$). The above relations might indicate the inability of the rabbits' digestive system to degrade cell wall constituents of forages. However, cell wall constituents, though broken down by ruminants resulted in reduced intake.

Chemical analysis and intake were used to calculate intake of the various nutrients expressed as intake per 100 lb live body weight (cwt). Sulfur and protein intake were adequate based on N.R.C. requirements (201). The assumption appear warranted that sheep performance on the different forages was limited by the level of energy consumed.

Lignin and fiber content have been reported to adversely affect intake of forages. Fiber content of forages used

TABLE 5. Simple Correlation Coefficients Between Digestibility and Intake of Forage Dry Matter by Animals and Forage Content of Fiber, Lignin and Cell Wall Constituents.

	No. Forages	r
1. Sheep % digestible DM vs.% fiber in grasses	12	-.58*
2. Sheep % digestible DM vs. % fiber in legumes	11	-.79**
3. Sheep % digestible DM vs.% fiber in all forages	23	-.66**
4. Sheep % digestible DM vs.% lignin in grasses	12	-.65*
5. Sheep % digestible DM vs.% lignin in legumes	11	-.53
6. Sheep % digestible DM vs.% lignin in all forages	23	-.50*
7. Sheep % digestible DM vs.cell wall constituent	14	-.20
8. Rabbit % digestible DM vs. cell wall constituent	14	-.74**
9. Sheep DM intake/cwt vs.% fiber in all forages	23	.37
10. Sheep DM intake/cwt vs.% lignin in all forages	23	.78**
11. Sheep intake vs. cell wall constituent	23	-.70**
12. Heifer intake vs. cell wall constituent	13	-.66*
13. Rabbit intake vs. cell wall constituent	14	.09
14. Sheep digestible DM intake vs.% lignin in all forages	23	.59**

continued

TABLE 5 CONTINUED

	No. Forages	r
15. Sheep digestible DM intake vs.% lignin (1961 forages)	14	.61*
16. Sheep digestible DM intake vs.% lignin as determined by Van Soest (1961 forages)	14	.61*

* Significant P <.05
** Significant P <.01

in these experiments did not appear to be a decisive factor in regulating intake. The correlation coefficient between dry matter intake and % fiber was low but positive (r = +.37). A large positive correlation was found between lignin content and dry matter intake (r = +.78). Digestible dry matter intake was also positively correlated with lignin content of the experimental forages (r = +.59). As the fiber content of the forages increased the digestibility of the forages decreased.(Table 5 - lines 1 through 3). To a lesser extent, digestibility of the forages decreased as the lignin content increased (Table 5 - lines 4 to 6).

Sheep Performance

Various measurements of animal performance for the different forages and cuttings in 1961, 1962 and combined data were determined and tabulated (Tables 6,7,8- Appendix Tables II through XI).

TABLE 6. Several Criteria Used to Evaluate the Experimental Pure Stand Forages[1,2] (Sheep 1961 Crop).

Forage	DM intake/ cwt lb/day	DM dig. %	Dig.DM intake/ cwt lb/day	DM NVI	Body weight gain lb/day
Alf I	3.00ABa	60.0Bb	1.80AB	55.8	.19
Tre I	3.28Aa	61.5Bb	2.01A	62.3	.27
Brome I	2.61Bb	61.9ABb	1.62B	49.7	.12
Reed I	2.51Bb	65.1Aa	1.63B	50.8	.16
Tim.I[3]	2.43	63.8	1.55	49.0	.13
Alf II	3.20AB	55.8ab	1.78ABb	54.7ABb	.21AB
Tre II	3.63A	60.0a	2.20Aa	66.7Aa	.34A
Brome II	2.61BC	55.0b	1.43BCc	44.5BCc	.02B
Reed II	2.26C	55.0ab	1.25Cc	38.7Cc	.08B
Alf 2[3,5]	2.77	65.1	1.81	56.7	.29
Tre III	2.95	64.1Ab	1.83	64.4	.30
Alf III[4]	2.71	56.6Bc	1.53	47.1	.03
Brome III	2.54	65.7Ab	1.65	50.7	.19
Reed III	2.40	68.6Aa	1.63	50.3	.20
Average					
1st cut	2.85	62.2A	1.76	54.6	.18
2nd cut	2.92	56.6B	1.67	51.2	.11
3rd cut	2.62	63.0A	1.66	53.1	.18
Alf	2.97b	57.5Bc	1.71Bb	52.5	.13
Tre	3.25a	61.9Aab	2.01Aa	64.5	.28
Brome	2.59c	60.6Ab	1.57Bbc	48.3	.11
Reed	2.38c	63.1Aa	1.50Bc	46.6	.09

[1]The values given for each cutting represents an average of 4 sheep.

[2]Values with like superscripts represents a homogenous group (large superscript $P < .01$ and small superscript $P < .05$)

[3]Not included in the statistical analysis.

[4]The second cutting was removed from this field 7/12 rather than 8/3.

[5]Harvested 7/12 from the same field as 1st and 3rd cutting used in this study.

TABLE 7. Several Criteria Used to Evaluate the Experimental Pure Stand Forages (Sheep 1962 Crop)

Forage	DM intake/ cwt lb/day	DM dig. %	Dig.DM intake/ cwt lb/day	DM NVI	Body weight gain lb/day
Alf I	3.52Aa	65.3	2.30Aa	68.7Aa	.28
Tre I	3.20Ab	61.7	1.98ABb	59.6ABb	.17
Brome I	2.70Bc	66.8	1.80BCb	53.4BC	.19
Reed I	2.24Bd	65.0	1.45Cc	43.5BC	.07
Tim.I[1]	2.66	62.2	1.65	50.3	.01
Alf II	3.58A	60.8B	2.18Aa	65.5A	.17
Tre II	3.34A	62.5ABb	2.09Aa	61.9ABa	.18
Brome II	2.56B	66.1Aa	1.69ABb	50.4Bb	.11
Reed II	2.37B	61.1B	1.45B	43.4Bb	.12
Average					
1st cut	2.91	64.7a	1.88	56.3	.18
2nd cut	2.97	62.6b	1.85	55.3	.15
Alf	3.56Aa	63.1B	2.24A	67.1A	.23
Tre	3.27Ab	62.1B	2.03ABa	60.8ABa	.17
Brome	2.63Bc	66.4A	1.75Bb	51.9BCb	.15
Reed	2.31Bd	63.1B	1.33C	43.4Cc	.09

1. Not included in statistical analysis.

TABLE 8. Several Criteria Used to Evalute the Experimental Pure Stand Forages (Sheep 1961 and 1962 Crop Combined)

Forage	Dry matter intake/ cwt lb/day	Dry matter digestibility %	Digestible dry matter intake/cwt lb/day	DM NVI	Body weight gain lb/day
Alf I	3.26A	62.6	2.05	62.2	.24
Tre I	3.24A	61.6	2.00	61.0	.22
Brome I	2.66B	64.4	1.71	51.6	.16
Reed I	2.38B	65.0	1.54	47.2	.12
Tim.I[1]	2.54	63.0	1.60	49.6	.07
Alf II	3.39A	58.3	1.98A	60.1A	.19ab
Tre II	3.48A	61.2	2.14A	64.3A	.26a
Brome II	2.58B	60.6	1.56Ba	47.4B	-.01c
Reed II	2.32B	58.4	1.35Bb	41.1B	.02bc
1st cut	2.88	63.4	1.82	53.0	.18
2nd cut	2.94	59.6	1.76	53.2	.12
Alf	3.32A	60.4	2.02	61.2	.21ABab
Tre	3.36A	61.4	2.07	62.6	.24Aa
Brome	2.62Ba	62.5	1.64	49.5	.10ABb
Reed	2.35Bb	61.7	1.44	44.2	.07Bbc

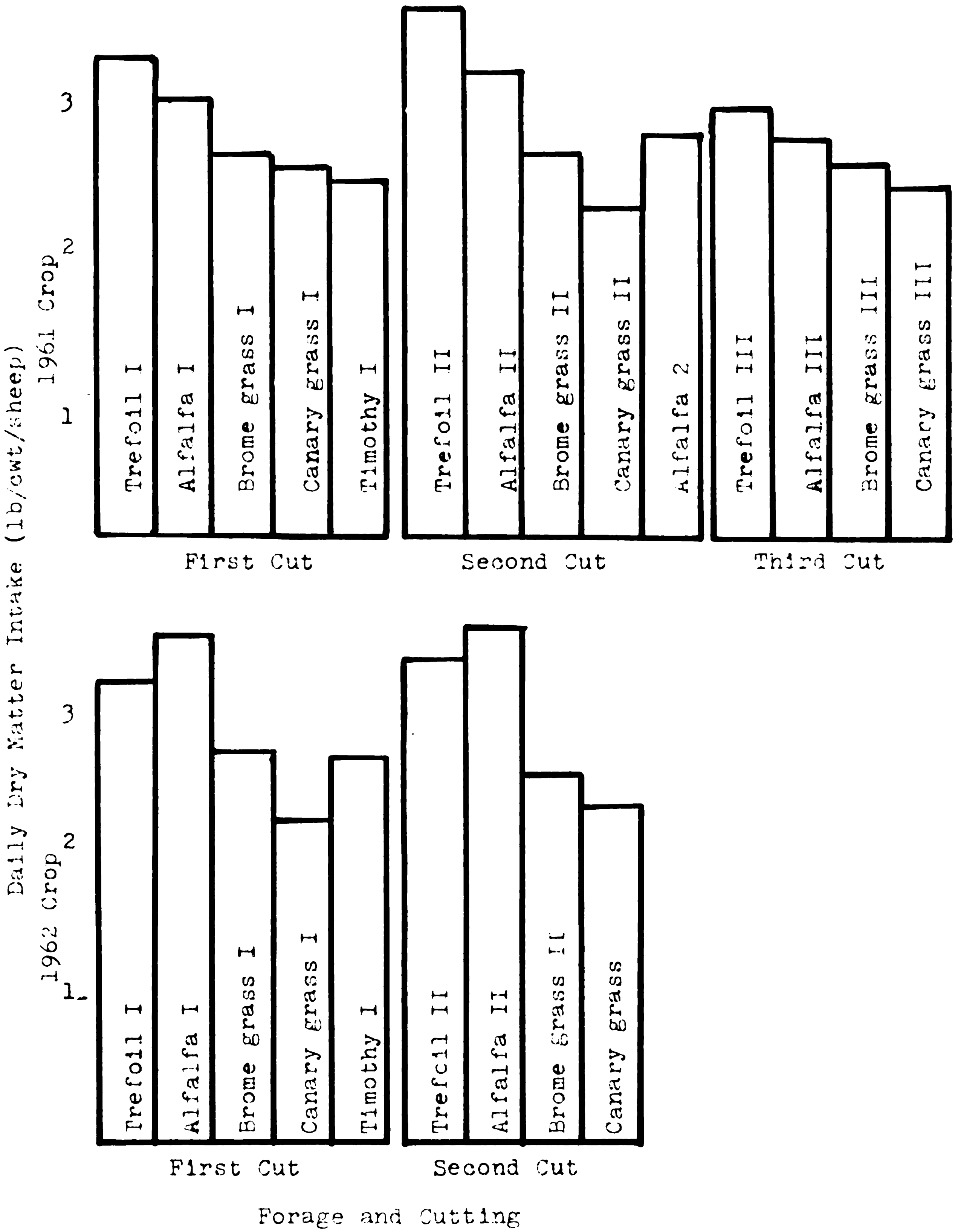
[1]Not considered in statistical analysis.

A graphic presentation of dry matter (DM) intake of all forages is shown in Figure 1. For each cutting DM intake ranked the 1961 forages in the order of trefoil, alfalfa, brome grass and canary grass. A similar pattern was shown for the 1962 forages except that alfalfa ranked ahead of trefoil. During both years DM intake of the legumes ranked ahead of the grasses for first and second cutting forages ($P < .05$). There was very little difference in average DM intake of first and second cut forages especially the 1962 forages for which the first cutting was made June 1 rather than June 17 as was the case for 1961 forages.

The maximum dry matter intake occurred between days 3 and 13 of the 28 day feeding trial for most forages. There was no consistant length of time required to reach maximum intake for the different forage species. Average daily intake of all forages reached a maximum after 9 days on feed (Appendix Table I). In many cases after intake of a particular forage reached a maximum, a slight decrease in consumption followed. Consumption also decreased slightly while sheep were in the collection stalls. After removal of the sheep from the collection stalls intake tended to increase to previous levels (Appendix Table I).

Some differences in dry matter digestibility of specific forages were found (Tables 6, 7, 8). The grasses, especially canary grass harvested in 1961, tended to have slightly larger dry matter digestion coefficients than the legumes.

Figure 1


Daily Dry Matter Intake (lb/cwt/sheep)
1961 Crop
1962 Crop
1
2
3
Trefoil I
Alfalfa I
Brome grass I
Canary grass I
Timothy I
Trefoil II
Alfalfa II
Brome grass II
Canary grass II
Alfalfa 2
Trefoil III
Alfalfa III
Brome grass III
Canary grass III
First Cut
Second Cut
Third Cut
Trefoil I
Alfalfa I
Brome grass I
Canary grass I
Timothy I
Trefoil II
Alfalfa II
Brome grass II
Canary grass
First Cut
Second Cut
Forage and Cutting

Second cutting trefoil was more digestible than the other 1961 second cut forages. Digestibility of third cutting alfalfa was low, probably because the interval between cutting and harvesting was longer for this forage than for the other third cutting forages resulting in a more mature forage. First and second cutting 1962 brome grasses were more digestible than the other forages, ($P < .01$). First cutting 1962 trefoil and timothy were slightly less digestible than alfalfa, brome grass and canary grass. The 1962 second cut forages were more digestible than the 1961 second cut forages ($P < .05$). Differences in dry matter digestion coefficients for the four forage species were not consistant.(Appendix Table XIV).

Dry matter digestion coefficients were determined for the 1961 forages based on feed intake 0, 24, and 48 hours previous to feces collection (Appendix Table IX). Analysis of variance showed no significant difference in the resulting digestion coefficients. All data presented in this thesis are based on zero time difference between intake and feces collection.

Digestible organic matter, digestible energy and estimated TDN values for the different forages were determined (Table 9, and Appendix Table II). Digestible dry matter, TDN and digestible energy values for all forages were correlated ($P < .01$). The correlation between % digestible energy or % TDN and % dig. dry matter were not significant ($P > .05$) for the forages harvested in 1962. This is probably due to large

TABLE 9. Dig. Organic Matter, Estimated TDN and Dig. Energy of 1961 and 1962 Pure Stand Forages as Determined by Sheep (Oven Dry Basis).

Forage	Dig. Organic Matter 1961	Dig. Organic Matter 1962	Estimated TDN[1] 1961	Estimated TDN[1] 1962	Dig. Energy 1961	Dig. Energy 1962
	%		%		%	
Alf I	62.5	66.2	58.9	62.4	58.2	64.5
Tre I	63.3	63.4	61.3	61.2	61.7	61.5
Brome I	61.3	66.9	58.2	63.7	55.4	63.7
Reed I	66.0	64.9	63.1	62.4	63.3	63.6
Tim.I	64.2	62.7	62.8	62.2	58.3	60.4
Alf.II	59.1	62.9	55.7	59.6	54.2	64.9
Tre II	61.7	63.3	59.4	60.9	57.1	60.7
Brome II	56.5	65.8	54.8	63.4	55.5	62.5
Reed II	55.5	60.9	53.8	58.8	50.4	59.0
Alf 2	67.6		62.8		65.2	
Alf III	60.0		55.1		56.4	
Tre III	67.7		63.0		62.4	
Brome III	66.0		63.2		61.5	
Reed III	67.7		63.2		63.5	

Simple Correlations

1961 % dig. energy vs. % dig. D.M.	.85**
1962 % dig. energy vs. % dig. D.M.	.47
1961+1962 % dig.energy vs. % dig.D.M.	.81**
1961 % TDN vs. % dig. D.M.	.95**
1962 % TDN vs. % dig. D.M.	.54
1961+1962 TDN vs.% dig. D.M.	.94**

[1]By method of Lofgreen - J. Animal Sci. 12: 359, 1953

variations between animal digestion coefficients for a single forage and a small range between minimum and maximum digestion values for the 1962 forages.

Digestible dry matter intake/cwt dry matter nutritive value indices followed a trend similar to that of dry matter intake regardless of dry matter digestibility of that forage (Tables 6,7, 8). This is an indication that intake *per se* was more important than digestibility of the forage. In most cases nutritive value indices ranked the two legumes at the top followed by brome grass and then canary grass. There was a significant ($P < .01$) forage species x year interaction for combined 1961 - 1962 first cutting dry matter nutritive value indices and digestible dry matter intake (Appendix Table XV). Digestible dry matter intake of the second cutting 1962 forages (1.85 lb) was greater than that of second cut 1961 forages (1.67 lb) ($P < .05$). Dry matter nutritive value indices and digestible dry matter intake of combined second cut 1961 and 1962 alfalfa and trefoil were larger than those of second cutting brome grass and canary grass ($P < .01$).

Analysis of variance of dry matter nutritive value indices and digestible dry matter intake indicated significant ($P < .01$) cutting x forage species and forage species x year interactions for the four different forage species when first and second cuttings for both years were combined (Appendix Table XV).

Dry matter nutritive value indices reported in the present study were determined as the product of relative intake and % digestible dry matter. However, nutritive value indices determined from the product of relative intake and % digestible energy were highly correlated to the above values (r = +.98 for both 1961 and 1962 crops and r = +.97 for all forages - Appendix Table XI).

Body weight change in growing animals is generally considered the best estimate of the true nutritive value of a forage being fed. The validity of the last statement may be questioned because of short feeding periods used in this and other experiments of a similar nature. However, this is the approach used by many investigators on this subject. Average daily body weight changes are given for each forage (Tables 6 and 7). The relation between body weight gain and other responses are given in Table 10. Although there were differences in digestibility, dry matter intake and dry matter nutritive value indices there was difficulty in showing significant differences in body weight gains due to the large variations among individuals on the same forage. More numbers and a longer experimental period probably would help overcome the above difficulty. Sheep fed the 1961 trefoil II gained more than animals receiving brome grass II or canary grass II ($P < .01$). Combined 1961 and 1962 weight gains ranked trefoil over the grasses ($P < .05$) and alfalfa over the canary grass ($P < .01$).

Relationships among the several criteria used to evaluate the experimental forages when fed to sheep were studied (Table 10 and Figures 2,3,4 and 5). Correlation coefficients tended

TABLE 10. Simple Correlation Coefficients of Several Criteria Used to Evaluate Forages[1] (Sheep 1961 Crop).

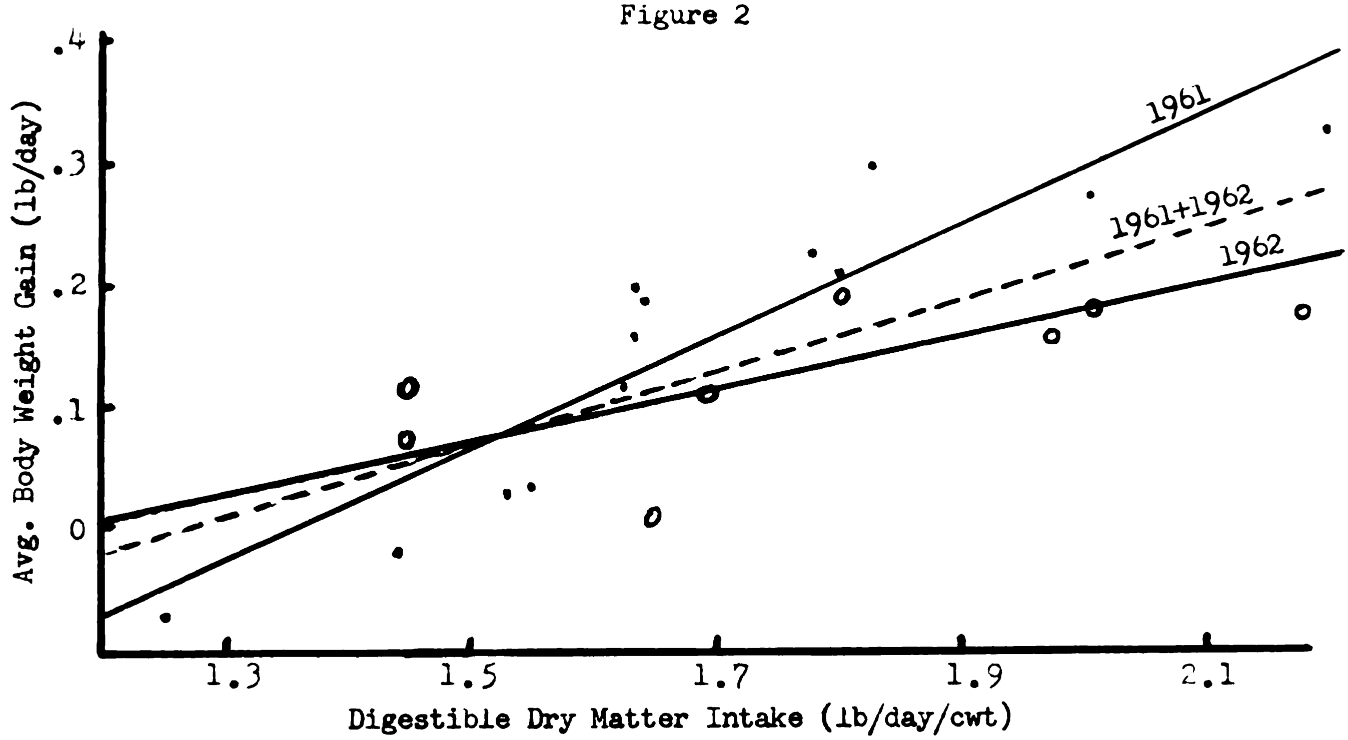
	DMI	DDM%	DDMI	DM NVI	Body Weight Gain
Dry matter intake/cwt (DMI)	-	-.20	.92**	.82**	.52**
% dig. dry matter (DDM%)	-.22	-	.14	.27	.34*
Dig.dry matter intake/cwt (DDMI)	.90**	.22	-	.91**	.63**
DM NVI	.85**	.28	.96**	-	.71**
Body weight gain	.73**	.47	.92**	.93**	-
Dig.energy intake/cwt	.92**	.14	.97**	.95**	.88**
			1962 Crop		
Dry matter intake/cwt	-	.30	.97**	.95**	.11
% dig. dry matter	-.28	-	-.10	-.08	-.90**
Dig.dry matter intake/cwt.	.98**	-.09	-	.98**	.15
DM NVI	.98**	-.11	.99**	-	.20
Body weight gain	.71*	.21	.79*	.73*	-
Dig.energy intake/cwt	.99**	-.19	.98**	.99**	.74*
			Combined 1961-1962 Crop		
Dry matter intake/cwt	-	.17	.94**	.88**	.24*
% dig. dry matter	.15	-	.12	.18	.29**
Dig. dry matter intake/cwt.	.93**	.20	-	.94**	.49**
DM NVI	.92**	.20	.97**	-	.59**
Body weight gain	.66**	.39	.78**	.84**	-
Dig. energy intake/cwt	.94**	.14	.98**	.95**	.72**

[1]The upper right hand portion of each table represents correlation coefficients using data from individual animals while the lower left is correlation coefficients using group averages (four animals/group).

