Microdigestion of Grazed Annual Forage, Clipped Herbage, and Standard Samples by Cattle and Sheep[1]

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Highlight

Microdigestion estimates were correlated with macrodigestion estimates obtained by lignin ratio technique under grazing or total collection procedures under dry-lot feeding. Over all techniques the correlation was about 0.72. Forages grazed by either cattle or sheep in midsummer were more disgestible than those grazed in early or late summer.

Artificial rumen and nylon bag microdigestion techniques have been used recently for nutritive evaluation of individual range plants (Frederiksen and Washburn, 1961; Wallace et al., 1961; Van Dyne, 1962; Pritchard et al., 1963), native grass hays (Kercher, 1963; Taylor et al., 1960), and mixed grazed forages (Van Dyne, 1962; Ordoveza, 1963). This paper reports on digestibility by microtechniques of forage samples obtained from esophageal fistulated animals grazing on the same ranges as were the ruminal fistulated animals providing the inocula for microdigestion. The purpose of the experiment was to answer the following questions: (1) Do forages grazed by cattle differ in digestion from those grazed by sheep?, (2) Do grazed forages differ from alfalfa in digestion?, (3) Do differences in herbage availability cause differences in microdigestion of grazed forages?, (4) Are individual herbages clipped from the range digested to the same degree as mixed forage samples grazed from the range?, and (5) Do estimates of digestion of range forages obtained with microtechniques correlate well with macrodigestion estimates calculated by lignin ratio?

Methods

Nine each of ruminal fistulated steers and wethers provided inocula for microdigestion by nylon bag and artificial rumen techniques described by Van Dyne (1962, 1963). Forage or Solka-floc samples of about 1 g were used in artificial rumen tubes and about 2 g samples were used in nylon bags for 48-hr duration fermentations. Percent cellulose digestion (PCD) and percent dry matter digestion (PDMD) were determined by nylon bag technique and PCD was determined in the artificial rumen.

Duplicate samples of two standards, i.e. alfalfa and Solka-floc, were digested by inocula from each animal in each period for comparisons between periods. Composite samples of forage, obtained in each period from five esophageal fistulated cattle and seven esophageal fistulated sheep, were digested each period by inocula from or in each ruminal fistulated animal. After range grazing experiments early in July, August, and September of 1961 (periods I, II and III), all forages and standards were digested when the animals were being fed in dry-lot on pelleted alfalfa (period IV). The alfalfa fed was one of the standards. Herbage availability and botanical composition of the diets varied widely through the summer. Total grass and forb herbage on this foothill annual range varied from about 1490 to 420 lb. per acre from early to late summer.

Microdigestion data on the grazed forage samples and the standard samples were analyzed separately in two major statistical designs (Table 1). In each design the interactions of main effects were investigated and the error term was subdivided into pooled, class, sheep, and cattle errors. Where a significant difference occurred, means were compared by Tukey's test (1953).

Results And Discussion

Microdigestion of Different Cellulose Sources

Standards vs. grazed forages.—Six grazed forage samples, an alfalfa sample, and Solka-floc were not always ranked in the same order by three microdigestion techniques. This resulted in a technique x forage interaction in the analyses of variance and is partly responsible for differences detected among forages and the base feed x forage interaction detected in the analyses of variance.

Solka-floc had higher means than the forages by all three techniques (Table 2). The higher value for Solka-floc presumably is because this material is almost completely free from lignin incrustation; whereas, the grazed forages contained about 12% lignin and the alfalfa about 7.5% lignin. The magnitudes of the Solka-floc digestions are within the range of those reported for animals on high-quality diets. The within-animal variability in Solka-floc digestion is greater than that for the forages and Solka-floc digestion was affected easily by minor variations in processing and digestion techniques as has been reported by Donefer et al. (1961).