* significant P< .05

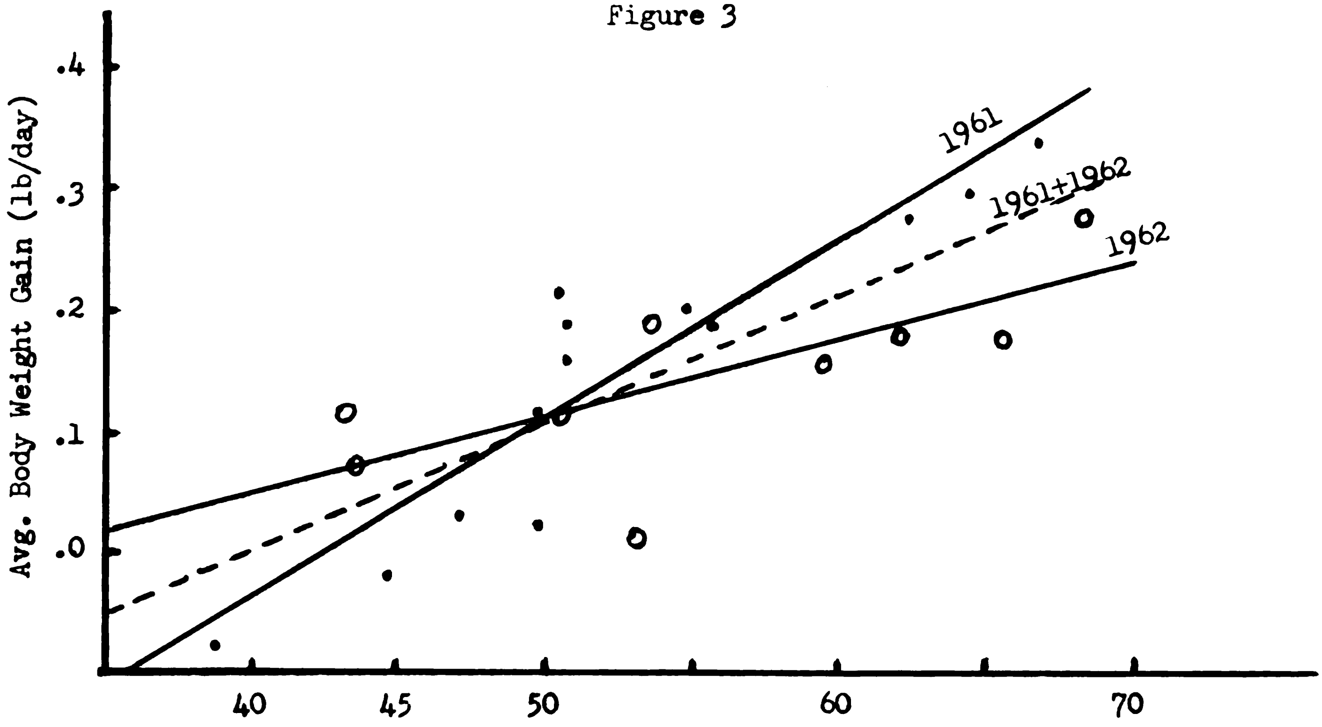
** significant P< .01

Figure 2



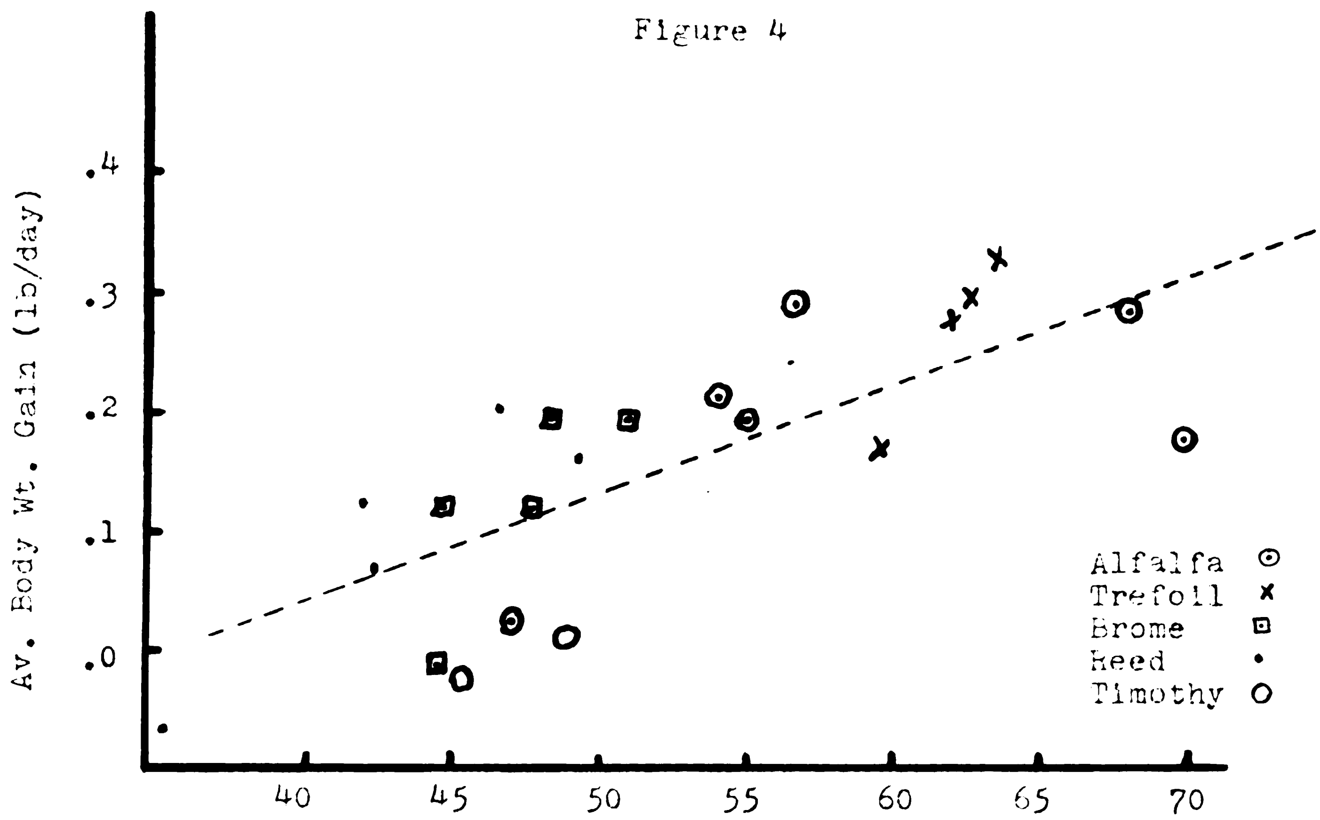
Regression of Gain on Dig. DM Intake
(Each Point Represents Average of 4 Sheep)

Figure 3



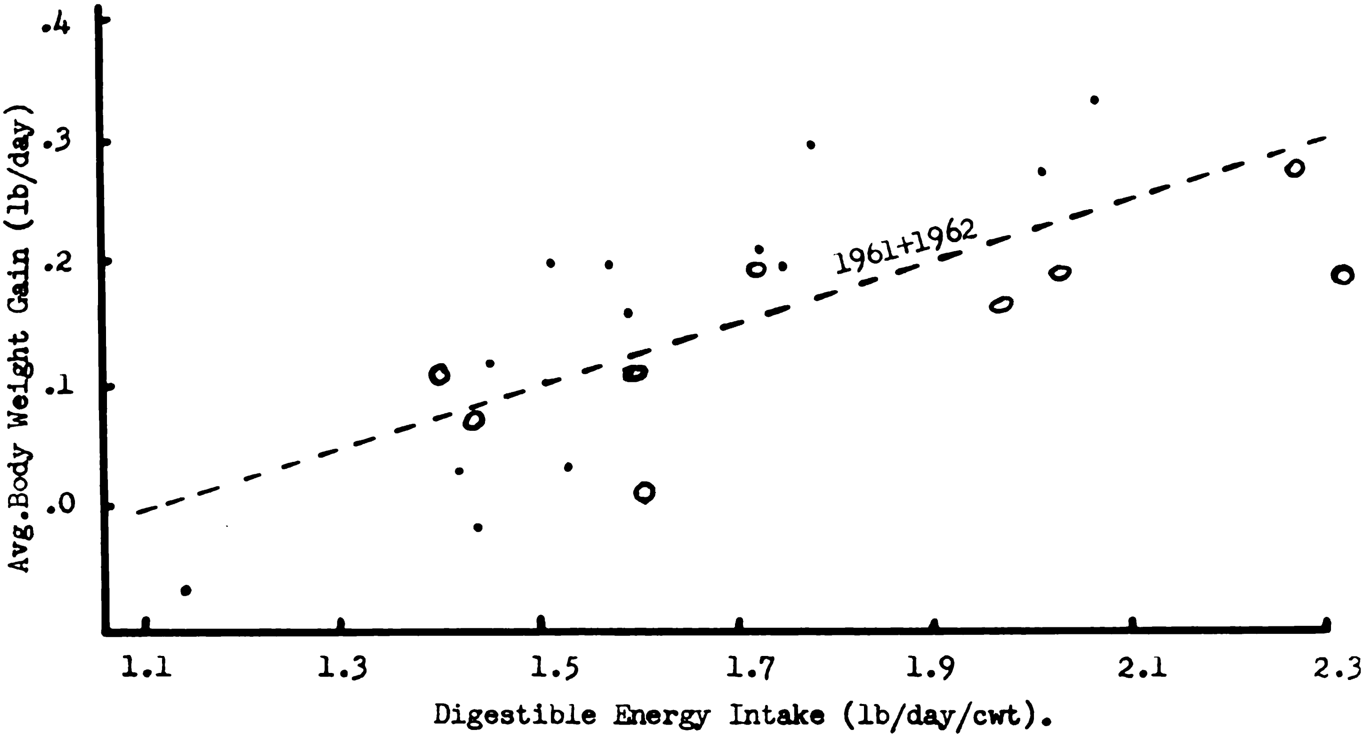
Regression of Gain on DM NVI
(Each Point Represents 4 Sheep)

Figure 4



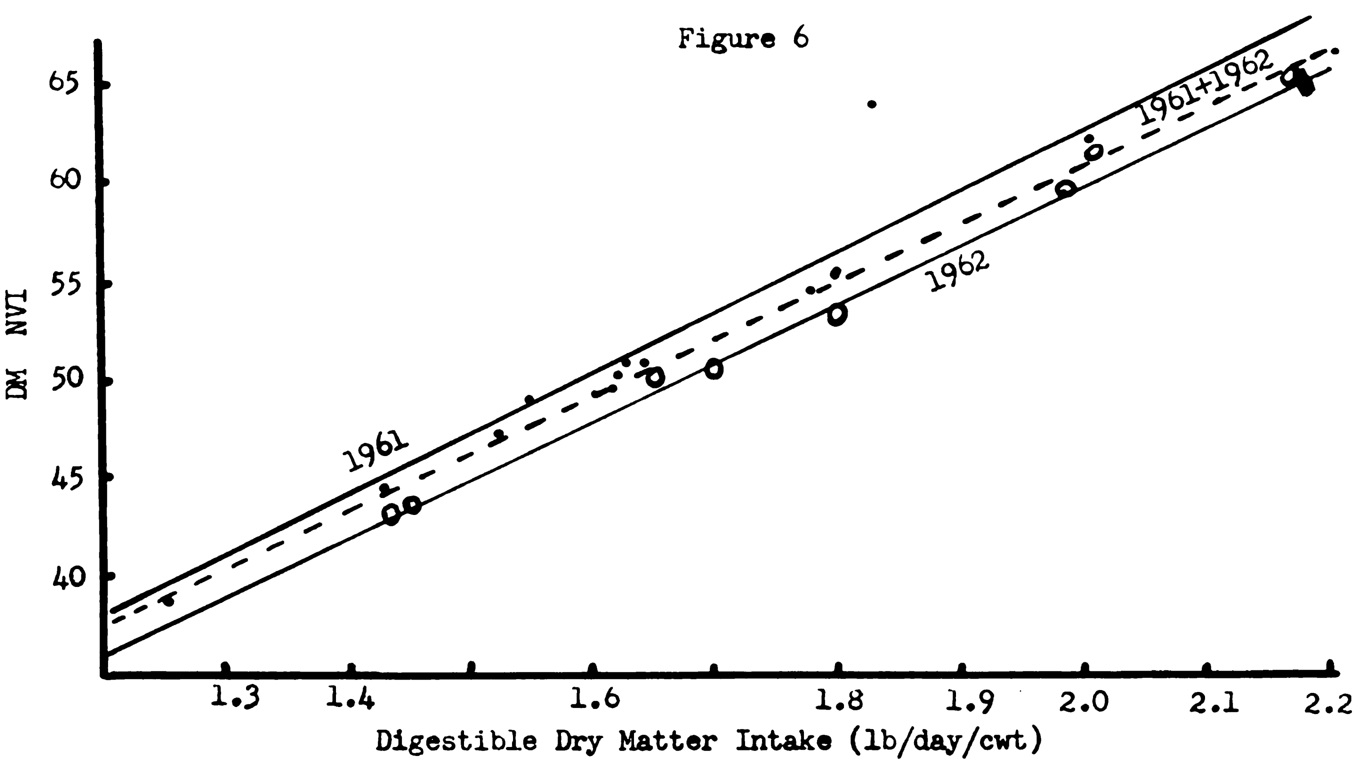
NVI
Regression of Gain on NVI
(Each point represents 4 sheep)

Figure 5



Regression of Gain on Digestible Energy Intake
(Each Point Represents 4 Sheep)

Figure 6



Regression of DM NVI on Dig.DM Intake
(Each Point Represents 4 Sheep)

to be smaller when individual animal values were used rather than when group averages were used. This was especially true of weight gain correlations. Correlations among % digestible dry matter and digestible dry matter intake or dry matter nutritive value indices were small and non-significant. Dry matter intake was, however, highly correlated to digestible dry matter intake (r = +.93). Weight gain was correlated with dry matter intake, digestible dry matter intake and dry matter nutritive value index with correlation coefficients of +.66, +.78 and +.84 respectively.

Regression of body weight gain on digestible dry matter intake, digestible energy intake, DM NVI are shown in Figures 2,3,4 and 5. Regression lines were drawn in Fig.2, and 3 for 1961 forages, 1962 forages and all forages combined. The regression equations, standard error of Y on X and r values for the above relations were calculated and presented in Table 11. These data indicated that there was little difference between digestible dry matter intake/cwt, digestible energy intake/cwt, *in vivo* dry matter nutritive value index and nutritive value index for estimating sheep weight gain when several different forages are fed to sheep with similar average group weights.

Heifer Performance

Forages harvested in 1961, with the exception of brome grass III, were fed to dairy heifers. Dry matter intake was similar for trefoil I, canary grass I and timothy I while the rate of consumption for alfalfa I was slightly greater and that

TABLE 11. Regression Equations for Estimating Live Weight Gains from Dig.DM Intake/cwt., DM NVI and NVI and for Estimating DM NVI from Dig.DM Intake/cwt.

Crop year data	Equation	r	Sy.x
	Body weight gain lb/day (Y) and digestible DM intake/cwt. (X)		
1961	Y = -.646 + .471 X	.92	.05
1962	Y = -.216 + .196 X	.79	.05
1961 & 1962	Y = -.379 + .300 X	.78	.07
	Body weight gain lb/day (Y) and DM NVI (X)		
1961	Y = -.621 + .015 X	.93	.05
1962	Y = -.208 + .006 X	.77	.05
1961 & 1962	Y = -.417 + .011 X	.84	.06
	Body weight gain lb/day (Y) and NVI (X)		
1961 & 1962	Y = -.322 + .009 X	.76	.07
	Body weight gain lb/day (Y) and Dig.Energy Intake (lb/day/cwt)(X)		
1961 & 1962	Y = -.280 + .252 X	.72	.08
	DM NVI (Y) and Dig.DM Intake (X)		
1961	Y = -.176 + 31.337 X	.96	2.38
1962	Y = .485 + 29.671 X	.99	.40
1961 & 1962	Y = 2.386 + 29.309 X	.97	2.11
	DM NVI (Y) and Dig.Energy Intake (lb/day/cwt) (X)		
1961	Y = 4.834 + 29.392 X	.94	2.68
1962	Y = 7.556 + 26.215 X	.99	1.59
1961 & 1962	Y = 9.569 + 26.010 X	.95	2.70

for brome grass I was less. The above differences were not significant ($P > .05$) (Table 12). Dry matter intake of alfalfa II or alfalfa 2 and trefoil II was greater than intake of brome grass II and canary grass II ($P < .01$). Intake of dry matter was related but not significantly ($P > .05$) to % fiber or lignin content of the forages ($r = +.34$ and $+ .45$ respectively). Dry matter nutritive value index, the product of heifer relative intake and sheep dry matter digestion coefficients, follow a trend similar to that of dry matter intake. Weight gains were determined only on heifers that were on trial for 28 days. Weight gains were not apparently related to digestible dry matter intake (lb/day), or dry matter nutritive value index ($r= -.08$). This indicates that number of heifers and/or length of the feeding trial were such that heifer weight gains on the different forages gave an inaccurate estimate of the nutritive value of the forages.

Rabbit Performance

Rabbits were fed the 1961 forages to determine intake, % digestible dry matter, dry matter nutritive value indices and body weight changes. Dry matter consumption ranked the first cutting forages in the order of timothy, brome grass, alfalfa, canary grass and trefoil (Table 12). Dry matter intake of second and third cutting as compared to the first cutting did not follow a definite pattern with respect to forage species. Dry matter intake was not significantly ($P > .05$) correlated to the

TABLE 12. Comparative Forage Consumption (DM) by Three Different Animal Species.

Forage	Sheep lb/cwt	S.E.	Heifers lb/cwt.	S.E.	Rabbits g/Kg.75	S.E.	Sheep g/Kg.75	Heifers g/Kg.75	No Heifers per grp.
Alf.I	3.00	.07	2.64	.37	90.2^{AB}	3.9	74.4	105.7	4
Tre.I	3.28	.13	2.42	.10	77.0^{C}	2.8	88.1	99.6	4
Brome I	2.61	.12	2.27	.07	91.5^{ABa}	7.3	64.3	89.1	2
Reed I	2.51	.23	2.43	.11	81.4^{BCb}	3.9	62.3	99.0	4
Tim.I	2.43	.09	2.47	.03	98.8^{A}	3.5	61.4	101.7	4
Alf.II	3.20	.20	2.79	.07	80.7^{ABa}	5.8	78.7	111.2^{A}	3
Tre.II	3.63	.08	2.68	.07	85.0^{A}	4.6	89.0	105.9^{A}	3
Brome II	2.61	.13	1.67	.02	70.2^{Bb}	3.9	64.3	59.0^{B}	3
Reed II	2.26	.10	1.80	.18	83.3^{A}	4.0	55.6	73.1^{B}	2
Alf.2	2.77	.24	2.66	.12	87.5^{A}	4.4			3
Alf.III	2.71	.14	2.62	.11	93.0^{A}	5.7	66.8	107.3^{a}	4
Tre.III	2.95	.08	2.60	.14	79.2^{BCa}	3.6	80.3	101.5^{a}	3
Brome III	2.54	.18	-	-	85.3^{AB}	4.8	62.5	-	
Reed III	2.40	.21	1.96	.42	68.9^{Cb}	4.4	58.7	75.7^{b}	3
<u>Avg.</u>									
Alf.					87.8		73.3	106.8	
Tre.					80.4		83.5	102.0	
Brome					82.3		63.7	71.0	
Reed					77.8		58.9	85.5	
Avg.	2.8^{A}		2.38^{B}		83.6^{Ab}		70.3^{Bc}	94.8^{Aa}	

continued

TABLE 12. CONTINUED.

Simple Correlations

	r
Rabbit intake g/Kg.^{75} vs. sheep intake g/Kg.^{75}	- .08
Rabbit intake g/Kg.^{75} vs. heifers intake g/Kg.^{75}	.57*
Sheep intake g/Kg.^{75} vs. heifers intake g/Kg.^{75}	.57*

* Significant ($P < .05$)

Values with like superscripts represent a homogenous group, (Large superscript $P < .01$ and small subscript $P < .05$).
S.E. = Std. Error.

forage content of fiber or lignin (r = +.26 and +.01 respectively). Dry matter digestion coefficients for legumes were higher than those for grasses ($P < .01$) with the exception of reed II which was contaminated with corn (Table 13). Dry matter nutritive value indices, % digestible dry matter and digestible dry matter intake were correlated to weight gain ($P < .01$ - r = +.85). Weight gain by rabbits on the same forage varied a great deal (Appendix Table XIX). For example weight gain of rabbits receiving timothy ranged from 58 to 271 g. Alfalfa and trefoil resulted in greater weight gains than timothy, brome grass or canary grass ($P<.01$, Table 17). Weight gains during the first week on trial were less than gains during the second and third week ($P < .05$). This might indicate that it took the rabbit's digestive system at least a couple of weeks to become adjusted to an all forage ration.

Comparisons of Responses to Various Forages by Growing Rabbits, Sheep and Dairy Heifers.

Forage dry matter intake by the three animal species was compared (Table 12). Heifers consumed about the same amount of all first cutting forages (2.3, to 2.6 lb) in contrast to distinct differences for sheep (2.4 to 3.3 lb). There was a low but significant correlation ($P < .05$) between sheep vs. heifer and rabbit vs. heifer dry matter intakes. However, rabbit vs. sheep dry matter intakes were not significantly correlated ($P > .05$). Based on intake/cwt, sheep consumed more

TABLE 13. Dry Matter Digestion Coefficients for Pure Stand Forages by Sheep and Rabbits.

Forage	% Dig. DM			
	Sheep %	S.E.	Rabbits %	S.E.
Alf.I.	60.0	.7	46.2^{A}	1.8
Tre.I	61.5	.7	46.5^{A}	1.2
Brome I	61.9	.7	38.2^{B}	.6
Reed I	65.1	.4	38.7^{B}	.3
Tim.I	63.8	1.1	39.8^{B}	4.2
Alf.II	55.8	1.8	45.3^{A}	1.3
Tre.II	60.0	.7	43.5^{A}	.8
Brome II[1]	55.1	.7	33.8^{B}	3.2
Reed II[1]	55.6	.9	45.2^{A}	2.8
Alf.2	65.1	1.1	47.1^{A}	1.3
Alf.III	56.6	1.4	40.7^{B}	1.9
Tre.III	64.1	.8	54.1^{A}	1.5
Brome III	64.7	1.0	40.2^{B}	1.2
Reed III	68.6	.5	37.8^{B}	3.3
Avg.by Specie.				
Alf.	59.4		44.8	
Tre.	61.9		48.0	
Brome	60.6		37.4	
Reed	63.1		40.6	
Average	61.3^{A}		42.6^{B}	
Average of grass	62.1		39.1*	
Average of legume	59.7		46.0*	

Simple Correlations

	r
Sheep Dig. DM vs. Rabbit Dig. DM (all forages)	+ .10
Sheep Dig. DM vs. Rabbit Dig. DM (Legumes)	+ .69
Sheep Dig. DM vs. Rabbit Dig. DM (grasses)	+ .31

* The two values different, $P < 0.01$
Values with the same large superscript represent a homogenous group ($P < .01$).

[1]This sample was contaminated with corn when preparing the forage in pellet form for rabbits.

TABLE 14. Relative DM Intake of Pure Stand Forages by Three Animal Species.[1]

	1961 Crop		
Forage	Sheep	Rabbits	Heifers
Alf. I	93.0	112.6	132.1
Tre.I	101.3	96.2	124.3
Brome I	80.4	114.3	111.3
Reed I	77.9	101.7	123.7
Tim.I.	76.7	123.5	127.0
Alf.II	98.3	100.8	138.9
Tre.II	111.3	106.3	132.3
Brome II	80.6	87.6	73.7
Reed II	69.6	104.1	91.4
Alf. 2	86.8	109.4	129.0
Alf.III	83.4	116.2	134.2
Tre.III	100.4	98.9	126.8
Brome III	78.2	106.5	-
Reed III	73.3	86.2	94.6
Avg.			
Alf.	90.4	109.8	133.6
Tre.	104.3	100.5	127.8
Brome	79.7	102.8	92.5
Reed	73.6	97.3	103.2
Average	87.1[B]	104.4[Ab]	118.4[Aa]

[1]Relative intake = $100 \cdot \frac{(\text{g daily forage DM intake})}{80 \ (\text{wt. Kg.}^{.75})}$

Simple correlation coefficients

	r
Relative intake, sheep vs. heifers	.59*
Relative intake, rabbits vs. heifers	.57*
Relative intake, rabbits vs. sheep	-.01

* Significant ($P < .05$).

TABLE 15. Digestible DM Intake of Pure Stand Forages by Three Animal Species.

Forage	Sheep g/Kg.75	1961 Crop Rabbits g/Kg.75	Heifers g/Kg.75
Alf. I	44.6	41.7	63.4
Tre.I	54.2	35.8	61.3
Brome I	39.8	35.0	55.2
Reed I	40.6	31.5	64.4
Timothy I	39.2	39.3	64.9
Alf.II	43.9	36.6	62.0
Tre.II	53.4	37.0	63.5
Brome II	35.4	23.7	32.5
Reed II	30.9	37.7	40.6
Alf.2	45.2	41.2	67.2
Alf.III	37.8	37.9	60.7
Tre.III	51.5	42.8	65.1
Brome III	40.4	34.3	-
Reed III	40.3	26.0	51.9
Avg.			
Alf.	42.9	39.4	63.3
Tre.	53.0	38.5	63.3
Brome	38.5	31.0	43.8
Reed	37.3	31.7	52.3
Avg.[1]	42.66^{Ba}	35.75^{Bb}	57.90^{A}

Simple Correlation Coefficients

	r
Digestible DM Intake, sheep vs. heifers	.64*
Digestible DM Intake, rabbits vs. heifers	.67*
Digestible DM Intake, rabbits vs. sheep	.38

[1]Does not include Brome III.

TABLE 16. DM NVI Values[1] for Pure Stand Forages by Three Animal Species

Forage	Sheep	Std. error	Heifers	Std. error	Rabbits	Std. error
Alf.I	55.8	2.0	79.3	3.0	51.9[Aa]	2.1
Tre.I	62.3	2.2	76.5	5.8	44.7[ABb]	1.9
Brome I	49.7	1.3	68.9	1.9	43.7[ABb]	3.5
Reed I	50.8	4.7	80.5	1.3	39.4[B]	1.9
Tim.I	49.0	2.2	81.0	3.4	48.9[A]	4.8
Alf.II	54.7	5.2	77.5	3.8	45.3[A]	2.4
Tre.II	66.7	1.8	79.4	3.3	46.3[A]	2.8
Brome II	44.4	2.4	40.6	4.7	29.5[B]	2.8
Reed II	38.7	2.6	50.7	3.2	47.2[A]	3.7
Alf.2	56.7	5.4	84.0	1.3	50.5[A]	2.2
Alf.III	47.1	1.5	75.9	4.5	47.2[AB]	3.2
Tre.III	64.3	3.1	81.3	7.8	53.5[A]	2.9
Brome III	50.7	4.3	-	-	43.0[B]	3.4
Reed III	50.3	4.4	64.9	12.2	32.8[C]	3.8
Avg.						
Alf.	52.5		79.0		48.6	
Tre.	64.5		78.8		48.2	
Brome	48.3		51.9		38.7	
Reed	46.6		68.7		36.1	
Avg.	53.1[Ba]		72.3[A]		44.7[Bb]	

<u>Simple Correlations</u>

		r
Sheep DM NVI vs. heifer DM NVI	+	.67**
Rabbits DM NVI vs. sheep DM NVI	+	.41
Rabbits DM NVI vs. heifer DM NVI	+	.66**

[1] $\text{DM NVI} = 100 \times \frac{(\text{g daily forage DM intake})}{80 \quad (\text{Wt.Kg}^{.75})} \times \%\ \text{dig.DM}$

[2] Values with like superscripts represent a homogenous group (large superscripts $P < .01$ and small superscripts $P < .05$).

** Significant ($P < .01$).

TABLE 17. Weight Gain of Sheep, Heifers and Rabbits Fed Pure Stand Forages.