The alfalfa sample had appreciably higher digestion than the average of range forages only when measured as PDMD in vivo. For PCD both in vitro and in vivo, in 5 of 12 comparisons the grazed forages had as high or higher values

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Table 1. Statistical and experimental designs

Factor in experiment	Number of levels	Classification in analysis
— — — — — — — — — — — Standard forages — — — — — — — — — — —		
Technique (PCD and PDMD *in vivo* and PCD *in vitro*)	3	Fixed-crossed
Standards (Alfalfa and Solka-floc)	2	Fixed-crossed
Periods (I-III on range, IV on dry-lot)	4	Fixed-crossed
Animals	18	Fixed-crossed
Class of stock (cattle and sheep)	2	Fixed-crossed
Sheep (individuals)	9	Fixed-nested in class
Cattle (individuals)	9	Fixed-nested in class
Duplicates	2	Random-nested in animal
Total	864	
— — — — — — — — — — — Grazed forages — — — — — — — — — — — (separately by technique)		
Class grazing forage (cattle and sheep)	2	Fixed-crossed
Period of grazing (early, mid-, and late summer, I-III)	3	Fixed-crossed
Base feed during digestion (range or alfalfa)	2	Fixed-crossed
Animal digesting	18	Fixed-crossed
Class of stock (cattle and sheep)	2	Fixed-crossed
Sheep (individuals)	9	Fixed-nested in class
Cattle (individuals)	9	Fixed-nested in class
Duplicates	2	Random-nested in animal
Total	432	

Table 2. Means and standard errors for microdigestion of eight cellulose sources by 18 animals fed pelleted alfalfa.

Sample	Cellulose digestion *in vitro* (PCD)	Cellulose digestion *in vivo* (PCD)	Dry matter digestion *in vivo* (PDMD)
	— — — — — — Percent — — — — — —		
Standards:			
Solka-floc	74 ± 1.7	83 ± 1.3	87 ± 1.5
Alfalfa	57 ± 0.4	61 ± 0.6	67 ± 0.8
Grazed forages:			
Sheep—Period I	51 ± 0.4	53 ± 0.5	52 ± 1.0
Sheep—Period II	57 ± 0.4	61 ± 0.4	59 ± 0.1
Sheep—Period III	54 ± 0.5	55 ± 0.6	55 ± 0.8
Cattle—Period I	58 ± 0.4	60 ± 0.5	55 ± 0.9
Cattle—Period II	62 ± 0.8	64 ± 0.5	59 ± 0.8
Cattle—Period III	56 ± 0.5	57 ± 0.6	54 ± 0.8

than alfalfa (Table 2). The alfalfa sample was lower in cellulose, but higher in crude protein content than the grazed forage samples. Alfalfa was more comparable in chemical composition to the period I forages than to those grazed in periods II or III, but the alfalfa sample and the early summer forage samples clearly were not digested equally.

The alfalfa standard used in this study was compared in period IV to an alfalfa sample furnished by Purdue University for interstate studies in standardization of techniques. Our alfalfa standard was significantly more digestible, about 11% higher, than the Purdue. The Purdue standard alfalfa had about 51% PCD in 48 hr in vitro and about 42% in 24 hr by our technique.

Differences among grazed forages. —The forage samples obtained with esophageal fistulated animals contain many plant species and parts and are composites for each animal species. The means depicted in Figure 1 are average microdigestion of forage samples by inocula obtained from, or in, animals on a low quality diet (range) and later by the same animals on a high quality diet (alfalfa).

There were differences in digestion among the six grazed forage samples (Figure 1), but the three microtechniques did not rank the forages in the same way. Although there generally was a high correlation between PDMD and PCD results in vivo, the two in vivo microtechniques did not rank these forages identically; however, both in vivo techniques ranked early and midsummer forages (CI, SII, and CII) as among the highest in digestibility (Figure 1). Also, both in vivo techniques ranked forage grazed by sheep in late summer (SIII) as one lowest in digestibility. The artificial rumen was gassed inadequately in period I which resulted in the forages grazed in that period being ranked as lowest in digestibility for PCD in vitro. Disregarding these two forages, the in vitro procedure ranked the remaining four forages in a manner closer to PCD in vivo than to PDMD in vivo ranks.

The inocula used in most dry-lot studies has been obtained from animals fed high quality diets, but the inocula used in period I came from

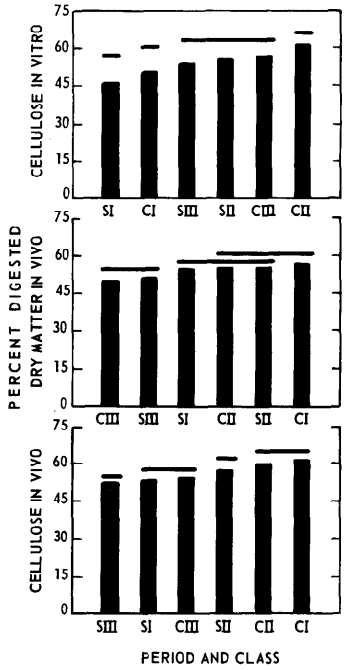

FIGURE 1. Microdigestion of forages grazed by cattle (C) and sheep (S) from annual range in early (I), middle (II), and late summer (III).

animals on a low quality diet. Such an inocula may require intensive gassing to yield maximum microdigestions. Still, Tilley and Terry (1963) used in vitro systems in which there was no gassing after the initiation of fermentation. Perhaps when high quality diets are used, providing a vigorous inocula, and when highly digestible roughages are fermented, sufficient gas may be generated in the fermentation to maintain anaerobic conditions. Preliminary studies showed high quality range and pasture forages have higher rates of fermentation early in the fermentation than do low quality forages (Van Dyne, 1962). The type of forage x type of inocula interaction, therefore, may be important when comparing different artificial rumen techniques.

Cattle vs. sheep forage. — Cattle and sheep forage did not differ in PDMD in vivo, but cattle-grazed forage had about 4% higher cellulose digestibility in vitro and in vivo (Figure 2). Cattle grazed more grass than did sheep (Van Dyne and Heady, 1964)[3] and perhaps grass cellulose is more easily digested than the cellulose in forbs or shrubs. There was no significant difference in lignin content of forage by cattle and sheep. However, there could have been differences in the position of lignification in plants grazed by cattle as compared to those grazed by sheep. Although the same plant species generally were found in both

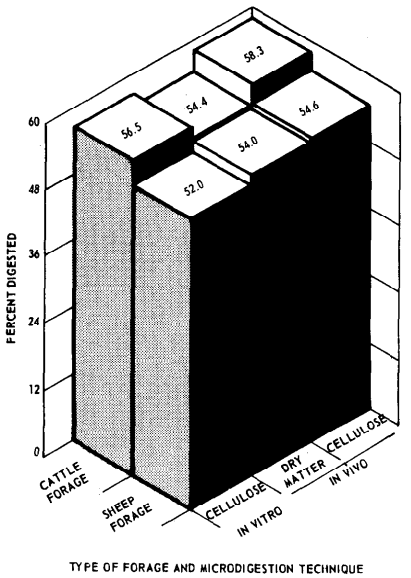

FIGURE 2. Cellulose and dry matter digestion of cattle- and sheep-grazed forage.

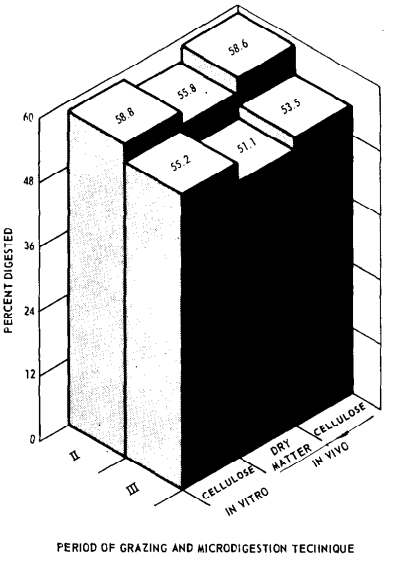

FIGURE 3. Comparison of digestion of forage grazed in midsummer, 1220 lb/acre available herbage, with forage grazed in late summer, 420 lb/acre available herbage.

cattle and sheep diets, individual plant parts may differ in digestibility (Pritchard et al., 1963). Further studies are needed on microdigestion by parts of annual plants grazed by cattle and sheep.