	1961 Crop		
Forage	Sheep lb/day	Heifers lb/day	Rabbits g/day
Alf.I	.19	1.93	13.5[Aa]
Tre.I	.27	1.71	12.3[A]
Brome I	.12	2.07	2.6[B]
Reed I	.16	2.38	5.2[B]
Tim.I	.13	2.38	7.1[ABb]
Alf.II	.21	1.76	9.8[A]
Tre.II	.34	1.87	13.3[A]
Brome II	-.20	-	- 4.7[B]
Reed II	-.08	2.04	12.3[A]
Alf.2	.29	1.68	12.8[1]
Alf.III	.03	1.66	10.3[A]
Tre.III	.30	-	13.0[A]
Brome III	.19	-	3.0[AB]
Reed III	.20	-	3.6[B]

Simple Correlation

	r
Sheep wt. gain vs. Rabbit wt. gain	.23
Sheep wt. gain vs. Heifer wt. gain	.29
Rabbit wt. gain vs. Heifer wt. gain	- .67*

dry matter than heifers ($P < .01$). However, dry matter intake per unit of metabolic size ($Wt._{Kg.}{}^{.75}$) shows a different relationship (Table 12). The average intake per $Wt._{Kg.}{}^{.75}$ of all forages by heifers was 94.8 g which was greater than 83.6 g from rabbits and greater than 70.3 g for sheep ($P < .01$). Relative dry matter intake of pure stand forages were compared for three different animal species (Table 14) and were similar to those found with actual dry matter intakes. Average relative intake of the forages was 118 for heifers, 104 for rabbits and 87 for sheep. The same formula was used to calculate relative intake by the three animal species. Heifers consumed more digestible dry matter per $Wt._{Kg.}^{.75}$ than did sheep or rabbits ($P < .01$) (Table 15). Dry matter digestion coefficients for 1961 experimental forages as determined by sheep and rabbits were compared (Table 13). Digestible dry matter coefficients by rabbits ranked the legumes above the grasses ($P < .01$) whereas sheep tended to give larger dry matter digestion coefficients for the grasses. The latter difference was not significant ($P > .05$). Forage consumed by sheep had larger dry matter digestion coefficients than the same forages fed to rabbits ($P < .01$). The correlation between rabbit and sheep digestion coefficients was not significant ($P > .05$). Considering the seven legume forages alone, the correlation between digestion coefficients for sheep and rabbits approached significance ($r = +.69$).

Dry matter nutritive value indices (DM NVI) as determined by sheep, heifers and rabbits were calculated for the different forages (Table 16). Sheep vs. heifer or rabbit vs. heifer DM NVI were significantly correlated ($P < .01$). In contrast rabbit and sheep DM NVI were not found to be significantly correlated ($P > .05$). Sheep DM NVI for first cutting forages ranked trefoil first followed by alfalfa and then the three grasses. Heifer DM NVI ranked timothy, canary grass and alfalfa the top followed by trefoil and then brome grass. Rabbit DM NVI ranked alfalfa and timothy at the top followed by trefoil and brome grass with canary grass last. Thus there did not seem to be a consistent ranking of the forage species by the different animal species.

However, significant positive correlation coefficients indicated some relationship between DM NVI as determined by sheep, rabbits and heifers (Table 16).

Sheep weight gains did not appear to be related to rabbit or heifer weight changes (Table 17). Rabbit and heifer weight gains tended to be negatively correlated (Table 17). Sheep and rabbit weight gains were significantly ($P < .05$) correlated to digestible dry matter intake and dry matter nutritive value indices (DM NVI) (Table 18). Sheep dry matter intake appeared to have more effect on weight gains than % digestible dry matter. The reverse was found with rabbits. Heifer weight gains were not related to DM NVI or digestible dry matter intake/cwt. This would indicate heifer weight gains were inaccurate even though obtained over two 2-week periods following a 10 day pretrial on that forage.

In Vitro Fermentation Trials

Experimental forages were incubated with rumen fluid to determine *in vitro* dry matter disappearance and its relationship with animal performance. *In vitro* dry matter disappearance values for 1961 and 1962 forages are an average of four replicates (Appendix Table XXIII). Analysis of variance was used to analyze *in vitro* dry matter disappearance as affected by forage species, fermentation time and forage cutting (Appendix

TABLE 18. Simple Correlations Among Several Criteria Used to Evaluate Nutritive Value of Forages by Three Animal Species (1961 Forages)

	Sheep			Heifers			Rabbits		
	Gain	NVI	DM intake	Gain	NVI	DM intake	Gain	NVI	DM intake
NVI	.93**			-.08			.85**		
% Dig. DM	.47	.28	-.22	.42	.48	.13	.85**	.80**	.10
Dig.DM intake	.92**			-.08			.85**		
DM intake	.73**			.34			.36		

** Significant ($P < .01$)

Table XXIV). Cutting and fermentation time significantly ($P < .05$, and $P < .01$ respectively) affected *in vitro* dry matter disappearance of the 1961 forages. Forage species and fermentation time were found to affect *in vitro* dry matter disappearance ($P < .01$) for the 1962 forages. Forage species and fermentation time interactions were significant ($P < .01$) for both crops. This would indicate that rate of dry matter disappearance for all forages with time was not the same. Different rates of dry matter disappearance are evident in Figures 7 and 8. Dry matter disappearance after three hours of fermentation was greater for the legumes than for the grasses with the exception of alfalfa III (Figs. 7, 8 and Appendix Table XXIII). However, dry matter disappearance after 48 hours was greater for the grasses with the exception of first cutting alfalfa. Three or six hour fermentation values ranked the forages differently than the 36 or 48 hour fermentation values. The correlation coefficient between 6 hour and 36 hour fermentation values was not significant ($r = + 0.34$; $P > .05$). The forage species and cutting interaction terms were significant ($P < .01$) for both crops (Appendix Table XXIV). This indicates that total *in vitro* dry matter disappearance of different forage species did not all change the same with first, second and third cuttings.

Simple correlation coefficients between sheep performance and *in vitro* dry matter disappearance were calculated for 1961 forages, 1962 forages and all forages (Table 19). Dry matter intake, digestible energy intake, *in vivo* dry matter nutritive value

TABLE 19. Simple Correlations Between *In Vitro* Fermentation DM Disappearance and Sheep Performance Data.

	3 hr.	6 hr.	12 hr.	18 hr.	24 hr.	36 hr.	48 hr.	6 x 36 hr.	Soly. CHO [2]	3 hr. sol. material [3]
1961 Crop										
Daily DM intake/cwt.	.48	.54	.47	.08	.22	-.11	-.09	.32	-.18	.66
% *In vivo* DM dig.	.41	.50	.37	.43	.59	.70	.61	.69	-.32	.14
Dig. DM intake/cwt.	.64	.76	.63	.28	.50	.22	.01	.64	-.25	.72
In vivo DM NVI	.76	.85	.84	.33	.55	.26	.20	.72	-.26	.72
Weight gain	.85	.88	.67	.28	.50	.29	.27	.75	-.20	.56
Dig.energy intake/cwt	.78	.86	.63	.22	.46	.10	.08	.66	-	-
Daily DM intake/cwt.[1]	.33	.60	.50	.18	.32	-.09	-.01	-	-	-
% *In vivo* dig. DM[1]	.45	.37	.31	.28	.51	.68	.60	-	-	-
In vivo DM NVI[1]	.67	.86	.76	.38	.66	.28	.33	-	-	-
1962 Crop										
Daily DM intake/cwt.	.92	.94	.90	.81	.65	.00	-.44	.82	-.57	.21
% *In vivo* DM dig.	-.13	-.15	-.23	-.24	.13	.66	.62	.10	.02	.63
Dig. DM intake/cwt.	.92	.95	.89	.80	.70	.14	-.31	.97	-.53	.48
Daily DM intake/cwt.[1]	.91	.93	.89	.78	.65	-.02	-.46	-	-	-
In vivo DM NVI	.93	.95	.91	.82	.72	.15	-.31	.89	-.56	.65
Weight gain	.68	.67	.56	.41	.36	.08	-.32	.64	-.62	.62
Dig. energy intake/cwt.	.93	.94	.89	.81	.64	.04	-.39	.84	-	-

continued

TABLE 19 CONTINUED

	3 hr.	6 hr.	12 hr.	18 hr.	24 hr.	36 hr.	48 hr.	6 x 36 hr.	Soly. CHO[2]	3 hr. sol. material[3]
					Combined 1961-1962 Crop					
Daily DM intake/cwt.	.68	.74	.68	.45	.37	.00	-.05	.56	-.28	.41
% *In vivo* DM dig.	.35	.34	.23	.30	.58	.72	.64	.57	.07	.58
Dig.DM intake/cwt.	.79	.85	.76	.57	.59	.27	.19	.77	-.23	.60
In vivo DM NVI	.81	.89	.82	.56	.56	.25	.11	.78	-.32	.66
Weight gain	.70	.75	.59	.28	.38	.21	.09	.64	-.37	.48
Dig.energy intake/cwt.	.86	.90	.76	.56	.55	.18	.13	.76	-	-

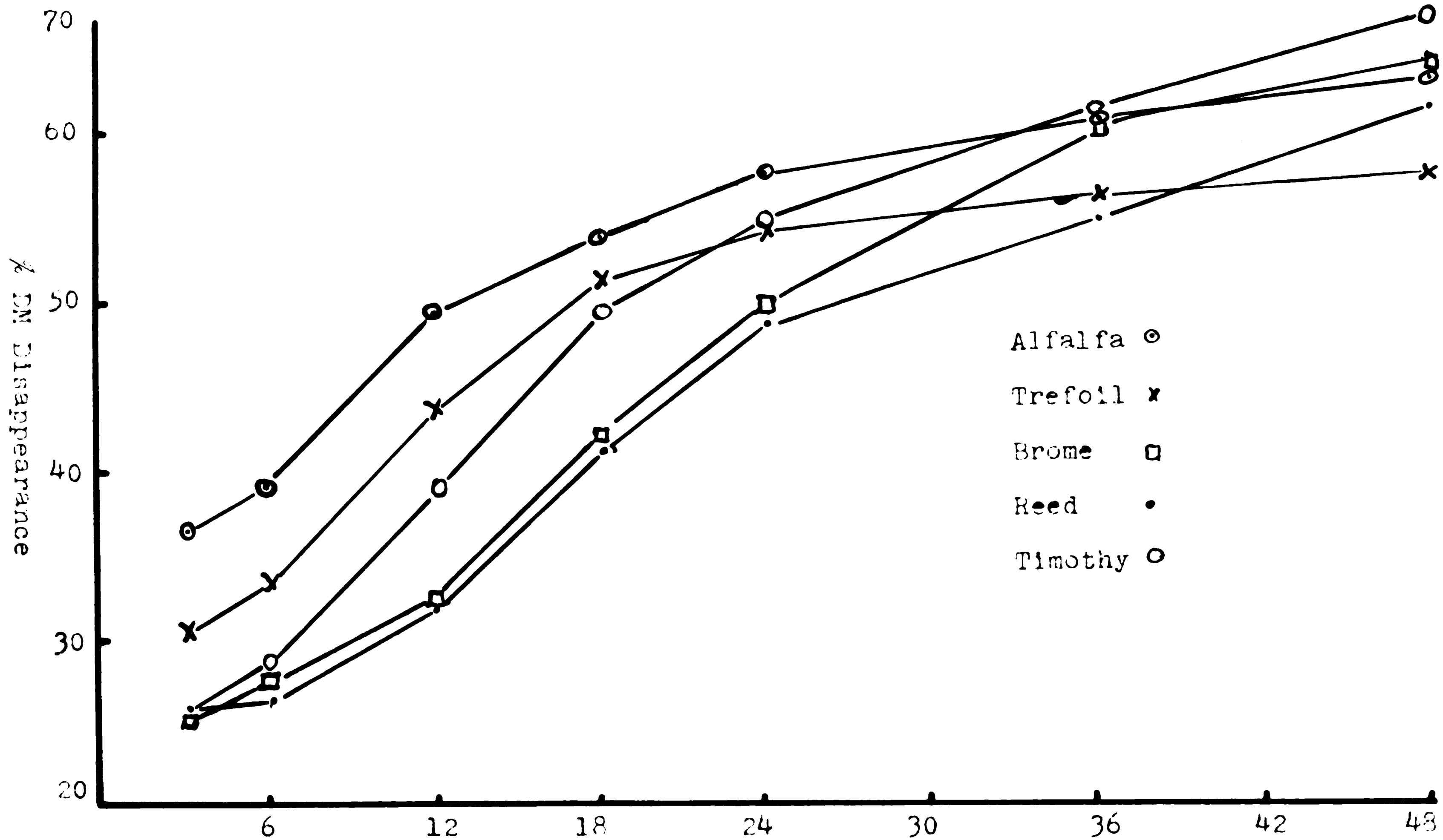
[1]Corrected for day to day variation using an alfalfa standard hay.

[2]Soluble carbohydrates in filtrate of Van Soest fiber determination.

[3]Procedure same as 3 hour fermentation except that buffer was substituted for rumen inoculum.

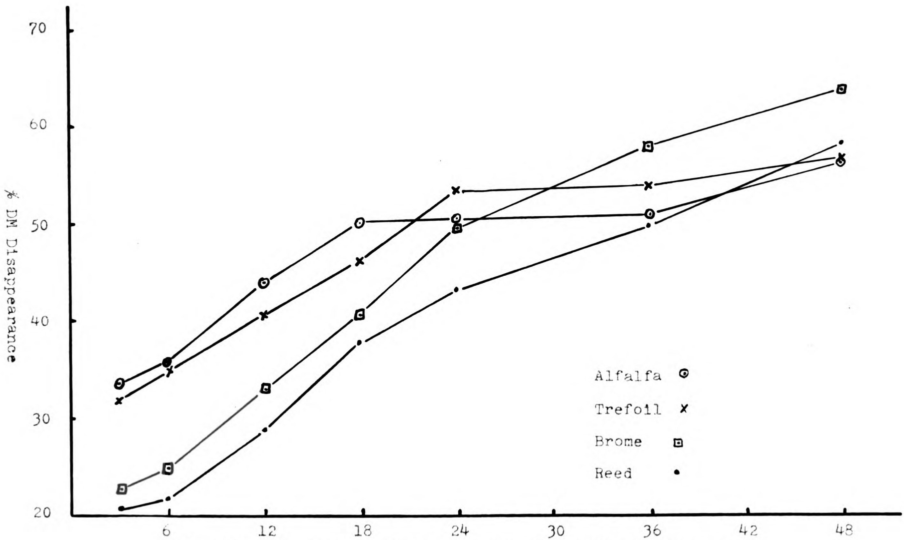
1% P for r 1962 = .80; 1961 = .66; 1961 + 1962 = .53

Figure 7



In vitro DM Disappearance of 1962 First Cutting Forage

Figure 8



In vitro DM Disappearance of 1962 Second Cutting Forages indices and body weight gains were all significantly correlated with 6 hour *in vitro* dry matter disappearance ($P < .01$).

The correlation coefficient of animal performance and 6 hour dry matter disappearance was higher for 1962 forages than 1961 forages. This difference may be due to larger variations between replicate dry matter disappearance for the 1961 forages. Dry matter disappearance standard deviation, standard error and % coefficient of variation for 1961 forages were 4.42, 2.21, 11.18% and for the 1962 forages, 2.27, 1.14, and 5.13% respectively (Appendix Table XXIV).

Daily intake/cwt and other *in vivo* criteria of intake were more highly correlated with 6 hour fermentation values than with other fermentation intervals. Correlation coefficients between *in vivo* % dig. DM and *in vitro* DM disappearance were largest for the 36 hour fermentation values. The product of 6 hour x 36 hour dry matter disappearance divided by 100 was termed *in vitro* dry matter nutritive value index. Combining the two time values, one highly related to intake and the other to digestibility into one term, might result in a higher correlation with comparable *in vitro* measurements. However, six hour dry matter disappearance values resulted in larger r values when correlated to animal performance than did *in vitro* nutritive value indices and also resulted in regression equations with smaller standard errors of estimate (Table 20).

Regression equations with their standard errors of Y on X were calculated for predicting animal performance from *in*

TABLE 20. Regression of Forage Intake, Digestibility and *In Vivo* NVI on *In Vitro* DM Disappearance. (1961 and 1962 Forages).

		r	Sy.X
1.	*In vivo* DM NVI (Y) vs. 6 hr *in vitro* DM disappearance. (X) Y = 13.2 + 1.395 X	.89	3.77
2.	*In vivo* NVI (Y) vs. 6 hr DM disappearance (X) 7.032 + 1.55 X	.90	4.04
3.	*In vivo* DM NVI (Y) vs. (*in vitro* NVI) (X) Y = 26.6 + .017 X	.78	5.24
4.	*In vivo* DM NVI (Y) vs. 6 hr DM disappearance due to inoculum (X) Y = 43.203 + 1.926 X	.77	5.33
5.	Digestible DM intake/cwt (Y) vs.6 hr *in vitro* DM disappearance (X) Y = .462 + .044 X	.85	.15
6.	Digestible Energy Intake/cwt (Y) vs. 6 hr *in vitro* DM disappearance (X) Y = .220 + .051 X	.90	.14
7.	DM Intake/cwt (Y) vs. 6 hr *in vitro* DM disappearance (X) Y = 1.020 + .062 X	.77	.30
8.	DM Intake/cwt (Y) vs. 6 hr DM disappearance due to inoculum (X) Y = 2.253 + .1036 X	.79	.27
9.	% Digestible DM (Y) vs. 36 hr *in vitro* DM disappearance (X) Y = 38.90 + .435 X	.72	2.56
10.	Wt. gain lb/day (Y) vs. 6 hr *in vitro* DM disappearance (X) Y = .292 + .015 X	.75	.07

vitro dry matter disappearance data (Table 20).

Daily intake of dry matter, digestible energy and digestible dry matter were predicted from *in vitro* dry matter disappearance values with standard errors of .30, .14 and .15 lb respectively (lines 5,6 and 7, Table 20). The standard error for actual dry matter intake/cwt of an individual forage by four sheep ranged from .07 to .24 lbs while the standard error for observed daily digestible dry matter intake/cwt ranged from .02 to .17 lb.

The standard errors of estimate for weight gain based on 6 hour fermentation values, *in vivo* dry matter nutritive value index, *in vivo* dry matter intake or *in vivo* digestible energy intake were .07, .06, .07, and .08 lb respectively. Thus it was possible to use *in vitro* fermentation data with some degree of accuracy to predict intake of energy, intake of dry matter, dry matter nutritive value indices and resulting body weight gain. The standard errors are, however, large enough so that this *in vitro* method would not detect small differences in nitritive value of forages.

Soluble carbohydrates and three hour buffer-soluble material were compared to animal performance data. Correlation coefficients for soluble carbohydrates and animal performance data (Table 19) were negative but not significant ($P > .05$). Three hour buffer soluble dry matter was significantly correlated to *in vivo* dry matter digestibility, digestible dry matter intake/cwt. and *in vivo* dry matter nutritive value index ($P < .01$) but the correlation coefficients between sheep performance and in vitro dry matter disappearance were larger in all cases.

Duplicate samples of a standard alfalfa* were fermented for each time interval with each fermentation trial (with each days trial) to make possible a correction for day to day variation (Appendix Table XXV). Corrected in vitro dry matter disappearance values did not increase the correlation coefficients between in vitro dry matter disappearance and sheep performance (Table 19). The coefficient of variation for 1962 corrected fermentation values was 5.95% as opposed to 5.13% for the non-corrected values.

Duplicate dry matter disappearance values for standard alfalfa hay were obtained on 6 different days with seven different fermentation periods for each day. Three missing values were determined according to Snedecor (233). Day to day coefficients of variation for 6 and 36 hour fermentation values were 7.06% and 4.41% respectively. However, if values for one day, which are nearly two standard deviations from the mean, are eliminated, the coefficient of variation drops to 1.68% and 3.53% for 6 and 36 hr dry matter disappearance values respectively. Coefficient of variation between duplicates was .55% and 3.09% for 6 and 36 hour fermentation values respect-

* Standard alfalfa hay from Kansas used in cooperative in vivo and in vitro experiments by several universities.

ively.

Several variations in the <u>in vitro</u> method were studied. Dry matter disappearance of forage substrate after three hours of fermentation with and without rumen inoculum was compared (Table 21, and Appendix Table XXII). Increased dry matter disappearance due to the action of rumen inoculum was larger for legumes than grasses ($P < .01$).

TABLE 21. DM Disappearance When Buffer was Substituted for Rumen Inoculum and Incubated for 3 Hours.

Forage	Crop	1961 Crop Buffer only %	1961 Crop Rumen inoculum %	1962 Crop Buffer only %	1962 Crop Rumen inoculum %
Alfalfa	I	28.4	29.2	29.6	36.5
B. Trefoil	I	23.8	28.4	26.3	30.5
Brome	I	21.6	20.9	24.6	25.5
R. Canary	I	24.9	26.4	26.2	26.1
Timothy	I	22.0	20.0	24.4	26.0
Alfalfa	II	21.8	29.0	26.6	33.7
B. Trefoil	II	22.6	25.0	24.8	32.0
Brome	II	16.8	15.2	22.2	23.1
R. Canary	II	17.9	13.9	20.8	20.8
Alfalfa	2	27.0	30.1	-	-
Alfalfa	III	17.8	23.0	-	-
B. Trefoil	III	26.0	28.2	-	-
Brome	III	22.6	24.5	-	-
R. Canary	III	23.2	24.0	-	-

The negative values obtained with the 1961 (Table 21) forages may be due to variations in residual rumen inoculum added to the flasks. The change in 3 or 6 hour dry matter disappearance due to added rumen inoculum for all forages was correlated with intake (r = + .79, P < .01, Table 22).

TABLE 22. Simple Correlations Between DM Disappearance Due to Rumen Inoculum and *In Vivo* DM Intake, DM NVI and Weight Gain.

	r
1961	
DM intake vs. 3 hr DM disappearance due to rumen inoculum	.63*
DM intake vs. 6 hr DM disappearance due to rumen inoculum	.65*
DM intake vs. 12 DM disappearance due to rumen inoculum	.53
DM NVI vs. 6 hr DM disappearance due to inoculum	.64
Weight gain vs. 6 hr DM disappearance due to inoculum	.58
1962	
DM intake vs. 3 hr disappearance due to rumen inoculum	.97**
DM intake vs. 6 hr disappearance due to rumen incoulum	.97**
DM intake vs. 12 hr disappearance due to rumen inoculum	.89**
DM NVI vs. 6 hr DM disappearance due to rumen inoculum	.63
Weight gain vs. 6 hr DM disappearance due to rumen inoculum	.94
1961 plus 1962	
DM intake vs. 3 hr DM disappearance due to rumen inoculum	.79**
DM intake vs. 6 hr DM disappearance due to rumen inoculum	.79**
DM intake vs. 12 hr DM disappearance due to rumen inoculum	.70**
DM NVI vs. 6 hr DM disappearance due to rumen inoculum	.77
Weight gain vs 6 hr DM disappearance due to rumen inoculum	.56

If only 1962 forages are considered the correlation coefficient between dry matter intake/cwt and 3 hour or 6 hour dry matter disappearance due to rumen inoculum or microbial degradation was + .97. All the correlation coefficients between dry matter intake and dry matter disappearance due to rumen inoculum (Table 22) were larger than those determined for total *in vitro* dry matter disappearance (Table 19). Dry matter nutritive value index and weight gain correlation coefficients were larger when total *in vitro* dry matter disappearance was used rather than dry matter disappearance due to rumen inoculum with the exception of weight gain for the 1962 forages. If these differences in rate of digestion are found *in vivo* and rumen fill does affect intake then early rate of degradation may have a large affect on *ad lib* consumption of any all roughage ration.

Brome grass II (1962 crop) was incubated at all time intervals with and without rumen inoculum (Table 23). After 3 hours of incubation with buffer 23.4% of the dry matter was filterable and this increased up to 28.8% after 48 hours of incubation compared to 63.7% for fermentation with added rumen inoculum.

TABLE 23. DM Disappearance (%) When Buffer was Substituted for Rumen Inoculum and Incubated for Various Times Using Brome II - 1962 Crop.

	Time Hour (Single Observations)						
	3	6	12	18	24	36	48
Buffer only	23.4	25.0	25.5	26.1	26.8	27.8	28.8
Rumen inoculum	23.1	25.1	33.2	40.8	49.9	57.9	63.7

Sulka flock was added to the *in vitro* fermentation flasks as the only substrate on two different days (Table 24). Digestion of sulka flock started after about 12 hours of fermentation. It is difficult to explain the long "lag" period for dry matter diaappearance with a sulka flock substrate.

TABLE 24. DM Disappearance (%) When Sulka Flock was Used as Substrate in Usual Procedure.

	Time Hour (Single Observations)						
	3	6	12	18	24	36	48
Day 1	0	0	1.5	14.1	29.4	43.2	54.5
Day 2	0	0	0	6.7	25.8	42.8	39.8

In vitro dry matter disappearance using different volumes of settled and nonsettled rumen fluid were studied (Table 25). Ten or 60 ml of settled rumen fluid resulted in disappearance of similar amounts of dry matter after 24 hours of fermentation and there was only slightly less dry matter disappearance with 10 ml of rumen fluid after six hours of fermentation. A similar relationship was found between 10, 24, and 60 ml of nonsettled rumen fluid. Using 10 or 60 ml of settled rumen inoculum resulted in slightly less dry matter disappearance than equal amounts of nonsettled inoculum. After six hours of fermentation, 60 ml of settled rumen fluid resulted in slightly more dry matter disappearance than with 10 ml of nonsettled rumen fluid.

In vitro dry matter disappearance for canary grass I (1961 crop) and standard alfalfa were similar when 60 ml of nonsettled or 24 ml of settled rumen fluid were used (Table 26). Values for the standard alfalfa indicate that dry matter disappearance values were about the same for both methods or possibly slightly higher for the 24 ml of settled rumen fluid.

TABLE 25. Dry Matter Disappearance of Standard Alfalfa Using Different Volumes of Both Settled and Non-Settled Rumen Inoculum.