Period of grazing influence.—Forages grazed in midsummer were significantly more digestible than those grazed in early or late summer as measured by these three microdigestion techniques. Because of difficulties in gassing the artificial rumen system in period I and because of puncturing of nylon bags by seed heads grazed in early summer, only period II and III forages are compared in Figure 3. Averaged over all three techniques, the digestion of forages grazed in midsummer was about 8% more, relatively, than for forages grazed in late summer. These results agree with changes in chemical composition because the forages grazed in midsummer were about 8% higher, relatively, in crude protein than those grazed in late summer. Contrastingly, macrodigestion estimates averaged for cattle and sheep were about the same in middle and late summer (Van Dyne and Lofgreen, 1964). Cattle and sheep did not digest their diets in midsummer as well as would be expected if based on chemical composition. There were considerable differences in herbage availability, 1220 vs. 420 lb./acre, and in botanical composition of the diets grazed in middle and late summer (Van Dyne and Heady, 1964)[3], but knowledge of individual annual range plant species digestion is inadequate at present to explain the differences in microdigestion of the mixed samples.

Individual range plants. — Composite samples of four annual and one perennial grass, clipped throughout the experimental pasture during period II, were digested by nylon bag technique in cattle and sheep in midsummer. Their digestion is compared in Table 3 with that of the mixed forage grazed by cattle and sheep and digested by nylon bag procedure.

The annual grasses had a significantly higher microdigestion than the perennial *(Stipa pulchra)*. This is probably because in hand-clipping, large amounts of old, dead material were obtained with the perennial samples, but only the current year's growth was obtained with the annuals. The nutritive value of the perennial is thereby negatively biased and, furthermore, livestock selected primarily green portions of perennials in their diets (Van Dyne and Heady, 1964)[3]. Dry matter digestion was not significantly different from cellulose digestion when averaged over the five species.

Table 3. Microdigestion of five grasses and mixed forages by cattle and sheep in midsummer.

Species	Dry matter digestion C.[1]	Dry matter digestion S.[2]	Cellulose digestion C.	Cellulose digestion S.
	— — Percent — —			
Avena barbata	39	50	53	52
Bromus mollis	42	49	46	48
Bromus rigidus	41	48	48	46
Bromus rubens	40	47	43	48
Stipa pulchra	23	30	21	27
Avg.—annuals	41	49	47	48
Avg.—all grasses	37	45	42	44
Sheep forage	50	55	51	56
Cattle forage	49	57	52	60

[1] C=Cattle
[2] S=Sheep

[3] *Van Dyne, G. M. and H. F. Heady. 1964. Dietary botanical composition of cattle and sheep sharing a mature California annual range. Unpublished manuscript. 51 pp.*

Cattle digested significantly less of these grasses than did sheep, when averaged over both techniques, 45 vs. 40%. A significant class of stock x technique interaction occurred because dry matter digestion by cattle was considerably lower than that by sheep; whereas, cellulose digestion by sheep and cattle was similar. For sheep, all the individual species had lower dry matter and cellulose digestion than did the mixed sheep forage or cattle forage. For cattle, only one of the species, *Avena barbata*, had higher microdigestion than the sheep or cattle forage.

Micro- vs. Macrodigestion

One reason for digesting range plants by microtechniques is because microdigestion has been found to be highly correlated with macrodigestion estimates determined by conventional techniques for many farm roughages (Table 4). However, the degree of correlation varies widely between laboratories, forages, and often within the same forage and laboratory (Table 4).

The relationships of estimates of digestibility determined by nylon bag or artificial rumen technique and the corresponding macrodigestion estimate determined by lignin ratio during three range periods are illustrated in the left side of Figure 4. The macrodigestion estimates are calculated by lignin ratio using fecal excretion rate and composition during seven days from nine animals of each class in each period and composition of forage collections made twice daily for five days from five esophageal fistulated cattle and seven esophageal fistulated sheep in each grazing period (Van Dyne and Lofgreen, 1964).

Microdigestion per se.—The poor gassing of the artifical rumen in period I caused the relation of cellulose digestion in vitro to cellulose digestion by lignin ratio to be considerably different for forages SI and CI than for the other forages or techniques (Figure 4). Disregarding period I data there is a fair correlation between results from microdigestion and macrodigestion techniques, although the former are generally higher than the latter. Because numbers by a given technique are small, all data were combined to compute the correlation between microdigestion and macrodigestion which was 0.72 ($P < .01$). For only the cellulose digestion estimates the correlation is 0.45 (approaching $P < .05$) which is much lower than many which have been reported (Table 4).

Adjusted microdigestion.—Because procedural variations occur even under the best of conditions, and because the magnitudes of digestion estimates are affected by procedural variations, it is desirable to include standard samples in each trial for comparison between trials and adjustment of data to standard conditions (Tilley and Terry, 1963; Van Dyne, 1963). An example of the adjustment procedure is as follows. For sheep forage in period I, PCD in vitro was 39.8%. The PCD in vitro for the alfalfa standard in periods I (range grazing) and IV (dry-lot) were 52.5 and 58.8%, respectively. Thus, the adjusted microdigestion estimate for period I sheep forage was calculated as follows:

$$\frac{39.8\%}{52.5\%} \times (58.8\%) = 44.6\%$$

when inocula were from grazing animals / when inocula were from animals on dry-lot

Adjusted data, plotted in the right side of Figure 4, shows a considerably decreased range of microdigestion estimates. Disregarding period I forages, the correlation between adjusted microdigestion and macrodigestion was 0.52 (approaching $P < .05$). This suggests there was no improvement in correlation by the adjustment procedure, but the range in original data (per se), 20%, is considerably higher than the range in adjusted data, 9% (compare left and right portions of Figure 4). The

Table 4. Review of correlations of microdigestion and macrodigestion estimates.

Reference	For-ages[1]	Ani-mals[2]	Diet[3]	Correlations[4, 5]	Hours[6]
Barnett (1957)	27	S-S	U	(**) $PCFD_{TC}$: PCD_{AR}	48
Asplund *et al.* (1958)	11	S-S	U	.74 $PDMD_{TC}$: $PDMD_{AR}$	48
Hershberger *et al.* (1959)	35	S-S	U	.97 PCD_{TC}: PCD_{AR}	24
Quicke *et al.* (1959)	7	S-S	U	.67 PCD_{TC}: PCD_{AR}	48
Reid *et al.* (1959)	1	S-S	=	.98 $PDMD_{TC}$: $PDMD_{AR}$	—
Clark and Mott (1960)	11	S-C	U	.77 $PDMD_{TC}$: $PDMD_{AR}$	24
Donefer *et al.* (1960)	9	S-S	U	.91 NVI_{TC}: PCD_{AR}	12
LeFevre and Kamstra (1960)	16	S-C,S	U	.84 PCD_{TC}: PCD_{AR}	48
Reid *et al.* (1960)	124	C,S-S	U	(**) $PDMD_{TC}$: PCD_{AR}	36
Reid *et al.* (1960)	8	S-S	=	(**) $PDMD_{TC}$: PCD_{AR}	24,48
Reid *et al.* (1960)	1	S-S	=	(**) $PDMD_{TC}$: $PDMD_{NB}$	72
Taylor *et al.* (1960)	5	S-S	U	(**) PCD_{TC}: PCD_{AR}	—
Archibald *et al.* (1961)	2	C-C	=	.99 PCD_{TC}: PCD_{NB}	48
Baumgardt *et al.* (1962)	31	S-C	U	.85 DE_{TC}: PCD_{AR}	24,48
		C-C	U	.75	24,48
Bowden and Church (1962)	39	S-C	U	.73 $PDMD_{TC}$: $PDMD_{AR}$	48
Caballero *et al.* (1962)	2	S-C	U	(**) PCD_{TC}: PCD_{AR}	48
Donefer *et al.* (1962)	42	S-C	U	.89 NVI_{TC}: PCD_{AR}	12
Johnson *et al.* (1962b)	1	C-U	U	.86 $PDMD_{IND}$: PCD_{AR}	12
Johnson *et al.* (1962a)	12	S-C	U	.97 PCD_{TC}: PCD_{AR}	48
Lusk *et al.* (1962)	2	C-C	=	.83 PCD_{TC}: PCD_{NB}	48,72
Kercher (1963)	4	C-C	=	.24 PCD_{TC}: PCD_{NB}	72
				−.11 PCD_{TC}: PCD_{AR}	72
Tilley and Terry (1963)	148	S-S	U	(**) $PDMD_{TC}$: $PDMD_{AR}$	48