	Settled[1] %				Non-settled %					
Inoculum used (ml.)	10	10	60	60	10	10	20	20	60	60
Fermentation time (hrs)	6	24	6	24	6	24	6	24	6	24
DM Disappearance (Avg. of 4 replicates)	26.9	43.8	31.7	42.7	28.6	46.1	31.4	47.9	33.3	47.8

TABLE 26. DM Disappearance of Two Substrates Using 60 ml of Non-settled or 24 ml of Settled Rumen Inoculum

Fermentation Time	Reed Canary Grass I-1961		Standard Alfalfa	
	non-settled	settled[1]	non-settled	settled[1]
hrs.	%	%	%	%
3	26.4	26.7	24.3	30.7
6	28.2	25.6	29.9	33.1
12	38.0	31.0	38.7	42.5
18	46.0	43.6	44.9	46.5
24	51.3	49.4	46.5	48.3
36	61.6	58.6	48.5	50.8
48	63.3	63.3	50.9	52.9
No. observations/value	4	1	20	10-12

[1]Rumen fluid allowed to settle and the particulate material removed.

Thus 24 ml of settled and 60 ml of nonsettled rumen inoculum resulted in similar dry matter disappearance values. Allowing the particulate material in the rumen inoculum to rise and be discarded resulted in decreased dry matter in the remaining portion (Table 27 and Appendix Table XXVI) as would be expected. The 1962 fermentations were carried out with 24 ml of settled rumen inoculum compared to 60 ml of non-settled rumen inoculum for the 1961 fermentations. The non-settled inoculum contained 0.45% non-filterable dry matter whereas the settled inoculum contained 0.10% non-filterable dry matter. Thus non-filterable residual dry matter from the 1961 rumen inoculum per flask was 0.270 g in comparison to 0.024 g in the inoculum added to each fermentation flask in 1962.

TABLE 27. Total and Non-filterable Dry Matter in Settled and Non-settled Rumen Inoculum.

	Total DM	Non-filterable DM
	%	%
Non-settled	2.09	0.45
Settled	1.82	0.10

Slaughter Trials - 1961 and 1962

Previous trials indicated that sheep would consume more of some forage species than others. Forages selected for use in the slaughter trials had a large range in average daily consumption when fed to sheep (1961 second cuttings 1.78 to 3.87 and 1962 first cuttings 1.80 to 2.77 lb/cwt - Table 28). For both crops the average consumption of the legumes were greater than that of the grasses ($P < .01$) with the exception of timothy I. Dry matter intake of alfalfa II was greater than that of trefoil II ($P < .05$). Dry matter digestion coefficients for the forages were similar with ranges of 55 to 60% for 1961 forages and 62 to 65% for the 1962 forages (Tables 6 and 7). Thus the variations in consumption of digestible dry matter were similar to those of dry matter intake. Simple correlation coefficients between weight gain and dry matter intake/cwt or digestible dry matter intake/cwt were significant ($P < .01$) when both 1961 and 1962 crops were considered (Table 31 lines 6 and 7). The correlation coefficient between dry matter intake and dressing % was not significant ($P > .05$, Table 31, line 5). These relationships however, are based on a 14 day feeding period without a pretrial period.

Differences in fiber intake were similar to those of dry matter intake (Table 28) since all the forages contained 29 to 33% fiber with the exception of 1961 alfalfa II which contained 38.4% fiber. The variation in dry matter intake and its content of fiber resulted in similar fiber intakes for sheep receiving alfalfa II and trefoil II.

Daily lignin intake varied from 40 to 171 g and 28 to 110 g for the 1961 and 1962 forages respectively. Lignin

TABLE 28. Daily DM, Dig.DM, Fiber and Lignin Intake/cwt.by Wethers (Avg. for 3 Days Prior to Slaughter)

	1961 6 hr.[1]			Avg.		1962 6 hr.[1]		12 hr.[1]		Avg.
DM Intake (lb)										
Alf. II	3.33	2.66	3.76	3.25^{Ab}	Alf. I	2.52	2.88	2.64	3.02	2.76^{A}
Tre. II	3.79	4.11	3.67	3.87^{Aa}	Tre. I	2.83	2.96	2.54	2.75	2.77^{A}
Brome II	1.66	1.78	1.90	1.78^{B}	Tim. I	2.64	2.12	2.96	2.41	2.53^{A}
Reed II	2.10	2.27	1.87	2.08^{B}	Reed I	1.76	2.51	1.02	1.90	1.80^{B}
					Avg.	2.53		2.40		
Dig. DM Intake (lb)										
Alf.II	1.86	1.48	2.10	1.81^{B}	Alf. I	1.65	1.88	1.72	1.97	1.80^{a}
Tre.II	2.27	2.47	2.20	2.32^{A}	Tre. I	1.75	1.83	1.57	1.70	1.71^{a}
Brome II	.91	.98	1.04	.98^{C}	Tim. I	1.78	1.32	1.84	1.50	1.61^{a}
Reed II	1.16	1.26	1.04	1.16^{C}	Reed I	1.14	1.63	.66	1.24	1.17^{b}
					Avg.	1.62		1.52		
Fiber Intake (g)										
Alf.II	584	466	659	570^{A}	Alf. I	380	434	397	455	416^{A}
Tre.II	553	600	536	563^{A}	Tre. I	420	439	376	408	411^{A}
Brome II	252	271	288	271^{B}	Tim. I	397	319	446	363	382^{A}
Reed II	308	334	275	305^{B}	Reed I	236	337	137	255	241^{B}
					Avg.	370		355		

continued

Lignin Intake (g)

	1961			
	6 hr.[1]			Avg.
Alf.II	133	106	150	130[B]
Tre.II	168	182	163	171[A]
Brome II	53	57	61	57[C]
Reed II	40	44	36	40[C]

	1962				
	6 hr.[1]		12 hr.[1]		Avg.
Alf. I	71	82	75	85	78[B]
Tre. I	112	117	101	109	110[A]
Tim. I	52	42	58	48	50[C]
Reed I	27	39	16	30	28[D]
Avg.	68		65		

[1]Refers to interval between last feeding and slaughter.

consumption from trefoil was greater than that from alfalfa which was greater than that from the grasses for each year ($P < .01$). The legumes although containing more lignin (Table 3) were consumed in larger amounts thus resulting in large differences in lignin consumption.

Rumen digesta from sheep fed legumes contained higher percentages of dry matter, fiber and lignin than sheep fed grasses with the exception of timothy I (Table 29, $P < .01$). Digesta from sheep fed alfalfa II contained more fiber than the digesta from sheep receiving trefoil II ($P < .05$). Dry matter % of rumen contents for both years was related to intake ($P < .01$ - $r = +.59$). However, the relationship between dry matter intake of 1962 forages and % dry matter of rumen contents 6 hours after feeding was not significant ($P > .05$). The correlation coefficient was significant ($r = +.88$ - $P < .01$) 12 hours after feeding. The regression formula based on dry matter % of rumen contents 6 hours after feeding for all forages was $Y = 11.508 + .847X$ ($Sy \cdot x = .91\%$) where Y = % dry matter of rumen contents and X = dry matter intake/cwt. The dry matter % of rumen contents of sheep slaughtered 12 hours after feeding was significantly lower than that of sheep slaughtered 6 hours after feeding ($P < .05$). The % fiber and lignin content of rumen digesta expressed on a dry matter basis changed very little from 6 hours to 12 hours after feeding, but did show a slight increase with time after feeding.

TABLE 29. Percent DM, Fiber and Lignin Content of Rumen Digesta From Wethers Fed the Experimental Forages (Fiber and Lignin on a DM Basis) 6 and 12 Hours After Feeding.

		1961						1962				
		6 hr.[1]			Avg.			6 hr.[1]		12 hr.[1]		Avg.
% DM.												
Alf.	II	15.11	14.64	14.71	14.82^{A}	Alf.	I	15.04	12.49	13.63	12.62	13.44^{A}
Tre.	II	15.22	14.49	14.95	14.89^{A}	Tre.	I	13.96	14.20	12.16	13.85	13.54^{A}
Brome	II	12.85	13.12	12.16	12.86^{B}	Tim.	I	12.64	14.84	12.77	12.83	13.27^{A}
Reed	II	13.55	12.63	13.48	13.22^{B}	Reed	I	12.97	11.64	7.77	9.77	10.54^{B}
						Avg.		13.47^{a}		11.92^{b}		
% Fiber												
Alf.	II	46.00	45.61	49.51	47.04^{Aa}	Alf.	I	47.82	45.49	47.62	50.00	47.73^{A}
Tre.	II	41.18	39.62	42.45	41.41^{ABb}	Tre.	I	44.38	50.88	44.38	50.76	47.60^{A}
Brome	II	34.31	33.16	40.70	36.06^{B}	Tim.	I	37.02	37.86	37.78	38.22	37.72^{B}
Reed	II	33.59	35.72	35.51	34.94^{B}	Reed	I	37.94	38.04	40.32	42.76	39.76^{B}
						Avg.		42.43		43.98		
% Lignin												
Alf.	II	15.08	15.37	16.60	15.68^{A}	Alf.	I	15.78	14.44	16.60	17.30	16.03^{B}
Tre.	II	17.59	16.05	18.12	17.25^{A}	Tre.	I	18.48	21.06	18.48	20.84	19.71^{A}
Brome	II	10.59	10.47	12.85	11.30^{B}	Tim.	I	8.96	9.30	10.13	10.06	9.61^{C}
Reed	II	6.51	8.38	6.31	7.07^{C}	Reed	I	8.36	7.48	9.12	10.42	8.84^{C}
						Avg.		12.98		14.12		

[1] Refers to interval between last feeding and slaughter.

Data on sheep rumen contents were examined to study the relationship between rumen fill and ad lib. forage intake (Table 30). Weights of wet rumen contents were largest for sheep fed canary grass from the 1961 and the 1962 harvest. Intake of canary grass ranked next to last for the four 1961 forages and last for the 1962 forages. Sheep fed alfalfa had rumens with the least fill for both years but were next to the highest in consumption. Sheep fed trefoil ranked first in consumption but were second and third in wet rumen fill. Consumption of dry matter was not correlated to wet weight of rumen contents ($r = -0.01$ $P > .05$ Table 31 line 3). These data might indicate that the consumption of canary grass was limited by rumen fill. However, this line of reasoning is not in accord with the data obtained on the other forages.

Total dry matter in the rumen of sheep fed trefoil II and canary grass II (1961 forages) was high and about equal (Table 30). Brome grass II and alfalfa II were similar in dry matter fill, yet had very different intakes. Alfalfa I and trefoil I (1962 forages) had similar intakes yet were low and high in rumen fill respectively. Canary grass I with low intake resulted in an intermediate dry matter fill 6 hours after feeding. The correlation coefficients between dry matter intake and amount of dry matter in the rumen 6 hours after feeding were not significant ($P > .05$ Table 31, line 1). Dry rumen contents 12 hours after feeding were related to dry matter consumption ($r = +0.76$ $P < .05$). The

TABLE 30. Rumen Content of Wet Digesta, DM Fiber, and Lignin/cwt of Sheep.

		1961 Forages						1962 Forages				
			6 hr.[1]		Avg.			6 hr.[1]		12 hr.[1]		Avg.
						Wet Content (g)						
Alf.	II	4899	5928	6663	5829^{Bb}	Alf.	I	5080	5200	5152	6381	5453
Tre.	II	6677	7171	8419	7421^{ABa}	Tre.	I	6892	7200	5443	5715	6312
Brome	II	6613	5575	7586	6260^{B}	Tim.	I	7258	7200	7672	6225	7089
Reed	II	8092	8804	8060	8319^{A}	Reed	I	6581	7800	4881	8550	6953
						Avg.		6961		6252		
						Dry Content (g)						
Alf.	II	740	868	980	863^{ABb}	Alf.	I	764	791	702	805	766
Tre.	II	1017	1039	1259	1105^{Aa}	Tre.	I	962	1053	754	695	866
Brome	II	849	731	831	804^{B}	Tim.	I	917	1068	980	799	941
Reed	II	1096	1112	1087	1099^{Aa}	Reed	I	854	1040	379	835	777
						Avg.		931^{a}		744^{b}		
						Fiber Content (g)						
Alf.	II	341	396	485	407^{ABa}	Alf.	I	365	360	334	403	366
Tre.	II	419	411	547	459^{A}	Tre.	I	427	536	335	353	413
Brome	II	291	243	338	291^{Bb}	Tim.	I	340	404	370	305	355
Reed	II	368	397	386	384^{AB}	Reed	I	324	395	153	357	307
						Avg.		394		326		

continued

TABLE 30 CONTINUED

						Lignin Content (g)						
Alf.	II	112	133	163	136^{ABb}	Alf.	I	120	114	116	139	123^{Ba}
Tre.	II	179	167	228	191^{Aa}	Tre.	I	178	222	139	145	171^{A}
Brome	II	90	77	107	91^{Bc}	Tim.	I	82	99	99	80	90^{BCb}
Reed	II	71	93	68	78^{Bc}	Reed	I	71	78	35	87	68^{C}
						Avg.			121		105	

[1]Refers to interval between last feeding and slaughter.

later relation was based on only four forages and eight sheep fed the 1962 forages. Rumen dry matter fill was 744 g 12 hours after feeding when all forages were considered which was less than 931 g 6 hours after feeding ($P < .05$).

The amount of fiber and lignin in the rumen was positively related to level of dry matter consumption ($P < .01$, Table 31, lines 19 and 20). Forages that produced a large rumen fill of fiber and lignin were those that ranked high in dry matter consumption (Table 29). Thus 6 or 12 hours after feeding there did not appear to be a proportional build up of fiber or lignin in the rumen of animals receiving the grasses which were consumed in smaller amounts than the legumes.

Rumen retention time of dry matter, fiber and lignin was shorter when sheep received alfalfa or trefoil rather than the brome grass or canary grass forages ($P < .05$, Table 32). Rumen retention time of dry matter was about six-tenths of a day for the legumes and one day for the grasses. This indicated that the average "particle" of trefoil or alfalfa stayed in the rumen for six-tenths of a day. Rumen retention time of dry matter was less in sheep receiving alfalfa or the trefoil than those receiving brome grass or canary grass ($P < .01$). Rumen retention time of dry matter was less ($P < .05$) when based on 12 hours after feeding rather than on six hours as was expected, since there was less dry matter in the rumen 12 hours after feeding. Rumen retention time of fiber varied from .73 day for alfalfa II to 1.27 day for canary grass II, and from

TABLE 31. Simple Correlation Coefficients Between Intake of DM and Rumen Contents of DM, Fiber or Lignin

		r			
		1961	1962		Combined 1961+1962
		6 hr.[1]	6 hr.	12 hr.	6 hr.
1.	DM intake (lb/cwt) vs dry rumen contents (lb/cwt)	.31	.04	.76*	.28
2.	DM intake (lb/cwt) vs % DM in rumen contents)	.86**	-.04	.88**	.59**
3.	DM intake (lb/cwt) vs wet rumen contents (lb/cwt)	-.05	.05	.18	-.01
4.	Dig. DM intake (lb/cwt) vs dry rumen contents (lb/cwt)	.35	-.09	.75*	.26
5.	DM intake (lb/cwt) vs dressing %	-.44	.58	.65	-.25
6.	DM intake (lb/cwt) vs weight gain (lb/day)	.90**	.41	.58	.76**
7.	Dig. DM intake (lb/cwt) vs weight gain (lb/day)	.91**	.46	.62	.83**
8.	DM intake (lb/cwt) vs rumen retention time of DM (R_1)	-.86**	-.82*	-.68	-.82**
9.	DM intake (lb/cwt) vs rumen retention time of lignin (R_2)	-.76**	-.87**	-.62	-.71**
10.	DM intake (lb/cwt) vs rumen retention time of fiber (R_3)	-.75**	-.64	-.67	-.72**
11.	R_1 vs R_2	.93**	.93**	.93**	.78**
12.	R_1 vs R_3	.96**	.86**	.86**	.89**
13.	R_2 vs R_3	.95**	.94**	.95**	.91**
14.	DM intake (lb/cwt) vs R_2+R_3	-.77**	-.81*	-.64	-.73**
15.	Rumen fiber disappearance coefficient vs R_3	.25	.18	.42	.32
16.	Lignin intake (g/cwt) vs R_2	-.84**	-.61	-.79*	-.78**
17.	Fiber intake (g/cwt) vs. R_3	-.82**	-.71*	-.73*	-.79**
18.	Dig. DM intake (lb/cwt) vs R_1	-.84**	-.85**	-.67	-.83**
19.	Rumen contents of fiber (g/cwt) vs DM intake (lb/cwt)	.70*	.54	.88**	.64**

continued

TABLE 31 CONTINUED

		r			
		1961	1962		Combined 1961+1962
		6 hr.[1]	6 hr.	12 hr.	6 hr.
20.	Rumen contents of lignin (g/cwt) vs DM intake (lb/cwt)	.85**	.97**	.83**	.76**
21.	Fiber intake (g/cwt) vs rumen contents (g) of fiber	.65*	.50	.84**	.58**
22.	Lignin intake (g/cwt) vs rumen contents (g) of lignin	.90**	.94**	.95**	.84**
23.	Fiber digestion coefficients by total collection vs fiber retention time in rumen	-	-	-	.27

1 Refers to time interval between last feeding and slaughter.

* Significant ($P < .05$)

** Significant ($P < .01$)

TABLE 32. Rumen Retention Time of DM, Fiber and Lignin[1] in Days.

	1961 Forages					1962 Forages				
	6 hr.[2]			Avg.		6 hr.		12 hr		Avg.
				Retention time of DM						
Alf. II	.49	.72	.58	$.60^{B}$	Alf. I	.69	.61	.59	.59	$.61^{B}$
Tre. II	.59	.56	.76	$.64^{B}$	Tre. I	.75	.78	.65	.56	$.69^{B}$
Brome II	1.13	.90	.97	1.00^{A}	Tim. I	.77	1.11	.73	.73	$.83^{AB}$
Reed II	1.15	1.08	1.28	1.17^{A}	Reed I	1.07	.91	.82	.97	$.94^{A}$
					Avg.	$.83^{a}$		$.70^{b}$		
				Retention time of fiber						
Alf. II	.59	.86	.74	$.73^{Bb}$	Alf. I	.96	.83	.84	.89	$.88^{B}$
Tre. II	.76	.69	1.03	$.88^{Bab}$	Tre. I	1.02	1.22	.89	.87	1.00^{AEb}
Brome II	1.16	.90	1.18	1.08^{ABa}	Tim. I	.85	1.27	.83	.84	$.95^{ABb}$
Reed II	1.20	1.20	1.41	1.27^{A}	Reed I	1.37	1.17	1.11	1.40	1.26^{Aa}
					Avg.	1.07		.96		
				Retention time of lignin						
Alf. II	.84	1.26	1.09	1.06^{Bb}	Alf. I	1.69	1.40	1.56	1.63	1.57^{B}
Tre. II	1.07	.92	1.41	1.13^{Bb}	Tre. I	1.59	1.90	1.38	1.33	1.55^{B}
Brome II	1.69	1.35	1.77	1.60^{ABa}	Tim. I	1.57	2.35	1.70	1.69	1.83^{ABb}
Reed II	1.78	2.14	1.91	1.94^{A}	Reed I	2.62	1.99	2.18	2.95	2.43^{Aa}
					Avg.	1.89		1.80		

continued

TABLE 32 CONTINUED

1961 Forages				1962 Forages		
DM	Fiber	Lignin		DM	Fiber	Lignin
Avg. retention time of each constituent						
$.85^{Bb}$	$.98^{Ba}$	1.44^{A}	6 hr[1]	$.83^{B}$	1.09^{B}	1.89^{A}
			12 hr	$.70^{B}$	$.96^{B}$	1.80^{A}

[1]Retention time of constituent = $\frac{\text{lb. constituent in rumen/cwt}}{\text{lb. constituent eaten/cwt/day}}$

[2]Refers to interval between last feeding and slaughter

0.88 to 1.26 for alfalfa I and canary grass I. This difference was significant ($P < .01$). Sheep fed brome grass II had longer retention time of fiber than those fed alfalfa II ($P < .05$), and rumen retention time of fiber from canary grass I was longer than that of trefoil I or timothy I ($P < .05$). Rumen lignin retention time was less for sheep receiving the grasses as compared to the legumes ($P < .01$) with the exception of timothy I.

Average rumen retention time of dry matter from the 1961 forages was less than that of fiber ($P < .05$) and both less than that of lignin ($P < .01$, Table 32). A similar trend was found for rumen retention time for the 1962 forages with the exception that the difference between dry matter (.77 days) and fiber (1.02 days) retention time was not shown to be significantly different ($P > .05$). Average retention times indicate that some more soluble portions of the dry matter passed "through" the rumen faster than fiber and lignin.

Significant negative correlation coefficients between daily dry matter intake and rumen retention time of dry matter, fiber and lignin were obtained for the 1961 ($P < .01$) and 1962 forages ($P < .05$, Table 31, lines 8,9 and 10). Thus as dry matter intake increased, the rumen retention time of dry matter fiber and lignin decreased. Also as fiber and lignin intake increased, the respective retention times of fiber and lignin decreased ($P < .01$, Table 31, lines 16 and 17). Retention times of dry matter, fiber and lignin were all positively correlated ($P < .01$, Table 31, lines 11,12, and 13).

Although retention time of fiber, for individual animals, in the rumen varied from .59 to 1.41 days, there was no correlation between rumen fiber digestion as determined by the lignin ratio technique and rumen retention time of fiber ($P > .05$). Total fiber digestion as determined by collection trials was not related to rumen retention time of fiber ($P > .05$, Table 31, line 23).

Lignin ratio technique was used to determine dry matter and fiber digestion from the rumen and the lower large intestine and were compared to the total collection values (Table 33). Dry matter disappearance in the rumen for the 1961 forages ranged from 67.7 to 78.9% of the total dry matter digested. The values were somewhat higher for the 1962 forages (83.9 to 92.8% of total dry matter digested). This could be related to the larger total digestion coefficients obtained for the 1962 forages. Dry matter digestion was larger at 12 hours after feeding than at 6 hours, with the exception of trefoil I. Dry matter digestion by the time the ingesta reached the lower large intestine for the 1962 forages was approximately equal to total collection values as would be expected since the samples used to determine dry matter digestibility were essentially feces. Samples for 1961 forages were taken from the entire large intestinal contents excluding the cecum and in this case both dry matter

TABLE 33. Average DM and Fiber Disappearance in the Rumen and Lower Large (L.L.) Intestine as Determined by Lignin Ratio Compared to Total Digestion Coefficients Determined in Total Collection Trials.

Forage	DM dig. by Collection	DM Disappearance in Rumen				DM disappearance in L.L. intestine[1,3]			
		6 hr[2] %	% of total	12 hr %	% of total	6 hr %	% of total	12 hr %	% of total
1961									
Alf. II	55.8	44.0	78.9			57.3	102.7		
Tre. II	60.0	43.6	72.8			61.1	101.9		
Brome II	55.1	37.3	67.0			68.5	124.3		
Reed II	55.6	39.3	70.7			61.9	111.4		
1962									
Alf. I	65.3	60.6	92.8	63.2	96.8	65.2	99.8	64.9	99.4
Tre. I	61.7	55.7	90.3	55.4	89.8	58.5	94.8	59.8	96.9
Tim. I	62.2	52.2	83.9	56.9	91.5	61.5	98.9	63.6	102.2
Reed I	65.0	56.8	87.3	64.8	99.6	70.4	108.3	70.6	108.6
Avg.		56.3[b]		60.1[a]		63.9		64.8	
	Fiber dig. by Collection	Fiber dis. in Rumen				Fiber Dis. in L.L. Intestine[1,3]			
1961									
Alf. II	48.3[A]	31.5	65.2			47.3[B]	97.8		
Tre. II	33.6[B]	27.0	80.5			33.4[C]	99.6		
Brome II	51.0[A]	32.7	64.1			57.6[A]	112.9		
Reed II	49.5[A]	34.4	69.4			54.5[A]	110.1		

continued

TABLE 33 CONTINUED

Forage	Fiber dig. by Collection	Fiber dis. in Rumen				Fiber dis. in L.L. Intestine[1,3]			
		6 hr[2] %	% of total	12 hr %	% of total	6 hr %	% of total	12 hr %	% of total
1962									
Alf. I	50.7[A]	41.9	82.8	45.9	90.6	51.4	101.4	52.0	102.7
Tre. I	36.3[B]	35.7	98.6	35.4	97.6	37.7	103.9	35.6	98.1
Tim. I.	53.4[A]	46.1	86.3	50.5	94.6	53.0	99.3	54.9	102.8
Reed I	54.3[A]	44.3	81.5	50.6	93.2	43.2	79.5	53.8	99.1
Avg.		42.0[B]		45.6[A]		46.3		49.1	

[1]Corrected for lignin digestion found during the total collection trial (Appendix Table IV)

[2]Time between feeding and slaughter.

[3]Samples for 1961 forages were taken from the large intestine contents excluding the cecum where as samples for the 1962 forages were taken from "pelleted" digesta in the lower large intestine.

and fiber disappearance values from the large intestine were over 110% of total collection values for brome grass II and canary grass II, but close to 100% for alfalfa II and trefoil II (Table 33). The percentage of fiber that was digested in the rumen was similar to that of dry matter digestion. Fiber digestion in the rumen of trefoil as a % total fiber digestion appeared higher than that from the other forages for both years. But total digestibility of trefoil fiber was lower than that of other forages ($P < .01$). A faster rate of passage with the relatively large intake of trefoil could reduce fiber digestion. However, alfalfa with a similar fast rate of passage had fiber digestion coefficients only slightly less than the grasses. This might indicate a chemical difference between "fiber" from trefoil and that from the other forages.