[1] Forages varied from silages and pasture to hays and straw.

[2] Animals used for macrodigestion and microdigestion estimates respectively: C=cattle, S=sheep, U=unspecified.

[3] Diet of animals used as inocula source same as forage tested "="; diet not the same as forage tested or not specified "U".

[4] Correlations of micro- and macrodigestion as reported or calculated from their data; or (**) if highly significant but magnitude not reported.

[5] PDMD, PCD, PCFD = percent dry matter, cellulose, and crude fiber digested, TC=total collection, IND=indicator techniques, AR=artificial rumen, NB=nylon, dacron or silkbag, DE=digestible energy.

[6] Duration of fermentations in hours.

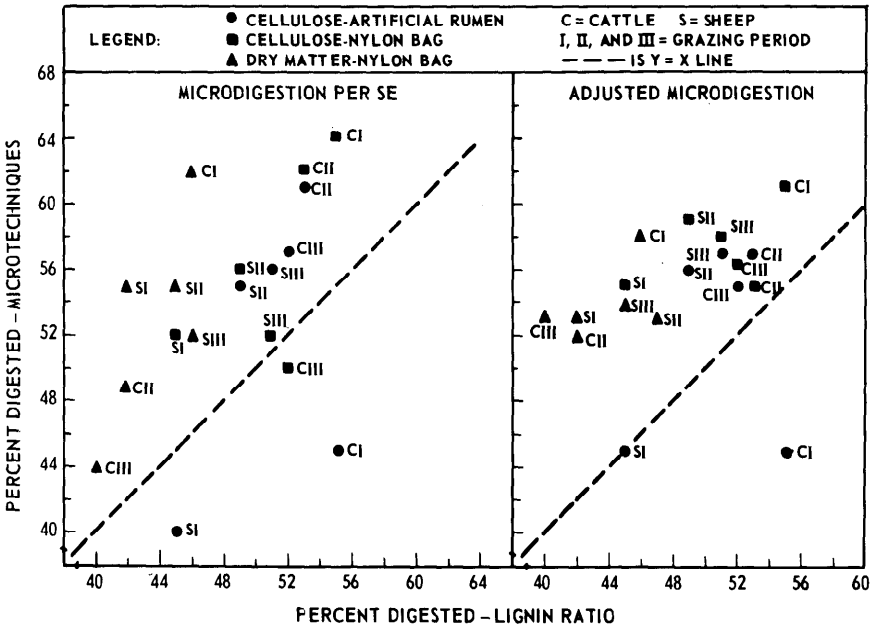

FIGURE 4. Cellulose and dry matter digestion of annual range forage measured by microdigestion techniques and by lignin ratio.

high correlation of microdigestion per se to macrodigestion may be spurious, i.e., it may be a function of the range of the data.

Even after adjustment of the data the in vitro values for period I forages are still considerably different from the other samples. Because the adjustment procedure accounts for methodological variations, these data suggest the forages grazed in early summer were different in microdigestion than those grazed in middle and late summer. However, in vivo PCD and PDMD for period I forages were similar to those of period II and III forages indicating a period x microtechnique interaction occurred.

Range vs. dry-lot studies.—Several general conclusions can be drawn from these studies and those reviewed in Table 4:

(1) There is a high correlation between micro- and macrodigestion estimates for dry matter and cellulose. In five investigations the correlation between micro- and macrodigestion was ≥ 0.90 (see Hershberger et al., 1959; Reid et al., 1959; Donefer et al., 1960; Archibald et al., 1961; and Johnson et al., 1962a in Table 4). Our correlations were not that high, but our data are over a more limited range.

(2) The base feed of animals used as a source of inoculum is important (see Asplund et al., 1958; Clark and Mott, 1960; Taylor et al., 1960; Van Dyne, 1962; and Hopson et al., 1963). In this experiment the average PCD by lignin ratio for forages grazed in periods I, II, and III and the PCD in vitro was as follows:

	Period digested in vitro			Lignin
	I	II	III	ratio
	— — Percent — —			
Period I grazed	46	58	54	50
II		58	60	51

Thus, here also, the macrodigestion was nearest microdigestion in the same period the forage was grazed.

(3) In many instances 48-hr microdigestion estimates for cellulose are within two to five percent of the macrodigestion estimate (e.g., see Caballero et al., 1962; Johnson et al., 1962a; Tilley and Terry, 1963; and Figure 4).

(4) The microdigestion estimates are often more repeatable, within a forage, than macrodigestion estimates (Archibald et al., 1961) and better results generally are obtained when the same class of stock is used for both micro- and macrodigestion estimates.

Most of the published studies have been concerned with higher quality roughages than mature range herbage and with forages encompassing a much wider range in digestibility than those investigated in this study. Few studies have involved grazing, but individual animal variations on range are greater than on dry-lot (Van Dyne and Weir, 1964). Individual species of plants rather than complex mixtures of forages were investigated in many instances (Table 4).

Existing techniques for measurement of range forage intake and digestion are not wholly satisfactory. Microdigestion techniques, having met with success under dry-lot and range conditions, may lead to more reliable estimates of range forage values and may be used in determination of forage intake (Van Dyne and Meyer, 1964).

Summary And Conclusions

Eighteen ruminal fistulated steers and wethers each provided inocula for microdigestion studies in three range grazing trials on mature annual range and in one dry-lot feeding trial. Artificial rumen and nylon bag cellulose digestion (PCD) and nylon bag dry matter digestion (PDMD) estimates were obtained. Each animal provided microdigestion estimates on Solka-floc, on an alfalfa sample, and on forages consumed by esophageal fistulated animals grazing on the same range. Two steers and wethers each provided nylon bag microdigestion estimates on five hand-clipped range forage plants during one period on the range.

Six grazed forages, an alfalfa sample, and Solka-floc were not ranked in the same order by the three microdigestion procedures. Solka-floc always had the highest digestibility, but forages varied in rank. Cellulose digestibility, but not dry matter digestibility, was higher in cattle-grazed than in sheep-grazed forage. Forages grazed by either cattle or sheep in midsummer were more digestible, by all techniques, than forages grazed in early or late summer.

The mixed forage samples obtained from esophageal fistulated animals generally had higher microdigestion estimates by nylon bag technique than any

of the five species hand-clipped from the range.

Microdigestion estimates were correlated with macrodigestion estimates obtained by lignin ratio technique under range grazing or total collection procedures under dry-lot feeding. Over all techniques the correlation between microdigestion and macrodigestion estimates was about 0.72. Adjusting microdigestion of range forages to that of a standard sample decreased the range of estimates but did not improve the correlation of microdigestion to macrodigestion. The correlations found were not as high as many of those in the literature for farm roughages and reasons are discussed for possible differences.

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