Wet G.I. tract contents as a % of body weight 6 hours after feeding ranged from 17.2% for alfalfa I to 24.1% for canary grass II (Table 34). Sheep fed alfalfa II and brome grass II had approximately the same total wet digesta contents while their dry matter consumption was 3.25 and 1.78 lb. respectively. Sheep that consumed canary grass II at the rate of 2.08 lb/day had about the same G.I. tract fill as sheep that received trefoil II at the rate of 3.87 lb/day. Gastrointestinal fill of sheep receiving trefoil I, timothy I and canary grass I was about the same. Wethers receiving alfalfa I had less fill than the above sheep though the

TABLE 34. Total Gastro Intestinal Tract Contents and Rumen Contents as a % of the Total.

	1961 Forages			Avg.		1962 Forages 6 hr.[1]		1962 Forages 12 hr.[1]		Avg.
	Total wet digesta in GI tract (g/100 lb. of sheep)									
Alf. II	7870	8836	10011	8904^{ABab}	Alf. I	6850	7800	7475	8818	7975
Tre. II	9335	10387	10954	10224^{ABa}	Tre. I	9840	9700	7815	9077	9086
Brome II	8455	8736	8863	8686^{Bb}	Tim. I	9679	9350	10614	8877	9553
Reed II	10365	11853	10569	10927^{A}	Reed I	8553	9700	6970	10715	9314
					Avg.	9169		8795		
	Wet rumen contents as a % of total wet GI tract contents									
Alf. II	62	67	67	65^{b}	Alf. I	74	72	69	72	72
Tre. II	72	69	77	73^{ab}	Tre. I	70	77	70	63	70
Brome II	78	64	74	72^{ab}	Tim. I	75	80	72	70	74
Reed II	78	74	76	76^{a}	Reed I	77	81	70	80	77
					Avg.	79^{a}		71^{b}		
	Total DM in GI tract (g/100 lb. of sheep)									
Alf. II	1043	1254	1273	1190	Alf. I	974	1009	920	1035	985
Tre. II	1379	1362	1556	1432	Tre. I	1200	1270	992	995	1114
Brome II	1033	1044	1052	1043	Tim. I	1116	1270	1268	1026	1170
Reed II	1339	1385	1332	1352	Reed I	1055	1200	554	980	947
					Avg.	1137^{a}		971^{b}		

continued

TABLE 34 CONTINUED

	1961 Forages			Avg.		1962 Forages				Avg.
						6 hr.[1]		12 hr.[1]		
	Dry rumen contents as a % of total dry GI contents[2]									
Alf. II	71	69	77	72	Alf. I	78	78	76	78	78
Tre. II	74	76	81	77	Tre. I	80	83	76	70	77
Brome II	82	70	79	77	Tim. I	82	84	77	78	80
Reed II	82	80	81	81	Reed I	81	87	68	85	80
					Avg.	82[a]		76[b]		

[1]Refers to the time interval between the last feeding and slaughter.

[2]Does not include small intestinal contents.

difference was not significant ($P > .05$). Wet rumen contents made up 65 to 79% of the total G.I. tract contents. Sheep receiving canary grass II had a higher percentage of their total wet G.I. tract contents as rumen contents than sheep receiving alfalfa II ($P < .05$). Total dry matter in the G.I. tract appeared to be different for sheep receiving the different forage species though the differences were not significant ($P > .05$). Animals receiving trefoil II and canary grass II had about 1400 g dry matter/cwt in the G.I. tract while those receiving alfalfa II and brome grass II had 1190 and 1043 g dry matter/cwt respectively. Total dry G.I. contents as a % of body weight ranged from 3.2% for sheep receiving trefoil II to 2.2% for those receiving alfalfa I.

The difference in pH due to time after feeding and forage species were not significant ($P > .05$) when the significant ($P < .05$) forage species x time interaction mean sum of squares was used for the error term (Table 35). The pH values tended to to be higher 12 hours after feeding than 6 hours postpraudial.

There were no significant ($P > .05$) differences in moles of acetate or propionate per gram of wet rumen digesta. Digesta from sheep fed alfalfa I contained more butyrate (12.0 μ moles/g) than did digesta from sheep fed canary grass I (6.8 μ moles/g)($P < .05$). Twelve hours after feeding there was less acetate ($P < .01$), propionate and butyrate ($P < .05$) per gram of wet digesta than at 6 hours after feeding.

TABLE 35. pH of Rumen Contents at Time of Slaughter.

	6 hr.		Avg.	12 hr.		Avg.	Total Avg.
Alf.	5.98	6.10	6.04	6.75	6.70	6.72	6.38
Tre.	6.10	6.00	6.50	6.40	6.58	6.49	6.27
Tim.	6.02	5.71	5.86	6.20	6.00	6.10	5.98
Reed	6.55	6.42	6.48	6.50	6.62	6.56	6.52
Avg.			6.11			6.47	

Digesta from sheep receiving the forages contained an average of 72.4, 18.1 and 9.6 molar % of acetate, propionate, and butyrate respectively. Molar % of acetate and propionate appeared to be similar for all forages and indicated little change with time after slaughter. Digesta from sheep receiving alfalfa I had a larger molar % of butyrate than did sheep receiving canary grass I ($P < .05$, Table 36). Digesta from sheep fed trefoil I contained more total VFA (C_1, + C_2 + C_3) per gram of digesta than did sheep fed canary grass I ($P < .05$, Table 36). Six hours after feeding total VFA content ranged from 92.3 for sheep receiving timothy I to 121.9 μ moles/g wet digesta for sheep receiving trefoil I. The above difference was not significant ($P > .05$). The change in acetate and propionate content of rumen digesta tended to be larger for the legumes than the grasses when comparing 6 and 12 hours postpraudial digesta (Table 36).

TABLE 36. VFA Content of Rumen Digesta at the Time of Slaughter

Forage	6 hr[1]		Avg.	12 hr[1]		Avg.	Total Avg.	Change 6 vs 12 hr.
	Micro moles of acetate/g wet rumen digesta							
Alf. I	81.0	86.3	83.6	60.3	57.9	59.1	71.4	- 24.5
Tre. I	87.5	86.7	87.1	70.0	62.2	66.1	76.6	- 21.0
Tim. I	64.0	72.4	68.2	64.4	65.8	65.1	66.6	- 3.1
Reed I	77.3	61.8	69.5	49.4	63.5	56.4	63.0	- 13.1
Avg.	77.1[A]			61.7[B]				
	Micro moles of propionate/g wet rumen digesta							
Alf. I	20.7	19.7	20.2	11.3	17.5	14.4	17.3	- 5.8
Tre. I	19.3	28.0	23.6	11.9	14.8	13.3	18.5	- 10.3
Tim. I	14.7	16.6	15.6	18.0	16.1	17.0	16.4	+ 1.4
Reed I	16.8	18.6	17.7	17.7	15.3	16.5	17.1	- 1.2
Avg.	19.3[a]			15.3[b]				
	Micro moles of butyrate/g wet rumen digesta							
Alf. I	13.7	16.4	15.0	8.8	9.1	8.9	12.0[a]	- 6.1
Tre. I	11.7	10.8	11.2	8.6	10.0	8.3	10.3[ab]	- 2.9
Tim. I	7.8	9.2	8.5	8.5	3.9	6.2	7.4[ab]	- 2.3
Reed I	8.2	5.6	6.9	5.0	8.5	6.7	6.8[b]	- .2
Avg.	10.4[a]			7.8[b]				
	Micro moles $C_2 + C_3 + C_4$/g wet rumen digesta							
Alf. I	115.4	122.4	118.9	80.4	84.5	82.4	100.7[ab]	- 36.5

contd.

[1]Refers to time interval between the last feeding and slaughter.

TABLE 36 CONTINUED

		6 hr[1]		Avg.	12 hr[1]		Avg.	Total Avg.	Change 6 vs 12 hr
Tre.	I	118.4	125.5	121.9	90.5	117.0	103.7	112.8[a]	- 18.2
Tim.	I	86.5	98.2	92.3	90.9	85.8	88.3	90.4[ab]	- 4.0
Reed	I	102.2	86.0	94.1	72.1	87.3	79.7	86.9[b]	- 14.4
Avg.		106.8[A]			88.6[B]				
Molar % acetate in rumen digesta									
Alf.	I	70.2	70.5	70.3	75.0	68.5	71.7	71.0	
Tre.	I	73.9	69.1	71.5	77.3	71.5	74.4	73.0	
Tim.	I	74.0	73.7	73.8	70.8	76.7	73.7	73.8	
Reed	I	75.6	71.8	73.7	68.5	72.8	70.7	72.2	
Avg.		72.4			72.6				
Molar % propionate in rumen digesta									
Alf.	I	17.9	16.1	17.0	14.0	20.7	17.3	17.2	
Tre.	I	16.3	22.3	19.3	13.2	17.0	15.1	17.2	
Tim.	I	17.0	16.9	16.9	19.8	18.7	19.2	18.1	
Reed	I	16.4	21.6	14.0	24.6	17.5	21.0	20.0	
Avg.		18.1			18.2				
Molar % butyrate									
Alf.	I	11.9	13.4	12.6	10.9	10.8	10.8	11.8[a]	
Tre.	I	9.9	8.6	8.2	9.5	11.5	10.5	9.9[ab]	
Tim.	I	9.0	9.4	9.2	9.4	4.5	6.9	8.1[ab]	
Reed	I	8.0	6.5	7.2	6.9	9.7	8.3	7.8[b]	
Avg.		9.6			9.1				

DISCUSSION

Comparative Responses of Sheep When Fed Various Forage Species and Cuttings

Although digestibility of forages *per se* has been used extensively as an indicator of their nutritive value little work has been done comparing relationships between the digestible energy concentration in some of our common forage species, intake and animal performance. Reid *et al.* (230,214) reported little difference in digestibility of forage species and varieties while Minson *et al.* (179) showed significant differences. In the present investigations reed canary grass (1961) had the largest digestion coefficients of first and third cuttings while trefoil (1961) had the largest digestion coefficient of the second cut forages. There was little variation of digestion coefficients between the 1962 forages but in both first and second cutting forages brome grass tended to have the larger digestion coefficients. Average digestion coefficients for the different forage species combining both years and both cuttings ranged from a low of 60.4% for alfalfa to a high of 62.5% for brome grass. Within a particular year and cutting there were significant differences in forage digestibility, but when first and second cuttings for two years were considered there was very little difference in the digestion coefficients for the different forage species, harvested on approximately the same calendar date. Thus, factors other than species may have a dominant effect on digestibility.

Average digestion coefficients for first cutting forages of 1962 were 2.5 percentage points higher than digestion coefficients for first cut 1961 forages which may be related to the fact that the 1961 forages were harvested approximately 17 calendar days later. Alfalfa and brome grass digestion coefficients were increased 5 percentage points by earlier harvesting, but first cutting trefoil, canary grass and brome grass had similar digestion coefficients for both years. Several workers (62,126,230) reported a .5% linear decrease in digestibility of forages with each day that harvesting was delayed. Murdock et al. (187) found that decreased digestibility of orchard grass with delayed harvesting was not a linear relationship. Data from the present experiments would indicate there may be variations due to different forages and species in respect to decreased digestibility with delayed cutting or large year to year variations.

Digestion coefficients for 1961 and 1962 forages were greater for first cutting (62.2 and 64.7 respectively) than digestion coefficients for second cutting forages (56.6 and 62.6 respectively). These results are in agreement with those of Reid et al. (230) who reported that early first cutting forages were more digestible than second cutting forages.

Lignin content of the forages studied was negatively correlated with dry matter digestibility as determined by sheep. Forages with the greatest lignin content (the legumes) were the same forages that tended to have smaller dry matter digestion coefficients. Fiber content of the present forages was also negatively related to forage dry matter digestion coefficients as determined by sheep. The above relationships could be an artifact due to the fact that the legumes were consumed in larger amounts, thus possibly resulting in lower digestion coefficients.

Large differences were found in ad. lib. consumption of the individual forages and forage species. Consumption of first, second and third cutting trefoil was greater than that of alfalfa for the 1961 forages. The reverse was true for the 1962 forages. Alfalfa and trefoil were consumed in larger amounts than the corresponding three grass hays for both years. Consumption of brome grass was greater than the corresponding canary grass. This was in agreement with work by Fulleman and Burlison (98), Garrigus and Rusk (99) and Blakeslee et al. (30). First cutting 1961 timothy was consumed in amounts slightly less than first cutting canary grass and slightly more than first cutting canary grass for the 1962 forages. Loosli et al. (152) reported cows consumed alfalfa and trefoil in slightly higher amounts than timothy while Pratt et al. (206) indicated that alfalfa was preferred by cows over timothy when they had a choice. McCall et al. (164) reported intake of brome grass was lower than other forages studied.

No significant differences were found between consumption of the different cuttings. Average consumption of both the first and second cuttings of 1961 and 1962 forages was about 2.9 lb. per cwt. Consumption of 1961 third cutting forages was slightly less than the first and second cuttings. Carroll (53) found that milking cows consumed more third cutting alfalfa than first or second cutting. Porter et al. (202,203) reported that there was very little difference in consumption of early bloom first, second or fifth cutting alfalfa. Since growth characteristics of the various cuttings change with differing climatic and environmental conditions etc. (53,202,203) there is little reason to expect similar results when comparing successive crops by different investigators.

Forages with high lignin content did not result in decreased forage consumption. In fact, a significant ($P < .01$) positive correlation was found between lignin content of forage and dry matter intake or digestible dry matter intake. Results reported by Stallcup et al. (256) were in direct opposition to these results. However, Stallcup et al. (256) were comparing forages with much larger lignin contents than found in forages used in the present study, forages in different stages of maturity and only one forage species. Results of the present study with sheep indicate that intake was not necessarily limited because a forage species contained a relatively high concentration of lignin. The positive correlation between intake and lignin comes about because the grasses were low in lignin and consumed in smaller amounts than the legumes. These results are not necessarily in opposition to the many findings indicating that intake decreased, as harvesting was delayed and lignin content increased. Meyer et al. (173) reported that lignin could not be used to predict forage quality when more than one forage species was involved.

A positive, though not significant ($P > .05$) correlation was found between intake by sheep and fiber content of the forages which is in opposition to general beliefs. These data might indicate that forage species had more effect on the ad lib. consumption than fiber content, when the forages were harvested on a similar calendar date.

Varying intakes of forage produced resulted in more variation in total energy consumed than did digestible energy concentration. Intake of experimental forages ranged from 3.63 to 2.24 lb/cwt. or a 62% increased in consumption of maximum over minimum forage intake compared to an increase of only 24.5% for dry matter digestibility. Thus there was 2.5 times more variation from minimum to maximum in forage dry matter intake/cwt than for % digestible dry matter. Other workers (44,67) have shown that total dry matter intake has a larger effect on animal response than the concentration of digestible energy in the forage.

Significant differences were found among _in vivo_ nutritive value indices (NVI) for the experimental forages. NVI values for trefoil ranged from 59.4 to 63.5 with an average value of 61.4 which included data from first and second cuttings for two consecutive years. Crampton _et al._ (67) reported an NVI value of 63 for early cut trefoil. In the present experiment NVI values for alfalfa harvested in 1961 were always lower than those of the corresponding trefoil. The reverse was found for 1962 forages. Thus over the two years there was little difference in average NVI values for trefoil and alfalfa. NVI values for brome grass and canary grass averaged 14.4 and 19.1 NVI units respectively lower than average alfalfa and trefoil NVI values. Crampton _et al._ (67) reported that the NVI value of alfalfa was 13 units below trefoil and that brome grass was 7 units below alfalfa. NVI values for timothy in the present experiments were about 9 NVI units higher than those listed by Crampton _et al._ (67). The present NVI values for canary grass ranged from 35.0 to 49.3 with an average of 42.2 which was slightly less than the average NVI values for timothy and brome grass.

Growing wethers were able to make satisfactory growth on first and second cutting alfalfa or trefoil forages (.22 and .24 lb/day respectively) harvested at a relatively early stage of plant maturity in early June. Wethers receiving first cutting 1961 and 1962 brome grass, canary grass or timothy averaged only 0.16, 0.12 and 0.07 lb of body weight gain per day. In contrast, wethers fed second cutting 1961 brome grass or canary grass lost weight, while 1962 second cutting brome grass and canary grass resulted in about 0.1 lb gain per day. The loss of body weight on the 1961 second cut grasses is difficult to explain. The second cut canary grass appeared to be a good hay. The brome grass however, was contaminated with some organic soil. These data indicate a nutritive value index (NVI) of 63 resulted in .25 lb of gain per day in contrast to 0.04 lb of gain per day for an NVI of 40. Starting at a maintenance level (NVI approximately 36) each increase of one NVI unit resulted in 0.009 lb of body weight gain per day while each increase of one dry matter NVI unit resulted in 0.011 lb of body weight gain per day. The above results were determined by regression. Similarily Crampton et al. (67) indicated that a change in one NVI unit resulted in 0.012 lb weight change per day.

Relationships among the criteria used to evaluate the forages were examined. Of all the criteria used to evaluate feed value of forages in this and other similar studies, body weight change or animal production has been considered the most important item to measure and to use in calculating relationships. Digestible energy intake per cwt, digestible dry matter intake per cwt and nutritive value indices (NVI) were correlated ($P < .01$) to body weight change ($r = +.72$, $+.78$ and $+.84$ respectively). Crampton et al. (67) reported that NVI were correlated to weight gain (r = +.88 to +.94). The above correlations were determined by using group averages. In the present study if individual animal values are used the correlation coefficient between NVI and body weight gain was much smaller (r = +.59).

Body weight change is a very difficult item to measure accurately, especially over short intervals. Weight gain of animals receiving 1962 forages were determined at several different time intervals during the experimental period (appendix Table X). A different weight change is indicated for each time interval used. Also weight gain determined over the different time intervals do not rank the forages in the same order. This was true especially for change in weight for the first 6 days after changing the animals to a new forage. For example wethers receiving timothy I gained .47 lb per day for the first six days while those receiving alfalfa I gained .27 lb. When weight gain was determined from the sixth to the 28th day, wether receiving timothy I gained .01 lb per day while those receiving alfalfa I gained .28 lb. Change in body fill may have been responsible for the discrepancy of the above results. Throughout this thesis the calculations presented are based on the difference between weight six days after the wethers were changed to each forage and the end of the experimental period. This period was chosen because it allows some time for body fill to reach a "steady state" and yet the longest possible length of time to measure body weight change. In order to measure small differences in body weight gains longer periods and more animals would be required.

Correlations between dry matter intake or digestible dry matter intake and digestible dry matter % were low (r = +.15 and +.20 respectively). These data indicate that digestibility of the dry matter was of little value in estimating dry matter intake or digestible dry matter intake of different forage species and cuttings. Although dry matter intake was correlated with animal gain, the correlation coefficients were larger when digestible dry matter intake or nutritive value indices were used. The latter two factors are a combination of dry matter intake and digestible energy concentration. Thus although digestible dry matter % was of little value in predicting animal response, when combined with intake data the relationship with animal response was improved compared to using either item alone.

Regressions of daily body weight gain on digestible dry matter intake, on digestible energy intake or on _in vivo_ nutritive value indices could be used to predict body weight gain with similar accuracy (Table 11). All three regression equations had a standard error of X on Y equal to about .07 lb. The above standard error of .07 lb is 17% of the observed maximum range (-.08 to .34 lb/day) found in average weight gains when the experimental forages were fed to growing wethers. Thus the above methods would indicate only large differences in forage nutritive value.

Correlation coefficients of nutritive value indices (NVI) with either digestible dry matter intake or digestible energy intake were large ($P < .01$, $r = .97$ and $.95$ respectively). These experiments indicate that the forages studied were ranked according to nutritive value (measured by weight gain) equally well by NVI values, dry matter values, digestible dry matter intake and digestible energy intake. NVI values are based on intake per unit of metabolic size while digestible dry matter intake and digestible energy intake were based on intake per cwt. The results of this experiment indicate that there was no advantage in predicting body weight gain by basing intake on metabolic size rather than intake per cwt. In the present trials average live body weights of the groups were approximately equal but individual body weights ranged from 70 to 110 lb.

Comparative Responses by Sheep, Heifers and Rabbits

Several workers have related forage dry matter digestion coefficients as determined by rabbits to those of the ruminant with varying results (70,128,218,219,270,271). Data from the present study involving several forages indicate that dry matter digestion coefficients of sheep and rabbits were not related. The correlation coefficients for dry matter digestibility between the two animal species were increased when grasses and legumes were considered separately.

Richards et al. (218,219) found similar results except that his correlation coefficients were larger than those found in the present study. Rabbits were able to digest a higher percentage of dry matter from legumes than from grasses. In contrast, the reverse tended to be true for sheep fed the same forages. Rabbits digested 63.0% and 77.1% as much of the dry matter in grasses and legumes, respectively, as did the sheep. Crampton et al. (70) reported that a pasture mixture was digested 71 to 85% as efficiently by rabbits as by steers.

The digestibility of dry matter had a greater effect on weight gain of rabbits than sheep. In the case of sheep, digestion coefficients of dry matter and weight gains were not significantly related ($P > .05$); however, weight gain and dry matter intake were correlated ($P < .01$). The reverse was found with rabbits. Cell wall constituents as determined by Van Soest were negatively ($P < .01$) related to dry matter digestion coefficients for rabbits but seemed to have little relationship to dry matter digestion coefficients determined by sheep. Weight gains by sheep and rabbits receiving the same forages were not significantly related ($P > .05$). These data support conclusions by Watson and Godden (271) as reported by Richards et al. (218) that rabbits could not be used to predict the nutritive value of a forage for ruminants.

Dry matter intake, digestible dry matter intake, dry matter nutritive value indices and body weight gains of rabbits and heifers were positively correlated ($P < .05$). The difference in observed response relationship between rabbit and sheep compared to that between rabbits and heifers if very difficult to explain.

Dry matter intake, digestible dry matter intake and dry matter nutritive value indices of sheep and heifers were correlated ($P < .05$). However, weight gains for the two animal species were not significantly related ($P > .05$). These data indicate a positive relationship of energy intake by sheep and heifers when receiving the same forages with no significant ($P > .05$) relationship between weight gains. Also weight gains of heifers were not significantly related to their energy intake. For these two reasons weight gains of heifers in this experiment were probably of little value in indicating the nutritive value of the experimental forages. Despite usual precautions and use of a 10 day preliminary period, the weight gains observed for the heifers appear of questionable value. A larger number of heifers with longer growing periods would be necessary to obtain sufficiently accurate weight gain data. However, dry matter intake or dry matter nutritive value indices as determined by the heifers would give an estimate of nutritive value for the experimental forages.

Several workers have indicated a relationship between digestion coefficients obtained on sheep and heifers, but there is little work comparing ad lib. intake and weight gains for the two animal species when the same forages were fed. Dry matter intake by sheep ranked trefoil first for each of the three 1961 cuttings, while intake by heifers ranked alfalfa first in each case. These differences were, however, small and not significant ($P > .05$). With heifers there was little difference in consumption of first cutting 1961 forages (2.3 to 2.6 lb/cwt). Intake/cwt of these same forages by sheep ranged from 3.3 lb for trefoil down to 2.4 lb for timothy. The correlation coefficient for dry matter intake, between sheep and heifers, though significant ($P < .05$), indicated that only 32% of variation found in dry matter consumption by heifers could be accounted for in dry matter consumption by sheep. These data indicated that dry matter intake by sheep may not rank forages in the same manner as intake by heifers.

Sheep consumed more forage per cwt than did the heifers. However, dry matter intake by sheep was determined from late fall to mid winter, while dry matter intake by heifers was determined during May when temperatures are warmer. Heifers consumed 94.8 g dry matter per $Wt._{kg}^{.75}$ which was larger than 83.6 g for rabbits and this in turn was larger than 70.3 g for sheep.

Relative intake (RI) of the forages was greater for heifers than for sheep with RI for rabbits being intermediate. All RI values for heifers and rabbits were determined by using Crampton's et al. (67) RI formula for sheep, i.e.,

$$RI = \frac{100 \times g \text{ daily forage DM intake}}{80\ (Wt._{kg}{}^{.75})}$$

Crampton and coworkers have suggested using a value of 140 in place of 80 in the above formula when dairy cows are used to determine forage nutritive value indices. The question arises as to what constant to use for heifers weighing 500 lb or any other intermediate weight. If 3 lb dry matter intake/cwt is a standard intake, researchers might better use this as a relative standard intake rather than intake per $Wt._{kg.}{}^{.75}$ corrected by a constant to equal 3 lb dry matter intake/cwt. The only reason for using relative intake was to compare dry matter intakes from trial to trial on a standard basis per unit metabolic size. If this is the intention, then all workers will have to use the same standard intake and express their individual values as a % of that standard. The necessity to use a different constant for each particular weight increment makes this cumbersome and time consuming, whereas expressing observed intake (lb/cwt) as a % of expected intake (3 lb/cwt) would aleviate all this mathematical manipulation.

In Vitro Fermentation vs. Animal Performance

In the present study the disappearance of forage dry matter was measured by an *in vitro* fermentation method described by Bowden and Church (41) with some modifications. Bowden and Church (41) concluded that with their *in vitro* fermentation method, variation between replicates were smaller when disappearance of dry matter rather than cellulose disappearance was measured. The literature as a whole indicates similar standard errors for *in vitro* cellulose and dry matter disappearance coefficients of forages. Bowden and Church (41) found dry matter disappearance of an alfalfa standard in 13 trials had a standard deviation of 1.9 and a coefficient of variation of 3.3%. In the present study duplicate disappearance values of dry matter for the 1962 standard alfalfa determined on 6 different days (or trials) resulted in a standard deviation of 2.3 and a coefficient of variation of 5.1 (Appendix Table XXIV). Bowden and Church (41) summarized data from several workers and listed standard deviation of ± 9.3 to 1.9 for *in vitro* cellulose digestion of forages. Standard errors and coefficients of variation in the present study ranged from .5 to 1.4 and 2.8 to 10.7% respectively (Appendix Table XXIII) for six hour disappearance of dry matter for the 1962 forages. Similar standard errors and coefficients of variation for 36 hour disappearance of dry matter ranged from .9 to 1.8 and 2.5 to 6.4 respectively. Coefficients of variation for dry matter disappearance of canary grass I and II tended to be higher than the other forages at the six hour fermentation interval. This difference was not apparent at other fermentation intervals. For comparison, the standard error of *in vivo* digestion of dry matter for the 1962 forages by four sheep ranged from .6 to 1.5. *In vitro* dry matter disappearance values for the 1961 forages had comparatively large standard errors and coefficients of variation (Appendix Table XXIII). The large standard errors were thought to be caused by variation in non-filterable dry matter from the rumen inoculum placed in each fermentation flask. The rumen inoculum was not settled before use in the 1961 forage fermentation trials. Allowing the strained rumen fluid to settle and removing the particulate matter reduced the non-filterable dry matter by a factor of 4.5 (Table 27). Also less rumen inoculum (24 vs. 60 ml) was used to digest the 1962 forages. The net result was a reduction of the variation between replicates by over half. Reduction in the amount of rumen inoculum and settling had little if any effect on the amount of dry matter that disappeared during fermentation (Tables 25 and 26) which is in agreement with work by Church and Peterson (58).

The thirty-six hour interval of fermentation resulted in the highest correlation (r = .72) with *in vivo* digestible dry matter % (Table 19). Bowden and Church (42) and Tilley *et al* (254) used 48 hour *in vitro* dry matter disappearance of dry matter to correlate with % *in vivo* digestibility while

Donefer et al.(82) used 24 hour cellulose digestion. Johnson et al. (130) used 12 hour in vitro cellulose digestion as an indicator of in vitro digestibility. These differences may be a result of the different in vitro systems comparing or coinciding with in vivo phenomenon at different times. Bowden and Church (42) summarizes the literature for correlations between in vitro digestibility and in vivo digestibility with r's ranging from .50 to .98. The above data would indicate that forages can be ranked according to in vivo digestibility by in vitro digestibility determinators only when there is a large range of values.

Of much more significance than digestibility of a forage is the amount that will be consumed. Daily intake/cwt of forages was correlated to 6 hour in vitro dry matter disappearance from 1962 forages (r = +.94), 1961 forages (r= +.54) and all forages (r = +.74). The lower correlations found between in vivo and in vitro data for the 1961 crop in comparison to data for the 1962 crop may be due to the very large variations in dry matter disappearance for replicates of the 1961 crop. Donefer et al. (82) reported that 12 hour in vitro cellulose digestion was correlated (r = .83) with relative intake of forages. Johnson et al. (130) also found that relative intake was correlated to 12 hour in vitro cellulose digestion (r=.87) when only grasses were considered. The correlation coefficient dropped to .69 when several alfalfa hays were included.

Disappearance of dry matter in the early portion of the *in vitro* fermentation (6 hr with the present study) may give values that indicate rate of forage degradation in the rumen and dry matter intake. Forages that were consumed in lesser amounts such as brome grass and canary grass in comparison to alfalfa and trefoil seem to have a slower rate of breakdown in the early portion of the fermentation period. Fermentation curves (Fig. 7 and 8) show the "lag" of dry matter disappearance of brome grass and canary grass and are similar to those of Donefer *et al.* (82) and Hershberger *et al.* (116). As the fermentation continues with time the dry matter disappearance curves cross over to rank the forages according to *in vivo* digestibility. This crossing over phenomenon was absent when four maturity stages of timothy were compared (48). However, there were differences in the lag period that were related to intake and digestibility of the forages. In the later case, digestibility of the forages would be positively related to intake whereas in the former case with crossing of dry matter disappearance curves there may be little relation between digestibility and *ad lib.* dry matter intake.

In vitro nutritive value index (NVI) (6 x 36 hr *in vitro* DM disappearance) values did not give a higher correlation with *in vivo* NVI than 6 hour dry matter disappearance values. Similar results were indicated by Johnson *et al.* (130)

and Donefer et al. (82). Digestible dry matter intake, digestible energy intake and dry matter NVI values were all highly correlated to 6 hour in vitro dry matter disappearance (r = +.85, .90, .89 respectively). Regression equations were calculated for the above relationships (Table 20). Daily digestible dry matter intake/cwt and digestible energy intake/cwt when estimated by 6 hour in vitro dry matter digestion had standard errors of estimate equal to .15 and .14 lb respectively. The standard error of estimates of nutritive value index from 6 hour in vitro dry matter disappearance was 4.0 compared to 5.5 from work by Donefer et al. (81). Although the slope of the regression (1.6 vs 1.3) is similar to that of Donefer et al. (81) the Y intercept is very different (7.0 vs -6.3). This difference may be due to differences in dry matter and cellulose disappearance or the fermentation system used. The fairly large standard errors of estimate indicate that only rather large differences in forage nutritive value will be indicated by this laboratory method of evaluating forages.

The six hour in vitro dry matter disappearance was correlated to weight gain (r = +.75). Other workers have failed to give any relation between their in vitro digestion values and body weight gain. The standard error of estimate was .07 for weight gain using 6 hour dry matter disappearance. With this large an error only forages that resulted in large differences in body weight gain could be evaluated by the above method.

Slaughter Trials

Slaughter trials were conducted to determine if the differences in *ad lib.* consumption by sheep of the pure stand forages could be explained by rumen fill. Blaxter *et al.*(34) suggested that sheep would eat forage until a constant fill was reached. Crampton *et al.* (67) suggested that hunger reoccurred when the rumen "load" or fill was reduced to a certain level and then ruminants would eat until some upper limit of fill was reached. Freer and Campling (96) concluded that dairy animals would consume roughage until the rumen reached a maximum fill or with poorer quality forages, to a level that would result in a certain maximum fill just before the next feeding. Data from the present experiment indicated that the relation between rumen fill and DM consumption is complex and that other controlling factors must play a role in regulating forage intake.

Six hours after feeding or midway between feedings, sheep receiving canary grass, though consumed in less quantities than some of the other forages, had a high rumen fill. There is some indication that rumen fill might have been a factor in limiting intake of canary grass.

Wet or dry rumen contents 6 hours after feeding were not significantly related to intake ($P > .05$). There was however, a positive correlation (r = +.76) between dry matter intake and rumen dry matter fill 12 hours after feeding or just previous to feeding. These findings might indicate rumen dry matter fill 12 hours after feeding is a result of the amount consumed. This relation, however, is based on only four forages each fed to 3 sheep.

Average dry matter intake (lb/cwt) of the experimental forages during the growth trials and the slaughter trials were different (Tables 6, 7 and 28). The forages tended to be ranked in the same order but the actual dry matter intake/cwt was different in some cases. This indicates the difficulty in repeating intake from trial to trial but the ranking appears repeatable.

Wet G.I. tract contents six hours after feeding varied from 17 to 24% of the body weight. Wet rumen contents as a percent of body weight varied from 11 to 18%. Waldo et al. (265) reported that wet rumen contents of cows receiving silage or hay ad lib. were 13.4% and 15.4% respectively which is in agreement with 12 to 13% found by Thomas et al. (251), and somewhat lower than found in the present experiments with sheep.

Rumen dry matter content as a percent of body weight ranged from 3.2% for sheep receiving trefoil II to 2.2% for those receiving alfalfa I. This compares with a value of 2.2% reported by Waldo et al. (265) for cows receiving hay *ad lib.* and to values of 1.7 and 1.5% reported by Thomas *et al.* (251)for cows fed hay and silage *ad lib.* respectively.

Average dry matter content in the rumen as a percent of the total G.I. tract content varied from 72.4% for alfalfa II to 83.8% for canary grass I. There tended to be a larger proportion of dry G.I. tract contents in the rumen of sheep receiving canary grass compared to the rumen of sheep receiving the other forages. This might indicate a slow digestion rate in the rumen of the sheep receiving canary grass which is supported by the slow 12 hour *in vitro* dry matter disappearance of canary grass. Thus rumen fill could be limiting intake of canary grass. Trefoil was consumed in large quanties and had high rumen fill in which case rumen fill may have prevented a higher intake. However the positive correlation between intake and ruman fill 12 hours after feeding also may indicate that this fill is a result of intake.

The amount of lignin and fiber in the rumen appeared to be a result of the amount consumed. The legumes, containing greater quantities of lignin, were consumed in larger amounts than the grasses, which were lower in lignin content. With the specific forages studied, lignin content of the forages or total intake of fiber and lignin did not appear to limit consumption. A positive correlation was found between dry matter intake and lignin content of the forages. This was in disagreement with work by Stallcup *et al.* (238). In many cases the negative correlation between intake and lignin content reported in the literature are confounded with a difference in harvest date or stage of plant maturity.

A positive correlation for all forages was found between dry matter intake and % dry matter in the rumen contents. Thomas *et al*. (251) found similar results. This would indicate that the digesta level in the rumen does not change directly with increased dry matter intake.

Rumen retention time was determined

$$(R = \frac{\text{DM in rumen}}{\text{Daily DM intake}})$$

to obtain some measure of how long the ingested forage stayed in the rumen or ingesta rate of passage. Retention time of the legumes was less than that of the grasses. The differences in passage rate may have been due, however, to increased intake. Cause and effect are difficult to separate in the above relationship. Palcheimo and Makela (192,193,194) found a curvelinear relation between dry matter intake and rumen retention time. Thomas *et al*. (251) found similar results. In both cases the relationship between retention time and intake was nearly linear from 1 to 2.5 lb forage dry matter intake/cwt.

Waldo *et al*. (265) reported that rumen retention time of dry matter was 1.07 days for cows receiving silage or hay *ad lib*. which increased to 1.4 days when intake of both was reduced to a maintenance level.

Fiber and lignin retention time decreased as intake of dry matter, fiber or lignin increased. This has to be true to a certain extent after a steady state is reached. For example dry matter is coming into the rumen and an equivalent amount has to leave the rumen each day or the rumen would become full of dry matter. However, this does not necessitate that a given food "particle" has to pass through the rumen in 24 hours, but that an equivalent amount will be passed which may include some of the previous day's intake where retention time is greater than one. Where it is less than one, the average food "particle" will pass on in less than 24 hours. The above relations probably indicate that with <u>ad lib</u>. forage intake, rumen retention time of dry matter, fiber or lignin was most affected by level of dry matter intake.

Rumen retention time of lignin was longer than that of fiber and dry matter. The retention time of fiber tended to be longer than that of dry matter. Paloheimo and Makela (194) reported lignin retention time measured by the method used in the present study as 1.7 times that of dry matter. The retention time of lignin from 1961 and 1962 forages in the present experiment was 1.7 and 2.0 respectively, times that of the dry matter.

Dry matter digested in the rumen amounted to 67 to 93% of the total dry matter digestion that occurred. Rumen dry matter and fiber digestibility from the 1962 forages was higher than that from the 1961 forages. The difference might be explained by the fact that total dry matter digestibility was larger for the 1962 forages. Balch (14) reported that 26 to 62% of the total dry matter digestion occurred in the rumen. The higher digestion coefficients in the rumen were from cows that were receiving some concentrate and the lower from an all roughage diet. Paloheimo and Makela (193) reported that 76 to 99% of the non N-free, non-lignin organic matter was digested in the rumen.

The concentration (µm/g) of acetate, propionate and butyrate in rumen digesta was greater at six hours postprandial than 12 hours postprandial, however, there was no difference in molar percent of the VFA at the two time intervals. The amount of butyrate and the molar percent of butyrate in the wether's rumen digesta were larger when fed alfalfa or trefoil, than when fed the grasses. Also the decrease in concentration of acetate and propionate from 6 to 12 hours after feeding tended to be greater for the legumes. This might indicate a different type of fermentation or a more rapid fermentation rate of the legumes with slower absorption of butyrate than acetate or propionate. Total VFA concentrations (92.3 to 118.9 µmoles/g rumen digesta) were normal for an all roughage ration as were molar % of acetate, propionate and butyrate.

SUMMARY

Pure stands of alfalfa, birdsfoot trefoil, brome grass, reed canary grass and timothy were harvested simultaneously in 1961 and 1962. First, second and third cuttings were harvested in 1961 while only first and second cuttings were available for the 1962 crop and only first cutting timothy was available both years. Fiber content of the forages ranged from 28 to 40% while the legumes contained up to 2 - 3 times more lignin than did the grasses harvested at the same time. A positive correlation was found between lignin content of the forages and dry matter intake/cwt. A significant negative correlation was found between lignin or fiber content of the forages and digestible dry matter %. Intake by sheep and heifers was negatively related to cell wall constituents while intake by rabbits did not appear to be so affected. Digestibility of the dry matter by sheep was not affected by cell wall constituents while digestibility of dry matter by rabbits was decreased.

Growing wethers were used to measure nutritive value of the forages in terms of animal performance. Dry matter intake by wethers ranked the 1961 forages in the order of birdsfoot trefoil, alfalfa, brome grass and reed canary grass. A similar pattern was shown for the 1962 forages except that alfalfa ranked ahead of birdsfoot trefoil. There was little difference in dry matter intake of first and second cut forages. Some differences were found in dry matter digestibility

of specific forages but when forages of all cuttings and both years were considered there was no difference in dry matter digestion coefficients for the different forage species. Digestible dry matter intake/cwt and nutritive value indices (NVI) followed a trend similar to that of dry matter intake. In most cases, NVI values ranked the two legumes at the top followed by brome grass and then reed canary grass. Weight gain was positively correlated to dry matter intake/cwt, digestible dry matter intake/cwt, dry matter nutritive value indices, and nutritive value indices. Digestibility of dry matter was not related to intake/cwt or weight gain. However, the product of dry matter digestibility and dry matter intake resulted in a larger correlation coefficient with weight gain than did either individually.

Regression equations of nutritive value index, dry matter nutritive value index and digestible dry matter intake on weight gain were about equal in precision of predicting weight gain as shown by similar correlation coefficients and standard errors of estimate. The standard errors of estimate (about .07 lb), however, were such that only large differences in forage nutritive value could be differentiated.

Dry matter intake, digestible dry matter intake, % digestible dry matter and dry matter nutritive value indices as determined by sheep were not related to the same values as determined by rabbits. Dry matter intake, digestible dry intake and dry matter nutritive value indices of rabbits and sheep were positively related to similar values determined by heifers. Weight gains of sheep and rabbits were not significantly (P > .05) related. Weight gains by rabbits appeared to be affected more by dry matter digestibility of the forages then dry matter intake whereas the reverse was true with sheep.

Artificial rumens were used to measure dry matter disappearance of the different forages at several time intervals. Initial in vitro dry matter disappearance was slower for the grasses than for the legumes. Dry matter disappearance values as determined by 6 hour fermentation periods were correlated with dry matter intake, digestible dry matter intake, dry matter nutritive value index, nutritive value index and body weight gains while dry matter disappearance at 36 hours was correlated to in vivo digestion coefficients. Correlation coefficients between weight gain and in vitro dry matter disappearance were larger when 6 hour rather than 6 hour x 36 hour (in vitro NVI) dry matter disappearance values were used and the standard error of estimate for the regression equation was smaller. Six hour in vitro dry matter disappearance as determined by 6 hour fermentation periods was effective in predicting the nutritive values of forages when there were large differences in nutritive value.

Wethers receiving experimental forages were slaughtered and their rumen contents examined to ascertain the relationships between rumen contents of dry matter, fiber or lignin and intake. Rumen digesta from sheep receiving the legumes contained a higher percentage of dry matter, fiber and lignin than those receiving brome grass or reed canary grass. A significant positive relationship was found between dry matter intake and % dry matter in the rumen. Sheep consumed the reed canary grass in smaller amounts than some of the other forages but their rumen contained the largest amounts of wet and dry rumen material 6 hours after feeding. The rumens of sheep fed birdsfoot trefoil which was consumed in larger quantities than some of the other forages also contained relatively large amounts of dry matter in the rumen. The relation between amount of dry matter in the rumen and ad libitum intake appeared complex and indicated there probably were other factors playing a role in controlling ad libitum intake. There was some indication that amount of dry matter in the rumen was a limiting factor in the consumption of reed canary grass. With the specific forages studied, lignin content of the forages or total intake of fiber and lignin did not appear to limit consumption. Rumen content of fiber and lignin was positively related to intake of fiber and lignin and did not appear to exert a limiting effect on intake.

Rate of passage was measured in terms of rumen retention time. Rumen retention time of dry matter was about six tenths of a day for the legumes and one day for the grasses. As dry matter, fiber and lignin intake increased, retention time of each constituent decreased. The differences in passage rate may be due to differences in dry matter intake or differences in intake may be limited by passage rate. Further studies will be necessary to determine which was the cause or effect.

Rumen retention time of lignin was greater than that of fiber, which was greater than that of dry matter. Thus, some portions of the dry matter were passing through the rumen faster than fiber and lignin.

Dry matter digested in the rumen amounted to 67 to 93% of the total dry matter digestion in the entire G.I. tract. Rumen dry matter digestion coefficients for the 1962 forages were larger and made up a larger portion of the total dry matter digestion coefficients than those for the 1961 forages which had lower total dry matter digestion coefficients. The proportion of fiber digested in the rumen compared to the entire G.I. tract was similar to that of dry matter.

Rumen digesta from sheep receiving birdsfoot trefoil I contained a higher concentration of total VFA than did wethers receiving reed canary grass I. Butyrate concentration was greater in the rumens of sheep receiving legumes rather than the grasses while there were no significant differences in acetate or propionate concentrations.

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Appendix Table I

Average Daily DM Intake of Forage by Sheep Through the Experimental Period

Forage - 1961

Day	Tim. I	Alf. I	Tre. I	Brome I	Reed I	Alf. II	Tre. II	Brome II	Reed II	Alf. 2	Alf. III	Tre. III	Brome III	Reed III	Avg.
								lb/day							
1	2.51	2.40	2.59	1.42	2.15	2.60	2.01	2.07	1.51	2.12	2.23	2.38	1.94	1.59	2.11
2	2.21	2.27	2.60	1.45	2.10	2.59	2.14	1.91	1.63	2.16	2.13	2.08	2.20	1.25	2.05
3	2.31	2.34	2.70	1.71	2.02	2.52	2.58	1.99	1.63	2.52	2.18	2.54	2.01	1.61	2.19
4	2.28	2.40	2.69	1.79	1.91	2.44	2.84	2.18	1.69	2.56	2.24	2.54	1.97	1.61	2.24
5	2.21	2.45	2.79	1.89	2.10	2.47	2.77	2.06	1.78	2.52	2.17	2.51	2.16	1.88	2.27
6	2.30	2.36	2.86	2.02	2.14	2.51	2.82	2.08	1.80	2.55	2.23	2.70	2.16	1.80	2.31
7	2.27	2.45	2.87	2.03	2.32	2.54	2.87	2.24	1.83	2.63	2.23	2.71	2.25	2.08	2.38
8	2.33	2.39	2.96	2.18	2.13	2.57	2.78	2.24	1.89	2.79	2.33	2.72	2.21	1.87	2.40
9	2.17	2.56	2.84	2.04	2.29	2.66	2.89	2.22	1.82	2.76	2.18	2.88	2.18	1.57	2.36
10	2.14	2.56	2.59	2.25	2.27	2.76	3.08	2.37	1.76	2.84	2.32	2.84	2.14	1.85	2.41
11	2.10	2.58	2.85	2.12	2.19	2.76	2.98	2.36	1.78	2.79	2.26	2.84	2.18	2.02	2.42
12	2.20	2.67	2.79	2.01	2.21	2.78	3.04	2.15	1.79	2.60	2.23	2.72	2.19	1.77	2.37
13	1.98	2.56	2.92	2.18	2.29	2.80	3.13	2.36	1.83	2.52	2.12	2.71	1.99	2.01	2.39
14	2.31	2.53	2.62	2.17	2.02	2.64	2.86	2.06	1.83	2.49	2.22	2.52	2.08	1.87	2.30
15	2.24	2.46	2.73	2.00	2.14	2.64	2.94	2.27	1.78	2.46	2.22	2.42	2.12	1.88	2.31
16	2.06	2.48	2.71	1.95	2.12	2.70	2.87	2.19	1.77	2.38	2.26	2.41	2.09	1.85	2.27
17	1.93	2.55	2.65	2.07	2.11	2.53	2.91	2.20	1.87	2.42	2.21	2.43	2.02	2.08	2.28
18	2.26	2.44	2.70	2.18	2.04	2.58	2.87	2.10	1.92	2.44	2.15	2.47	2.02	2.14	2.31
19	2.02	2.48	2.45	2.23	1.98	2.44	2.92	2.07	1.90	2.45	2.20	2.42	1.96	1.90	2.24
20	2.15	2.47	2.63	2.05	1.91	2.43	2.89	2.00	1.84	2.53	2.07	2.34	1.98	1.90	2.23
21	2.17	2.47	2.76	2.15	1.95	2.43	2.90	2.00	1.92	2.48	2.08	2.54	1.97	2.03	2.28
22	2.25	2.54	2.74	2.27	2.16	2.64	2.71	1.97	1.88	2.51	2.11	2.33	1.72	1.91	2.27
23	2.15	2.38	2.63	2.22	2.01	2.66	2.88	2.00	1.78	2.45	2.05	2.35	1.78	2.18	2.25
24	2.40	2.51	2.91	2.20	1.97	2.79	3.09	1.98	2.02	2.36	2.50	2.43	1.93	1.88	2.36
25	2.27	2.58	3.04	2.25	2.04	2.80	3.23	2.06	1.73	2.41	2.15	2.64	1.63	2.05	2.35

continued

Appendix Table I continued

Forage - 1962

Day	Alf. I	Tre. I	Brome I	Reed I	Tim. I	Alf. II	Tre. II	Brome II	Reed II	Avg.
					lb/day					
1	2.29	2.19	1.96	1.68	1.78	2.40	1.84	1.93	.90	1.87
2	2.52	2.55	1.87	1.20	1.97	2.54	2.30	1.85	.66	1.93
3	2.43	2.66	2.00	1.52	2.12	2.33	2.43	2.04	.90	2.04
4	2.20	2.63	2.11	1.51	2.20	2.30	2.57	2.13	1.08	2.08
5	2.30	2.56	1.94	1.66	2.14	2.47	2.42	1.90	1.32	2.07
6	2.18	2.61	2.10	1.68	2.20	2.60	2.28	2.10	1.50	2.14
7	2.26	2.56	1.88	1.78	2.29	2.64	2.14	1.96	1.80	2.14
8	2.49	2.57	1.96	1.58	2.39	2.70	2.28	1.93	2.00	2.21
9	2.73	2.70	1.97	1.72	2.33	2.85	2.46	1.98	1.72	2.27
10	2.59	2.52	1.96	1.79	2.12	2.77	2.44	1.72	1.60	2.16
11	2.64	2.45	1.83	1.61	1.92	2.64	2.32	1.80	1.78	2.11
12	2.63	2.45	2.05	1.66	2.06	2.72	2.28	1.72	1.58	2.12
13	2.50	2.64	1.71	1.62	1.91	2.41	2.28	1.53	1.58	2.01
14	2.60	2.15	1.78	1.76	2.00	2.53	2.02	1.97	1.62	2.05
15	2.68	2.24	1.96	1.75	2.00	2.67	2.51	1.68	1.89	2.28
16	2.45	2.52	2.00	1.84	2.12	2.67	2.54	1.91	1.96	2.23
17	2.61	2.24	1.85	1.72	2.17	2.73	2.44	1.64	1.96	2.16
18	2.53	2.24	1.80	1.39	2.04	2.59	2.20	1.88	1.69	2.04
19	2.34	2.37	1.81	1.58	1.99	2.61	2.26	1.99	1.68	2.08
20	2.55	2.35	1.86	1.56	1.85	2.48	2.26	2.00	1.54	2.05
21	2.60	2.48	1.90	1.61	1.94	2.74	2.46	2.04	1.76	2.18
22	2.53	2.54	2.02	1.74	2.11	2.73	2.40	2.01	1.94	2.23
23	2.72	2.06	2.00	1.76	2.16	2.51	1.95	2.06	1.87	2.12
24	2.35	2.34	1.98	1.74	2.18	2.65	1.99	2.03	1.90	2.13
25	2.74	2.50	1.88	1.53	1.84	2.62	2.32	1.93	1.84	2.14
26	2.54	.2.50	2.00	1.44	1.78	2.48	2.26	2.08	1.89	2.12

Appendix Table II

Digestible Organic Matter, Digestible Energy and Estimated TDN Values for Pure Stand Forages for Each Individual Sheep by Period

Forage 1961	% Dig. Organic Matter Period A	B	C	D	Avg	% Estimated TDN[1] Period A	B	C	D	Avg
Alf.I	60.00	63.45	64.60	61.96	62.50	56.54	59.79	60.87	58.38	58.89
Tre. I	62.06	63.77	62.47	64.75	63.26	60.11	61.77	60.51	62.72	61.28
Brome I	58.03	63.16	60.87	63.10	61.29	55.06	59.93	57.75	59.87	58.15
Reed I	63.14	66.75	68.79	65.68	66.09	60.27	63.71	65.66	62.69	63.08
Tim. I	62.33	66.18	63.09	65.35	64.24	60.90	64.66	61.64	63.85	62.76
Alf.II	56.76	57.75	59.21	62.68	59.10	53.46	54.39	55.76	59.03	55.66
Tre.II	59.40	60.71	63.14	63.61	61.71	57.15	58.42	60.75	61.21	59.39
Brome II	55.57	57.34	58.53	54.50	56.48	53.95	55.67	56.82	52.91	54.84
Reed II	53.91	55.01	56.94	56.08	55.48	52.29	53.36	55.23	54.40	53.82
Alf.2	64.76	68.99	69.11	-	67.62	60.10	64.03	64.14	-	62.76
Alf.III	58.68	58.54	60.70	61.99	59.98	53.94	53.82	55.80	56.99	55.14
Tre.III	66.31	68.86	68.00	67.85	67.75	61.65	64.03	63.23	63.09	63.00
Brome III	63.81	68.49	63.47	68.21	65.99	61.06	65.54	60.73	65.27	63.15
Reed III	67.66	68.09	67.36	67.64	67.69	63.23	63.63	62.95	63.21	63.25

	% Dig.Energy				
Alf.I	54.12	59.51	61.90	57.19	58.18
Tre.I	58.46	65.10	-	61.67	61.74
Brome I	52.19	58.06	54.79	56.61	55.41
Reed I	60.01	65.84	65.74	61.71	63.32
Tim. I	56.13	60.76	57.01	59.46	58.34
Alf. II	51.90	52.67	54.17	57.94	54.17
Tre. II	54.59	55.57	59.66	58.60	57.10
Brome II	55.56	56.09	58.07	52.33	55.51
Reed II	49.10	49.56	52.45	50.59	50.42
Alf.2	61.39	67.70	66.55	-	65.21
Alf.III	53.87	57.40	56.74	57.79	56.45
Tre.III	60.63	-	63.28	63.25	62.39
Brome III	-	63.69	58.21	62.57	61.49
Reed III	63.05	64.17	63.50	63.24	63.49

continued

[1]By method of Lofgreen - J.Animal Sci., 12:359, 1953.

Appendix Table II continued

Forage 1962	% Dig. Organic Matter Period					% Estimated TDN[1] Period				
	A	B	C	D	Avg	A	B	C	D	Avg
Alf. I	67.38	62.93	67.11	67.23	66.16	65.03	58.88	62.79	62.91	62.40
Tre.I	61.44	64.52	63.14	64.51	63.40	59.29	62.26	60.93	62.25	61.18
Brome I	65.30	65.25	69.97	67.29	66.95	62.16	62.11	66.60	64.05	63.73
Reed I	61.94	68.81	63.11	65.80	64.91	59.56	66.17	60.69	63.27	62.42
Tim. I	61.12	62.66	65.29	61.67	62.68	60.61	62.13	64.74	61.15	62.16
Alf. II	62.28	63.36	61.31	64.64	62.90	58.99	60.01	58.07	61.22	59.57
Tre. II	63.18	64.28	61.96	63.89	63.33	60.77	61.82	59.59	61.45	60.91
Brome II	63.85	64.46	69.26	65.74	65.83	61.53	62.12	66.75	63.35	63.44
Reed II	59.68	58.80	63.49	61.74	60.86	57.64	56.79	61.32	59.63	58.84

	% Dig. Energy				
Alf. I.	65.05	62.85	64.84	65.18	64.48
Tre. I	61.49	61.25	61.48	61.73	61.48
Brome I	62.12	62.41	65.93	64.52	63.74
Reed I	60.75	67.10	61.95	64.52	63.58
Tim.I.	58.92	60.98	62.61	59.24	60.44
Alf.II	64.48	65.34	63.45	66.43	64.92
Tre.II	60.06	62.48	59.09	61.33	60.74
Brome II	60.22	60.32	66.43	62.91	62.47
Reed II	57.82	56.85	61.47	59.99	59.03

Simple Correlation Coefficients

1961	% dig. energy vs. % dig. DM	r = .85
1962	% dig. energy vs. % dig. DM	r = .47
1961-1962	% dig.energy vs. % dig. DM	r = .81
1961	% dig. DM vs. % estimated TDN	r = .95
1962	% dig. DM vs. % estimated TDN	r = .54
1961-1962	% dig. DM vs. % estimated TDN	r = .94

[1] By method of Lofgreen - J. Animal Sci., 12: 359, 1953

Appendix Table III

Daily DM Intake/Cwt of Forages by Individual Sheep (avg. day 7-25)

Forage 1961	Period A	B	C	D	Average	S.E.
	lb/day					
Alf. I	2.981	2.932	2.878	3.203	2.999	.07
Tre. I.	3.665	3.133	3.153	3.115	3.267	.13
Brome I	2.884	2.759	2.386	2.423	2.613	.12
Reed I	2.568	3.071	1.927	2.463	2.507	.23
Alf.II	3.714	3.297	2.907	2.860	3.195	.20
Tre.II	3.452	3.825	3.653	3.587	3.629	.08
Brome II	2.644	2.833	2.247	2.695	2.605	.13
Reed II	2.352	2.297	1.955	2.421	2.256	.10
Alf.III	3.058	2.750	2.383	2.656	2.712	.14
Tre.III	2.610	2.896	2.961	2.933	2.850	.08
Brome III	2.217	3.067	2.449	2.432	2.541	.18
Reed III	2.477	1.760	2.650	2.638	2.381	.21
Tim. I	2.635	2.391	2.191	2.491	2.427	.09
Alf.2	2.196	2.778	2.739	3.360	2.768	.24

<u>Avg.day 8-21</u>

Forage 1962	Period A	B	C	D	Average	S.E.
Alf.I	3.706	3.597	3.603	3.191	3.524	.11
Tre.I	3.182	3.185	3.391	3.058	3.204	.07
Brome I	3.192	2.729	2.374	2.504	2.700	.18
Reed I	2.628	2.292	2.219	1.830	2.242	.16
Tim.I	2.333	3.016	2.348	2.948	2.661	.19
Alf.II	3.951	3.869	3.065	3.456	3.585	.21
Tre.II	4.131	3.509	3.124	2.614	3.344	.32
Brome II	2.937	2.632	2.387	2.302	2.564	.14
Reed II	2.865	2.190	2.466	1.969	2.372	.19

Appendix Table IV

Digestible DM % of Forages by Individual Sheep[1]

Forage 1961	Period A (%)	Period B (%)	Period C (%)	Period D (%)	Average	S.E.
Alf.I	57.98	60.64	61.43	59.92	59.99	.73
Tre.I	60.18	60.90	61.52	63.41	61.50	.69
Brome I	60.36	61.47	62.15	63.72	61.93	.70
Reed I	64.26	66.31	65.00	64.95	65.13	.42
Alf.II	53.80	52.39	56.86	60.27	55.83	1.75
Tre.II	58.06	60.18	60.50	61.21	59.99	.68
Brome II	55.64	56.94	53.68	54.20	55.11	.73
Reed II	55.64	54.29	54.32	58.11	55.59	.90
Alf.III	54.14	54.64	57.73	59.70	56.55	1.35
Tre.III	62.08	65.73	63.43	65.31	64.14	.85
Brome III	63.11	67.07	62.85	65.80	64.71	1.03
Reed III	69.13	69.48	67.27	68.64	68.63	.48
Alf.2	62.04	66.47	66.66	65.31	65.12	1.07
Tim.	61.44	64.52	62.85	66.33	63.78	1.05

Forage 1962	Period A (%)	Period B (%)	Period C (%)	Period D (%)	Average	S.E.
Alf.I	66.0	63.4	65.9	66.0	65.3	.64
Tre.I	60.0	62.7	60.96	63.2	61.7	.74
Brome I	65.3	65.6	69.2	67.2	66.8	.89
Reed I	62.0	68.9	63.2	66.0	65.0	1.54
Tim.I	60.6	62.4	64.7	61.2	62.2	.90
Alf.II	60.3	61.6	59.1	62.3	60.8	.71
Tre.II	61.8	62.9	61.0	64.6	62.5	.78
Brome II	64.1	64.8	69.2	66.2	66.1	1.13
Reed II	59.6	59.0	63.8	61.9	61.1	1.10

[1]Zero time sequence was used between the computing of feed intake and collection of feces.

Appendix Table V

Daily Digestible DM Intake/Cwt of Forages by Individual Sheep
(avg. day 7-25)

Forage 1961	Period A	B (lb/day)	C	D	Average	S.E.
Alf. I	1.788	1.759	1.726	1.921	1.798	.04
Alf.II	2.074	1.841	1.623	1.597	1.784	.11
Alf.III	1.729	1.555	1.348	1.502	1.534	.08
	1.362	1.847	1.826	2.194	1.807	.17
Tre.I	2.254	1.927	1.939	1.916	2.009	.08
Tre.II	2.177	2.295	2.191	2.152	2.204	.03
Tre.III	1.674	1.857	1.899	1.881	1.828	.05
Brome I	1.786	1.709	1.478	1.501	1.618	.08
Brome II	1.457	1.561	1.238	1.485	1.435	.07
Brome III	1.435	1.985	1.585	1.574	1.645	.12
Reed I	1.672	2.000	1.255	1.604	1.633	.15
Reed II	1.307	1.277	1.087	1.346	1.254	.06
Reed III	1.670	1.208	1.819	1.810	1.627	.14
Tim.I	1.619	1.543	1.377	1.652	1.548	.06

Forage 1962	A	B (lb/day)	C	D	Average	S.E.
Alf.I	2.446	2.280	2.374	2.106	2.301	.073
Tre.I	1.909	1.997	2.067	1.933	1.976	.035
Brome I	2.084	1.790	1.643	1.683	1.800	.099
Reed I	1.629	1.579	1.402	1.208	1.454	.096
Tim.I	1.414	1.882	1.519	1.804	1.654	.112
Alf.II	2.382	2.383	1.811	2.153	2.182	.135
Tre.II	2.553	2.207	1.906	1.689	2.088	.188
Brome II	1.883	1.706	1.652	1.524	1.691	.074
Reed II	1.708	1.292	1.573	1.219	1.448	.115

Appendix Table VI

Daily Digestible Energy Intake/Cwt of Forages
by Individual Sheep (avg.day 7-25)

Forage 1961	Period A	B	C	D	Average	S.E.
	lb/day					
Alf.I.	1.613	1.745	1.781	1.832	1.743	.046
Tre.I	2.143	2.040	1.947	1.921	2.013	.050
Brome I	1.505	1.602	1.307	1.372	1.446	.067
Reed I	1.541	2.022	1.267	1.520	1.588	.158
Tim.I	1.479	1.453	1.249	1.481	1.416	.055
Alf.II	1.928	1.737	1.575	1.657	1.724	.074
Tre.II	1.884	2.126	2.179	2.102	2.073	.063
Brome II	1.469	1.589	1.305	1.410	1.443	.059
Reed II	1.155	1.138	1.025	1.225	1.136	.039
Alf.2	1.348	1.881	1.823	2.191	1.811	.175
Alf.III	1.647	1.578	1.352	1.535	1.528	.063
Tre.III	1.582	1.807	1.874	1.855	1.780	.067
Brome III	1.363	1.953	1.426	1.522	1.566	.132
Reed III	1.562	1.129	1.683	1.668	1.510	.130

Avg. day 8-21

Forage 1962	Period A	B	C	D	Average	S.E.
	lb/day					
Alf.I	2.225	2.261	2.336	2.080	2.272	.055
Tre.I	1.957	1.951	2.085	1.888	1.970	.041
Brome I	1.983	1.703	1.565	1.616	1.721	.093
Reed I	1.596	1.538	1.375	1.181	1.426	.093
Tim.I	1.375	1.839	1.470	1.746	1.608	.110
Alf.II	2.548	2.528	1.945	2.296	2.327	.140
Tre.II	2.481	2.192	1.846	1.603	2.031	.193
Brome II	1.769	1.588	1.586	1.448	1.602	.066
Reed II	1.656	1.245	1.516	1.181	1.400	.112

Appendix Table VII

In Vivo DM NVI Values for the Pure Stand Forages as Determined by Individual Sheep

Forage 1961	Period A	B	C	D	Average	S.E.
Alf.I	51.14	56.27	54.98	60.75	55.78	1.98
Alf.II	60.90	51.24	52.31	54.36	54.70	2.16
Alf.III	49.43	45.52	43.59	49.93	47.11	1.53
Alf.2	42.62	57.24	58.33	68.63	56.71	5.35
Tre.I	67.04	57.67	59.80	64.63	62.28	2.15
Tre.II	62.70	70.77	68.73	64.79	66.74	1.83
Tre.III	68.35	70.86	57.53	60.67	64.35	3.14
Brome I	51.73	52.25	47.83	47.00	49.70	1.33
Brome II	43.51	49.31	38.13	46.88	44.45	2.42
Brome III	41.97	62.44	47.96	50.46	50.70	4.30
Reed I	51.34	61.60	38.41	51.70	50.76	4.75
Reed II	39.67	39.58	31.63	44.04	38.73	2.58
Reed III	50.60	37.87	55.18	57.42	50.26	4.37
Tim.I	50.07	48.78	43.12	53.86	48.96	2.20
Forage 1962	**Period A**	**B**	**C**	**D**	**Average**	**S.E.**
Alf.I	68.0	67.3	74.3	65.3	68.7	1.94
Tre.I	54.8	56.9	64.2	62.6	59.6	2.24
Brome I.	59.9	53.8	50.0	49.8	53.4	2.36
Reed I	48.4	46.6	40.8	38.1	43.5	2.42
Tim.I	41.8	55.7	46.9	56.7	50.3	3.58
Alf.II	67.7	71.1	56.0	67.2	65.5	3.28
Tre.II	73.7	65.5	55.9	52.6	61.9	4.78
Brome II	54.4	50.8	50.9	45.4	50.4	1.86
Reed II	50.1	37.2	48.0	38.2	43.4	3.31

Appendix Table VIII

Weight Gain for Sheep Receiving the Experimental Forates
(day 7-25)

Forage 1961	Period A	Period B	Period C	Period D	Average	S.E.
		lb/18 days				
Alf.I	2.93	2.14	2.24	6.33	3.41	.99
Tre.I	5.17	1.44	5.58	7.34	4.88	1.24
Brome I	- .03	.10	.33	8.17	2.14	2.01
Reed I	3.43	5.11	-6.17	9.00	2.84	3.22
Tim.I	.73	.43	- .79	2.00	.59	.57
Alf.II	2.63	3.00	4.24	5.00	3.72	.55
Tre.II	3.63	5.40	3.91	11.24	6.04	1.77
Brome II	- .53	2.24	-5.69	2.27	- .43	1.87
Reed II	.47	-2.33	-4.79	1.17	-1.37	+1.37
Alf.2-A	3.83	2.39	7.50	7.00	5.18	1.23
Alf.III	1.70	-2.80	- .83	3.90	.49	1.46
Tre.III	7.53	3.83	1.75	8.24	5.34	1.54
Brome III	1.90	2.66	3.91	5.50	3.50	.79
Reed III	4.67	-3.26	4.39	8.46	3.56	2.46

Avg.day 6-28

Forage 1962	Period A	Period B	Period C	Period D	Average	S.E.
		lb/22 days				
Alf.I	1.9	11.7	6.0	5.2	6.20	2.04
Tre.I	2.0	2.9	5.2	4.5	3.65	.73
Brome I	1.5	2.8	6.4	6.0	4.18	1.20
Reed I	-1.2	3.0	3.1	1.4	1.58	1.00
Tim.I	0	- .8	.7	1.3	.30	.48
Alf.II	2.5	1.0	5.5	6.3	3.82	1.25
Tre.II	4.8	5.7	.2	5.0	3.92	1.26
Brome II	2.5	2.3	1.9	3.4	2.52	.32
Reed II	5.5	1.0	3.0	.8	2.58	1.09

Appendix Table IX

Digestible DM % of Pure Stand Forages Based on Intake 48 Hours Prior to Feces Collection[1,2]

Forage 1961	Period A (%)	B (%)	C (%)	D (%)	Average (%)	S.E. (%)
Alf.I	57.2	60.8	61.7	59.3	59.8	.98
Tre.I	60.4	62.4	60.7	63.3	61.7	.69
Brome I	58.8	63.5	61.6	63.5	61.8	1.11
Reed I	63.6	67.2	69.3	66.1	66.6	1.19
Tim.I	61.8	65.7	62.8	65.1	63.8	.93
Alf.II	54.4	55.5	57.1	60.1	56.8	1.24
Tre.II	57.5	59.1	61.6	62.1	60.1	1.08
Brome II	55.0	56.9	58.0	53.9	56.0	.92
Reed II	54.1	55.1	57.1	56.0	55.6	.64
Alf.III	56.2	55.8	58.2	59.0	57.3	.77
Tre.III	62.5	66.6	64.5	64.4	64.5	.84
Brome III	63.3	68.2	63.2	67.7	65.6	1.36
Reed III	67.8	68.5	67.2	67.8	67.8	.08

[1]Forty eight hour lag in time between feeding and collection of feces.

[2]Data were not used in any of the other calculations.

Appendix Table X

Average Sheep Weight Gain on 1962 Pure Stand Forages For Different Portions of the Experimental Period

Forage 1962	Day 6 through 14 lb/day	Day 14 through 28 lb/day	End one trial to end of next lb/day	Day 6 through 28 lb/day	First 6 days lb/day
Alf.I	.34	.25	.32	.28	.27
Tre.I	.22	.14	.25	.17	.48
Brome I	.21	.18	.25	.19	.26
Reed I	.22	.01	.14	.07	.29
Tim.I	.09	.07	.09	.01	.47
Alf.II	.15	.19	.21	.17	.35
Tre.II	.21	.19	.31	.18	.56
Brome II	.16	.09	.20	.11	.50
Reed II	.28	.03	.12	.12	.41

Appendix Table XI

In Vivo NVI for Experimental Forages as Determined by Individual Sheep (Relative Intake x % Dig.Energy)

Forage 1961	Period A	B	C	D	Average
Alf.I	47.73	55.22	55.40	57.98	54.08
Alf.II	58.75	51.51	49.84	52.26	53.09
Alf.III	49.18	47.81	42.84	48.33	47.04
Alf.2	42.17	58.30	58.23	68.52	56.81
Tre.I	65.12	61.65	60.01	62.93	62.43
Tre.II	58.96	65.35	67.77	62.03	63.53
Tre.III	66.75	67.26	57.39	58.75	62.54
Brome I	44.73	49.35	42.17	41.76	44.50
Brome II	43.45	48.57	41.25	45.27	44.63
Brome III	40.89	59.30	44.42	47.98	48.15
Reed I	47.95	61.17	38.85	49.12	49.27
Reed II	35.01	36.13	30.54	38.34	35.01
Reed III	46.15	34.97	52.09	52.91	46.53
Tim.I	45.75	45.93	39.11	48.28	44.77
Forage 1962					
Alf.I	67.07	66.68	73.14	64.53	67.86
Alf.II	72.41	75.47	60.09	71.61	69.90
Tre.I	56.14	55.55	64.74	61.11	59.38
Tre.II	71.65	65.10	54.13	49.92	60.20
Brome I	56.96	51.18	47.60	47.81	50.89
Brome II	51.13	47.29	48.89	43.16	47.62
Reed I	47.45	45.36	39.96	37.23	42.50
Reed II	48.57	35.87	46.29	37.07	41.95
Tim.I	40.60	54.39	45.39	54.86	48.81

Simple Correlation Coefficient

NVI using % dig. energy vs. DM NVI using % dig. DM r = .97

Appendix Table XII

Sequence of Individual Sheep on the Experimental Forages

Forages 1961	Period A	B	C	D
	Sheep Number			
Alf.I	18	17	16	19
Tre.I	16	18	19	17
Brome I	19	16	17	18
Reed I	17	19	18	16
Tim.I	21	24	21	24
Alf.II	22	12	20	15
Tre.II	20	22	15	12
Brome II	12	15	22	20
Reed II	15	20	12	22
Alf.2	24	21	24	18
Alf.III	25	13	23	14
Tre.III	14	23	13	25
Brome III	23	25	14	13
Reed III	13	14	25	23
Forages 1962				
Alf.I	6	7	11	10
Tre.I	10	6	7	11
Brome I	7	11	10	6
Reed I	11	10	6	7
Tim.I	4	677	4	677
Alf.II	5	2	9	8
Tre.II	8	9	5	2
Brome II	9	8	2	5
Reed II	2	5	8	9

Appendix Table XIII

Analysis of Variance of Combined 1961 and 1962
Sheep Performance When Receiving First Cutting Forages

Source	D.F.	Sum Square	Mean S. Square	F
		Daily DM Intake/Cwt.		
Year	1	.0406	.0406	-
Species	3	4.6154	1.5384	26.21**
Period	3	.7938	.2646	4.51*
Y X S	3	.6766	.2251	3.83
Y X P	3	.2483	.0827	1.41
S X P	9	.4663	.0518	-
error	9	.5291	.0587	
Total	31	7.3690		
		% Digestible DM		
Year	1	53.4578	53.4578	23.26**
Species	3	60.1524	20.0508	8.73**
Period	3	23.4160	7.8053	3.40
Y X S	3	51.5457	17.1819	7.48**
Y X P	3	.2890	.0963	-
S X P	9	25.7227	2.8580	1.24
error	9	20.6814	2.2979	
Total	31	235.2650		
		Daily Digestible DM Intake/Cwt.		
Year	1	.1123	.1123	5.48*
Species	3	1.3707	.4569	22.29**
Period	3	.2718	.0906	4.42*
Y X S	3	.5252	.1750	8.54**
Y X P	3	.0839	.0279	1.36
S X P	9	.2200	.0244	1.19
Error	9	.1849	.0205	
Total	31	2.7688		

continued

Appendix Table XIII Continued

Source	D.F.	Sum Square	Mean S. Square	F
		In Vivo DM NVI Values		
Year	1	22.2111	22.2111	1.27
Species	3	1290.5561	430.1853	24.51**
Period	3	42.9938	14.3312	-
Y X S	3	460.0171	153.3390	8.74**
Y X P	3	99.7283	33.2427	1.89
S X P	9	337.5394	37.5043	2.14
Error	9	157.9399	17.5488	
Total	31	2410.9857		
		Body Weight Gain		
Year	1	2.6970	2.6970	-
Species	3	32.2065	10.7355	1.72
Period	3	71.9415	23.9805	3.84
Y X S	3	27.3845	9.1281	1.46
Y X P	3	88.2345	29.4115	4.71*
S X P	9	72.5640	8.0626	1.29
Error	9	56.2270	6.2474	
Total	31	351.2550		

Appendix Table XIV

Analysis of Variance of Combined 1961 and 1962 Sheep Performance When Receiving Second Cutting Forages

Source	D.F.	Sum Square	Mean S. Square	F
		Daily DM Intake/Cwt.		
Year	1	.0166	.0166	-
Species	3	8.1528	2.7176	20.72**
Period	3	1.6002	.5334	6.43*
Y X S	3	.4812	.1604	1.93
Y X P	3	.5509	.1836	2.21
S X P	9	.3881	.0431	-
Error	9	.7467	.0829	
Total	31	11.9365		
		% Digestible DM		
Year	1	288.6604	288.6604	53.96**
Species	3	56.3024	18.7674	3.51
Period	3	28.7610	9.5870	1.79
Y X S	3	75.0436	25.0145	4.68*
Y X P	3	2.9768	.9922	-
S X P	9	21.7187	2.4131	-
Error	9	48.1505	5.35	
Total	31	521.6134		
		Daily Digestible DM Intake/Cwt.		
Year	1	.2688	.2688	8.37*
Species	3	3.2384	1.0794	33.63**
Period	3	.5252	.1750	5.45*
Y X S	3	.2814	.0938	2.92
Y X P	3	.1443	.0481	1.50
S X P	9	.1673	.0185	-
Error	9	.2889	.0321	
Total	31	4.9143		

continued

Appendix Table XIV Continued

Source	D.F.	Sum Square	Mean S. Square	F.
		In Vivo DM NVI Values		
Year	1	136.7445	136.7445	3.37
Species	3	2821.2321	940.4107	23.16**
Period	3	194.2866	64.7622	1.59
Y X S	3	256.1262	85.3754	2.10
Y X P	3	133.5747	44.5249	1.10
S X P	9	130.8100	14.5344	-
Error	9	365.4174	40.6019	
Total	31	4038.1915		
		Body Weight Gain		
Year	1	11.9316	11.9316	1.68
Species	3	107.6513	35.8837	5.05*
Period	3	46.3093	15.4364	2.17
Y X S	3	45.6409	15.2136	2.14
Y X P	3	21.8588	7.2862	1.03
S X P	9	57.0470	6.3385	-
Error	9	63.9360	7.1040	
Total	31	354.3749		

Appendix Table XV

Analysis of Variance of Combined 1961 and 1962
Sheep Performance When Receiving First and Second Cutting Forages

Source	D.F.	Sum Square	Mean S. Square	F
		Daily DM Intake/Cwt.		
Cutting	1	.0615	.0615	-
Species	3	12.4751	4.1583	37.50**
Year	1	.0545	.0545	-
C X S	3	.2894	.0964	-
C X Y	1	.0026	.0026	-
S X Y	3	.9304	.3101	2.80
C X S X Y	3	.2300	.0766	-
Error	48	5.3234	.1109	
Total	63	19.3669		
		% Digestible DM		
Cutting	1	230.5463	230.5463	64.45**
Species	3	32.3995	10.7998	3.02
Year	1	295.2813	295.2813	82.54**
C X S	3	84.0553	28.0184	7.83**
C X Y	1	46.8369	46.8369	13.09**
S X Y	3	99.7000	33.2333	9.29**
C X S X Y	3	26.8893	8.9631	2.51
Error	48	171.7161	3.5774	
Total	63	987.4247		
		Daily Digestible DM Intake/Cwt.		
Cutting	1	.0635	.0635	1.62
Species	3	4.3269	1.4423	36.79**
Year	1	.3643	.3643	9.29**
C X S	3	.2822	.0940	2.40
C X Y	1	.0168	.0168	-
S X Y	3	.6618	.2206	5.63**
C X S X Y	3	.1449	.0483	1.23
Error	48	1.8862	.0392	
Total	63	7.7466		

continued

Appendix Table XV Continued

Source	D.F.	Sum Square	Mean S. Square	F
		In vivo DM NVI Values		
Cutting	1	80.3040	80.3040	2.64
Species	3	3912.6287	1304.2095	42.81**
Year	1	134.5890	134.5890	4.42*
C X S	3	199.1596	66.3865	2.18
C X Y	1	24.3666	24.3666	-
S X Y	3	583.8186	104.6062	6.39**
C X S X Y	3	132.3247	44.1082	1.45
Error	48	1462.2900	30.4683	
Total	63	6529.4812		
		Body Weight Gain		
Cutting	1	16.2510	16.2510	1.74
Species	3	121.6393	40.5464	4.34**
Year	1	12.9870	12.9870	1.39
C X S	3	18.2186	6.0728	-
C X Y	1	1.6416	1.6416	-
S X Y	3	38.6670	12.8890	1.38
C X S X Y	3	34.3584	11.4528	1.23
Error	48	448.0916	9.3352	
Total	63	691.8509		

Appendix Table XVI

Daily DM Intake of Pure Stand Forages by Individual Rabbits

Forage 1961	DM Intake grams/day/kg.^{75}						Avg.	S.E.
Alf.I	82.2	101.4	92.3	79.6	84.2	101.3	90.2	3.9
Tre.I	78.5	82.3	64.5	84.1	77.5	75.1	77.0	2.8
Brome I	61.0	110.6	104.4	83.0	91.2	98.8	91.5	7.3
Reed I	93.4	87.2	78.3	66.9	87.1	75.5	81.4	3.9
Tim.I	92.1	89.9	105.8	96.9	112.3	96.1	98.8	3.5
Alf.II	73.5	100.0	75.9	59.3	86.8	88.5	80.7	5.8
Tre.II	88.1	105.9	75.8	77.9	84.0	78.6	85.0	4.6
Brome II	78.8	56.9	67.7	70.6	63.9	83.1	70.2	3.9
Reed II	89.0	76.8	84.9	67.7	95.5	85.8	83.3	4.0
Alf.2	73.1	97.1	95.0		89.7	82.7	87.5	4.4
Alf.III	98.8	105.1	110.5	75.9	86.6	81.2	93.0	5.6
Tre.III	74.5	93.0	84.3	67.1	80.3	75.8	79.2	3.6
Brome III	84.6	77.0	99.8	68.4	96.8	85.0	85.3	4.8
Reed III	68.1	64.5	69.4	57.8	64.5	89.1	68.9	4.4

Appendix Table XVII

Digestible DM % of Pure Stand Forages as Determined by Individual Rabbits

Forage	% Dig.DM							
1961	%	%	%	%	%	%	Avg.	S.E.
Alf.I	54.6	44.7	45.0	43.3	47.2	42.4	46.2	1.8
Tre.I	46.9	45.6	43.8	43.5	47.9	51.2	46.5	1.2
Brome I	38.2*	37.3	40.5	38.2*	39.1	36.0	38.2	.6
Reed I	38.8	38.7*	39.9	38.7*	38.2	38.0	38.7	.3
Tim.I	32.1	52.2	30.9	52.0	40.6	30.7	39.8	4.2
Alf.II	46.8	39.7	43.9	49.1	47.2	45.0	45.3	1.3
Tre.II	45.6	44.2	43.5*	43.9	39.8	44.0	43.5	.8
Brome II	33.5	41.8	43.4	26.5	23.8	33.8*	33.8	3.2
Reed II	42.7	56.9	42.9	36.7	47.6	44.4	45.2**	2.8
Alf.2	50.7	45.6	46.8	51.4	44.3	43.9	47.1	1.3
Alf.III	35.6	36.3	43.1	40.7*	48.2	40.4	40.7	1.9
Tre.III	55.9	52.5	59.9	55.2	50.3	50.6	54.1	1.5
Brome III	37.4	40.2*	45.4	40.2*	41.0	36.9	40.2	1.2
Reed III	46.1	37.3	45.8	34.4	24.6	38.6	37.8	3.3

* Used average value (contamination of feces with feed).

** Same contamination with corn during pelleting.

Appendix Table XVIII

DM NVI Values for Pure Stand Forages as Determined by Individual Rabbits

Forage 1961	DM NVI Values						Avg.	S.E.
Alf.I	56.1	56.6	51.9	43.1	49.7	53.9	51.9	2.0
Tre.I	46.0	46.9	35.3	45.8	46.4	48.0	44.7	1.9
Brome I	29.1	51.6	52.8	39.6	44.5	44.5	43.7	3.5
Reed I	45.3	42.2	39.0	32.4	41.6	35.8	39.4	1.9
Tim.I	36.9	58.6	40.9	63.0	57.0	36.9	48.9	4.8
Alf.II	43.0	49.6	41.6	36.4	51.2	49.8	45.3	2.4
Tre.II	50.2	58.5	41.2	42.8	41.8	43.2	46.3	2.8
Brome II	33.0	29.7	36.7	23.4	19.0	35.1	29.5	2.8
Reed II	47.5	54.6	45.5	31.0	56.8	47.6	47.2	3.7
Alf.2	46.3	55.3	55.6		49.7	45.4	50.5	2.2
Alf.III	44.0	47.7	59.5	38.6	52.2	41.0	47.2	3.2
Tre.III	52.0	61.1	63.1	46.2	50.5	47.9	53.5	2.9
Brome III	39.5	38.7	56.6	34.3	49.6	39.2	43.0	3.4
Reed III	39.4	30.1	39.8	24.8	19.8	43.0	32.8	3.8

Appendix Table XIX

Body Weight Gain of Individual Rabbits Receiving Pure Stand Forages

Forage 1961	g/three week period						Avg. g/period
Alf.I	232	278	322	153	272	440	283
Tre.I	238	351	57	287	321	298	259
Brome I	43	70	-18	-15	66	182	55
Reed I	230	85	26	33	185	98	110
Tim. I	154	212	58	86	271	119	150
Alf.II	207	304	209	5	317	186	205
Tre.II	258	232	164	277	343	402	279
Brome II	-42	-121	-159	-139	10	-139	-98
Reed II	277	224	232	125	399	293	258
Alf.2	166	315	364	131	337	302	269
Alf.III	242	314	295	130	181	132	216
Tre.III	205	217	366	260	304	279	272
Brome III	148	198	192	79	231	155	167
Reed III	141	32	120	-21	-14	195	76

Appendix Table XX

Daily DM Intake/Cwt of Pure Stand Forages
by Individual Heifers

Forage 1961	DM Intake lb./day/cwt.				Avg.
Alf.I	2.38	2.95	2.58	2.64	2.64
Tre.II	2.32	2.32	2.34	2.72	2.42
Brome I	2.20	2.34	-	-	2.27
Reed I	2.70	2.39	2.48	2.16	2.43
Tim.I	2.43	2.48	2.57	2.41	2.47
Alf.II	2.65	2.86	2.87	-	2.79
Tre.II	2.81	2.66	2.57	-	2.68
Brome II	1.69	1.64	1.68	-	1.67
Reed II	1.62	1.99	-	-	1.80
Alf.2	2.87	2.64	2.46	-	2.66
Alf.III	2.73	2.35	2.85	2.55	2.62
Tre.III	2.39	2.87	2.53	-	2.60
Brome III	-	-	-	-	-
Reed III	2.28	1.14	2.47	-	1.96

Appendix Table XXI

DM NVI Values for Pure Stand Forages as Determined
by Individual Heifers[1]

Forage 1961					Avg.	S.E.
Alf.I	76.0	77.4	75.5	88.2	79.3	3.0
Tre.I	71.9	69.1	71.1	93.8	76.5	5.8
Brome I	70.8	67.0	-	-	68.9	1.9
Reed I	79.9	84.4	79.6	78.3	80.6	1.3
Tim.I	72.6	78.4	87.5	85.6	81.0	3.4
Alf.II	70.8	77.6	84.1	-	77.5	3.8
Tre.II	80.5	84.5	73.3	-	79.4	3.3
Brome II	31.4	47.0	43.5	-	40.6	4.7
Reed II	47.5	54.0	-	-	50.7	3.2
Alf.2	81.7	86.1	84.1	-	84.0	1.3
Alf.III	72.1	64.5	86.0	80.3	75.9	4.5
Tre.III	67.6	94.7	81.6	-	81.3	7.8
Brome III	-	-	-	-	-	-
Reed III	77.3	40.5	76.9	-	64.9	12.2

[1]Digestible DM % from sheet data.

Appendix Table XXII

Body Weight Gain of Individual Heifers Receiving
Pure Stand Forages

Forage 1961	Weight Gain lb/28 day				Avg.	S.E.
Alf.I	49	59	53	55	54.0	6.6
Tre.I	40	36	44	71	47.7	7.9
Brome I	69	47	-	-	58.0	11.0
Reed I	59	69	78	60	66.5	4.4
Tim.I	59	66	95	47	66.7	10.1
Alf.II	44	63	41	-	49.4	6.9
Tre.II	37	57	63	-	52.2	7.9
Reed II	67	47	-	-	57.0	10.0
Alf.2	49	57	35	-	47.0	6.4
Alf.III	36	32	72	46	46.5	9.0

Appendix Table XXIII

Average in vitro DM Disappearance of Pure Stand Forages with Standard Errors and % Coefficients of Variation

1961 Forages

%

	3 hr.	S.E.[1]	C.V.[2]	6 hr.	S.E.	C.V.	12 hr.	18 hr.	24 hr.	S.E.	C.V.	36 hr.	S.E.	C.V.	48 hr.	S.E.	C.V.
Alf.I	29.2	4.2	28.4	32.0	1.7	10.6	39.2	45.1	47.8	2.5	10.7	52.5	1.7	6.7	57.1	1.9	6.5
Tre.I	38.4	3.0	21.5	37.7	4.2	22.5	41.0	49.0	54.9	2.4	8.7	54.6	2.5	9.0	54.6	2.0	7.1
Brome I	20.9	1.6	14.8	25.7	1.4	11.3	36.0	42.3	48.6	2.0	8.2	54.7	2.5	7.9	62.8	.7	2.2
Reed I	26.4	4.1	30.7	28.2	3.2	22.7	38.0	46.0	51.3	3.9	15.0	61.6	2.7	8.8	63.3	1.9	5.8
Tim.I	20.0	1.1	11.0	26.2	.8	6.1	38.4	51.9	55.3	3.3	12.1	63.4	2.4	7.4	58.6	1.0	3.2
Alf.II	29.0	3.5	24.1	28.7	3.1	21.6	39.8	44.2	41.2	2.5	12.4	47.2	2.0	8.3	50.9	1.4	5.5
Alf.2	30.1	1.5	1.0	32.5	.6	3.7	41.4	43.2	46.3	1.7	7.1	51.7	2.3	9.1	52.7	2.1	7.8
Tre.II	25.0	2.1	17.2	30.0	.7	5.0	37.6	39.5	44.3	2.6	11.7	50.8	1.5	6.1	49.3	1.5	6.1
Brome II	15.2	.7	9.2	21.1	2.5	20.8	25.3	32.0	32.7	1.1	6.4	41.6	1.5	7.4	43.1	3.3	15.5
Reed II	13.9	.4	5.7	18.1	2.2	24.9	25.9	40.8	33.2	3.3	19.9	48.1	5.6	23.3	47.0	3.0	13.0
Alf.III	23.0	2.6	22.2	24.5	2.5	20.8	32.0	39.9	37.3	5.0	26.5	38.3	2.2	11.5	47.0	1.2	4.9
Tre.III	28.2	1.7	12.4	32.0	1.2	7.2	44.3	45.3	48.4	.9	3.7	54.0	1.6	6.1	54.6	.3	.9
Brome III	24.5	2.8	22.8	29.7	2.6	17.5	36.8	40.8	42.0	1.8	8.6	50.1	1.2	4.6	51.2	.8	3.3
Reed III	24.0	1.5	12.1	28.2	2.7	19.1	28.9	41.4	41.7	3.6	17.0	54.1	3.9	14.2	53.7	.8	3.0
Average																	
Alf.	27.0			28.4			37.0	43.0	42.1			46.0			51.6		
Tre.	27.2			33.2			30.9	44.6	49.2			53.1			52.8		
Brome	20.2			25.5			32.7	38.3	41.1			48.8			52.3		
Reed	21.4			24.8			30.9	42.7	42.0			54.6			54.6		
Average																	
1st cut.	26.2			30.9			38.5	45.6	50.6			55.8			59.4		
2nd cut.	20.7			24.4			32.1	39.1	37.8			46.9			47.5		
3rd cut.	24.9			28.6			35.5	41.8	42.3			47.1			51.6		

continued

Appendix Table XXIII Continued

1962 Forages

%

	3 hr.	S.E.	C.V.	6 hr.	S.E.	C.V.	12 hr.	18 hr.	24 hr.	S.E.	C.V.	36 hr.	S.E.	C.V.	48 hr.	S.E.	C.V.
Alf.I	36.5	1.0	5.2	39.2	1.0	5.2	49.7	53.7	57.8	.6	1.9	60.9	.9	3.0	63.1	.7	2.3
Tre.I	30.5	.2	1.5	33.6	.5	2.8	43.8	51.4	54.2	.8	2.9	56.3	.9	3.0	57.6	.7	2.3
Brome I	25.5	.9	6.8	27.5	.8	5.6	31.6	42.0	50.0	1.7	6.7	60.6	1.0	3.4	63.9	.6	1.9
Reed I	26.1	.7	5.2	26.6	1.4	10.6	31.7	41.4	48.7	1.0	3.4	54.9	1.2	4.4	61.4	1.3	4.1
Tim.I	26.0	.7	5.4	28.7	.5	3.5	39.1	49.5	54.8	1.3	4.8	61.1	1.8	5.8	66.7	.3	1.0
Alf.II	33.7	.9	5.3	35.8	.9	5.2	44.0	50.2	50.2	1.1	4.4	51.0	.8	3.3	56.2	2.0	7.1
Tre.II	32.0	.6	3.5	35.4	.7	4.1	40.7	46.2	53.5	1.1	4.1	53.9	1.3	4.7	56.5	1.1	3.8
Brome II	23.1	.6	4.9	25.1	1.1	8.6	33.2	40.8	59.9	.6	2.4	57.9	.7	2.5	63.7	1.7	5.4
Reed II	20.8	.8	7.9	22.1	1.1	10.7	29.1	38.0	43.3	.3	1.3	49.7	1.6	6.4	58.4	1.1	3.7
<u>Average</u>																	
Alf.	35.1			37.5			46.9	52.0	54.2			56.0			59.7		
Tre.	31.3			34.5			42.3	48.8	53.9			55.1			57.1		
Brome	24.3			26.3			32.4	41.4	50.0			59.3			63.8		
Reed	23.5			24.4			30.4	39.7	46.0			52.3			60.0		
Tim.	26.0			28.7			39.1	49.5	54.8			61.1			66.7		
<u>Average</u>																	
1st cut.	28.9			31.1			39.2	47.6	53.1			58.8			62.5		
2nd cut.	27.4			29.6			36.8	43.8	49.3			53.1			58.7		

[1]Standard error.

[2]% coefficient of variation.

Appendix Table XXIV

Analysis of Variance of *in vitro* DM Disappearance of Pure Stand Forages

Source	D.F.	Sum Squares	Mean S. Square	F	F[1]
		1961 Forages			
Species	3	1,622.70	540.9	27.72**	1.17
Time	6	34,449.69	5,741.6	294.29**	12.42**
Cutting	2	3,869.87	1,934.9	99.17**	4.18*
S . T	18	1,526.55	84.8	4.35**	
S . C	6	1,997.46	332.9	17.06**	
T . C	12	535.16	44.6	2.29**	
S . T . C	36	687.72	19.1	.98	
Subtotal	83	44,689.15			
Error	252	4,917.59	19.51		
Total	335	49,606.74			
	$S\bar{x}$ = 2.21		S.D. = 4.42	C.V. % = 11.18	
		1962 Forages			
Species	3	2,793.83	931.3	180.14**	5.12**
Time	6	28,727.72	4,737.9	926.09**	26.06**
Cutting	1	522.68	522.7	101.10**	2.88
S . T	18	1,977.80	109.9	21.25**	
S . C	3	215.85	71.9	13.91**	
T . C	6	47.80	7.97	1.51	
S . T . C	18	154.85	8.60	1.66	
Subtotal	55	34,440.53			
Error	168	868.06	5.17		
Total	223	34,308.59			
	$S\bar{x}$ = 1.14		S.D. = 2.27	C.V. % = 5.13	

[1]F value using the significant interaction terms as the error term.

* Significant ($P < .05$)
** Significant ($P < .01$)

Appendix Table XXV

DM Disappearance (%) of Alfalfa Hay Standard[1]

Hours Fermented	Sept. 21 %	Dec. 3 %	Dec. 3 %	Dec. 10 %	Dec. 17 %	Jan. 10 %	Jan. 14 %	Jan. 19 %	Jan. 28 %	Feb. 28 %	Mar. 13 %	Mar. 19 %
						DATE						
1961 Fermentation Trials												
3	31.1	26.0	26.4	26.0	18.82	19.72	15.39	21.45	25.18	25.05	19.90	21.54
	31.9	30.2	21.61	32.1	27.55	25.97	21.69		24.15	26.76	-	-
6	35.0	29.9	33.8	32.1	38.01	29.01	26.17	33.44	27.74	30.83	27.81	29.41
	27.3	29.9	32.6	28.6	36.76	33.87	20.01		26.24	31.20	27.88	26.72
12	38.9	33.9	41.4	38.6	42.42	41.70	38.68	48.03	28.56	38.17	35.42	31.47
	36.4	35.6	47.2	40.6	39.7	40.58	29.26		39.69	42.75	33.05	37.55
18	48.9	40.9	48.9	46.5	46.19	40.04	42.20	45.64	54.16	42.30	42.42	40.60
	43.1	43.4	47.5	42.5	62.05	42.97	35.13		53.31	44.95	41.21	38.83
24	43.9	45.7	57.4	41.4	60.14	45.35	41.88	43.54	49.13	41.80	49.90	45.92
	48.2	56.3	53.2	41.5	61.05	50.56	37.66		50.08	46.20	-	40.67
36	45.8	45.5	50.5	53.4	50.35	51.55	41.28	47.82	50.20	47.19	-	43.96
	45.4	52.4	50.4	47.7	51.99	50.70	45.26		55.52	46.84	-	41.70
48	47.1	49.8	53.5	51.5	49.84	52.34	41.53	46.78	59.22	47.50	55.87	49.87
	43.6	51.4	54.3	44.7	53.23	59.71	46.38		58.81	48.99	51.91	50.90
											52.85	
											50.60	
1962 Fermentation Trials												
	June 26 %		July 3 %		July 10 %		July 15 %		July 22 %		August 1 %	
3	30.62	29.28	31.91	33.14	29.66	29.21	28.45	30.48	31.90	31.19	33.08	29.34
6	34.08	33.79	35.04	34.76	27.89	29.05	34.61	32.84	34.48	33.85	32.46	34.37
12	44.97	42.73	-	41.86	40.98	36.55	41.81	-	45.02	45.38	44.73	41.22
18	50.31	48.88	47.91	47.28	44.11	45.46	45.76	-	41.70	45.25	44.24	50.18
24	50.34	51.86	45.50	47.91	48.33	42.13	48.70	50.99	47.05	49.44	48.52	48.78
36	53.92	50.96	49.78	49.61	46.73	48.73	52.65	47.39	53.02	55.08	49.63	51.74
48	53.81	56.07	54.46	53.48	42.25	47.97	55.15	52.11	55.14	57.74	52.82	53.70

[1] As dehydrated alfalfa hay obtained from Kansas which was used in cooperative forage evaluation experiments by several universities.

Appendix Table XXVI

Rumen Inoculum DM and Non-filterable DM From In Vitro Fermentation Blanks

Date	Non-filterable DM g/60 ml non-settled					DM Rumen Inoculum		Avg.
				1961 Forages				
Sept.21	.2554	.2690	-	.2642	.2628	-	-	-
Dec. 3	.1645	.1665	.1488	.1595	.1598	1.1792	1.1856	1.1824
Dec.10	.2513	.2679	.2423	.2529	.2536	1.1972	1.1940	1.1956
Dec.17	.2498	.2363	.2374	-	.2411	1.2301	1.2266	1.2284
Jan.10	.3512	.3500	.3871	.3764	.3661	1.4051	1.4145	1.4098
Jan.14	.2137	.2172	.2192	-	.2167	1.1776	1.1859	1.1818
Jan.19	.3808	.3681	.3703	.3357	.3637	1.3668	1.3709	1.3688
Jan.28	.2467	.3049	.2842	.3190	.2887	1.2171	1.2206	1.2188
			Average DM %		.45			2.09
				1962 Forages				
	g/24 ml of settled							
June 26	.0310	.0284	.0290	.0308	.0298	.4672	.4629	.4651
July 3	.0238	.0229	.0209	.0188	.0216	.3896	.3933	.3914
July 10	.0303	.0257	.0268	.0233	.0265	.4621	.4642	.4632
July 15	.0192	.0239	.0283	.0218	.0233	.4529	.4487	.4508
July 22	.0243	.0241	.0307	.0230	.0255	.4261	.4179	.4220
Aug.1	.0205	.0225	.0178	.0279	.0222	.4200	.4226	.4213
			Average DM %		.10			1.82

Appendix Table XXVII

DM Disappearance of Forage Substrates Due to Buffer and Due to Rumen Inoculum (Difference Between DM Disappearance with Buffer and Total *in vitro* DM Disappearanc)

	DM Dis. with buffer 3 hr.	DM Disappearance Due to Added Rumen Inoculum						
		3 hr.	6 hr.	12 hr.	18 hr.	24 hr.	36 hr.	48 hr.
				1961				
Alf.I	28.4	.8	2.6	10.8	16.7	19.4	24.1	28.7
II	21.8	7.2	6.9	18.0	22.4	19.4	25.4	29.1
III	17.8	5.2	6.7	14.2	22.1	19.5	20.5	29.2
Tre.I	23.8	4.6	13.9	17.2	25.2	31.1	30.8	30.8
II	22.6	2.4	7.4	15.0	16.9	21.7	28.2	26.7
III	26.0	2.2	6.0	18.3	19.3	22.4	28.0	28.6
Brome I	21.6	- .7	4.1	14.4	20.7	27.0	33.1	41.2
II	16.8	-1.6	4.3	8.5	15.2	15.9	24.8	26.3
III	22.6	1.9	7.1	14.2	18.2	19.4	27.5	28.6
Reed I	24.9	1.5	3.3	13.1	21.1	26.4	36.7	38.4
II	17.9	-4.0	.2	8.0	22.9	15.3	30.2	29.1
III	23.2	.8	5.0	5.7	18.2	18.5	30.9	30.5
Tim.	22.0	-2.0	4.2	16.4	29.9	33.3	41.4	36.6
Alf.-2	27.0	3.1	5.5	14.4	16.2	19.3	24.7	25.7
				1962				
Alf.I	29.6	6.92	9.64	20.12	24.07	28.21	31.33	33.48
II	26.6	7.12	9.21	17.40	23.56	23.89	24.39	49.09
Tre.I	26.3	4.22	7.26	17.50	25.10	27.88	30.00	31.25
II	24.8	7.22	10.61	15.88	21.45	28.66	29.11	31.67
Brome I	24.6	.86	2.89	6.98	17.45	25.39	35.96	39.27
II	22.2	.89	2.88	11.03	18.62	27.72	35.71	41.50
Reed I	26.2	- .07	.41	5.54	15.18	22.53	28.69	35.20
II	20.8	- .02	1.32	8.33	17.24	22.47	28.94	37.55
Tim.	24.4	1.55	4.34	14.71	25.11	30.42	36.70	42.34

Appendix Table XXVIII

DM and Fiber Digestion in the Rumen and Lower Large Intestine as Determined by the Lignin Ratio Technique

1961 Forages	DM Digestion in the Rumen %			DM Digestion[1] in the Large Int. %			Fiber Digestion in the Rumen %			Fiber Digestion[1] in the Large Int. %		
Alf.II	41.9	42.9	47.3	58.2	57.0	56.2	30.4	32.2	31.9	49.5	47.4	44.9
Tre.II	44.8	39.6	46.5	62.1	62.6	58.8	25.0	28.9	27.2	34.0	32.9	33.5
Brome II	33.4	33.2	45.4	73.0	68.2	54.3	31.7	33.2	33.2	56.7	54.4	61.7
Reed II	35.3	49.5	33.0	64.3	62.2	59.3	32.5	44.4	26.3	57.7	50.3	55.6
1962 Forages												
Alf.I												
6 hr.	60.6	60.7		66.4	64.0		43.1	40.8		52.2	50.5	
12 hr.	62.4	64.0		65.0	64.9		46.1	45.7		52.0	52.0	
Tre.I												
6 hr.	52.8	58.6		59.7	57.3		35.9	35.5		37.1	38.4	
12 hr.	52.7	58.1		60.3	59.3		35.9	35.0		33.3	38.0	
R.C.I												
6 hr.	59.3	54.2		70.4	70.5		47.4	41.1		46.6	39.8	
12 hr.	62.4	67.2		71.2	70.1		48.8	52.5		48.4	59.3	
Tim.I.												
6 hr.	51.5	52.9		61.3	61.7		45.7	46.5		51.6	54.4	
12 hr.	57.1	56.7		64.4	62.9		51.0	50.0		56.1	53.6	

continued

Appendix Table XXVIII Continued.

Fiber and Lignin "digestion" Coefficients as Determined In Total Collection Trials (Not Considering Orts)

1961 Forages	Fiber Digestion %				Lignin Digestion				Avg.
Alf.II	46.3	45.7	47.4	54.0	9.5	13.2	11.2	19.2	13.3A
Tre.II	29.4	32.4	36.8	35.8	-24.9	-24.7	-21.9	-18.2	-22.4C
Brome II	48.9	50.1	55.3	49.8	- 4.5	- 7.0	10.4	- 9.1	- 2.5Ba
Reed II	48.1	49.5	49.7	50.9	-29.3	-14.7	-12.9	- 6.70	-15.9BCb
1962 Forages									
Alf.I	51.4	49.2	51.4	50.6	2.9	3.9	5.9	2.1	4.0A
Tre.I	35.2	37.8	36.7	35.6	-22.8	-13.5	-24.7	-11.7	-18.2B
Tim.I	50.9	54.1	57.3	51.2	-19.6	-13.6	-17.4	-28.2	-19.7B
Reed I	51.2	58.8	51.3	55.9	- 4.6	6.5	- .6	- 2.4	- .2A

[1] Corrected for lignin "digestion" found during the total collection trial.

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