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The Digestibility, for Sheep, of the Cellulose in a Poor Veld Hay, as affected by Supplements of a Mixture of Concentrates and Green Feed.*

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INTRODUCTION.

The importance of the digestion of the fibrous constituents of mature pasturage, on which ruminants in this country have to subsist for several months during each year, in the energy economy of these animals has been emphasized in a preliminary communication by Louw and van der Wath (1943). These workers could not bring about an improvement in the digestibility of the cellulose in a basal ration of poor veld hay by means of supplementation with highly digestible feeds. It was concluded at the time that " the ingestion of the basal ration, representing, approximately, the nutritive value of winter grazing in the Transvaal, created conditions in the rumen of the sheep sufficiently favourable to the existence of that number of organisms of the right kind necessary for the maximum utilization of the cellulose in the ration ". A corollary to this conclusion was that the degree of lignification, which is known to have a pronounced influence on cellulose digestion, might have been the only factor which limited the breakdown of the cellulose in the basal ration of pasturage containing 3·0 per cent. of protein.

In a review of our present knowledge of the biological decomposition of cellulose in general, Norman and Fuller (1942) indicated that the presence of lignin in the cell-wall of plants markedly affects the availability of cellulose. The natural decomposition of plant material by a mixed flora is less rapid and less extensive with increased lignification. This latter process is known to be one of maturation and is associated with other changes in the composition of the plant, such as a reduction in protein content and water-soluble constituents. But even allowing for this reduction in available nutrients, it is found that the cellulose of material containing a low percentage of lignin (immature material) is far more readily attacked than the cellulose of mature material containing a high percentage of lignin. This is a matter of common experience in compost making. Lignin is of a resistant nature and, since it encrusts and penetrates the cellulose fabric, it acts as a physical barrier to the organisms and protects the cellulose. In the light of such considerations the corollary referred to above does not seem improbable.

* The data here presented formed the subject of a talk delivered before Section D. of the South African Association for the Advancement of Science on 4th July, 1946.

On the other hand, a low nitrogen content, or a deficiency of any other nutrient essential for the growth of the organisms, may so impede their proliferation in the rumen that the breakdown of the cellulose cannot take place to the limit assumed to be set by the degree of lignification present. We have unfortunately very little exact information on the nature and nutrient requirements of the organism-complex that is responsible for the normal breakdown of cellulose and other cell-wall polysaccharides in the rumen of farm animals. In *in vitro* studies with mature plant materials it has, however, according to Norman (1929), been shown that the amount of nitrogen available controls the rate and degree of decomposition by micro-organisms, provided that the carbonaceous constituents of the material are at all available to the organisms concerned. In his own studies on the biological decomposition of straws Norman added nitrogen in the form of ammonium carbonate at the rate of 1 gram per 100 grams of straw. This concentration of nitrogen is considerably in excess of that present in the basal ration of grass hay, containing 3·0 per cent. of crude protein, and creating, apparently, optimum conditions for the ruminal decomposition of its cellulose [c.f. Louw and van der Wath (loc. cit.)].

Interest at this Institute in the matter of ruminal digestion of cellulose is at present focussed on studies which aim at ascertaining to what extent the utilization of the mature natural pasturage, available to animals during the dry season, is modified by supplements of feeds which are in any case needed if the known deficiencies of such pasturage are to be rectified. A consignment of this grade of feed arrived during 1944 for general feeding purposes on the Station, and since it happened to contain a very low percentage of protein it was considered suitable material for the type of investigation in hand.

Experimental Procedure.

On the 16th August, 1944, sixteen 4 to 6-tooth Merino wethers, weighing between 60 and 80 lb., were selected. The investigation comprised six digestion trials each consisting of a collection period which lasted 8 days, preceded by a pre-period of at least the same duration. Faeces only were collected. For this purpose a harness and faeces-bag of the usual design was used. Each sheep was housed in an individual feeding pen with a concrete floor and measuring 7 by 7 feet, during both the preliminary and collection periods.

The sheep were placed in their pens on the day of selection and an initial ration of lucerne hay and crushed yellow maize was gradually replaced by the basal experimental ration of poor grass hay. The intake on this ration was, as may be expected, not high. However, by the middle of September most of the animals were consuming over 400 grams of the grass hay per day. To accustom them to the equipment the harnesses with faeces-bags were strapped in position on the 2nd of September; the lower ends of the bags which could be closed with draw strings were, of course, left open at this stage.

Prior to the commencement of the study an amount of grass hay thought to be sufficient for the experiment was chopped to 1 to 3 inch lengths in an electric chaff cutter. This was thoroughly mixed and stored in grain bags. This was done in order to reduce to a minimum any variations in the composition of the hay used in the successive digestion trials, an essential precaution in work of this nature.

The 16 sheep were divided into four groups of 4 head each according to the principle of stratified randomization on the basis of body-weights. During the first three periods of the study the groups received the basal ration only. The object in having more than one period was two-fold: to obtain a reliable average value for the digestibility of the basal ration and, incidentally, to establish whether the digestive powers of an animal on such a poor ration deteriorates with time. Supplementation of this basal ration was started in Period IV. The schedule of experimentation and the quantitative composition of the daily rations used, are given in Table 1. It will be noted that Period V is a repetition of Period IV, for all groups, and that Period VI was the same as the preceding one except that all the sheep were allowed an extra supplement of 200 grams of green feed per day.

TABLE 1.

Schedule of Experimentation and Daily Rations.

PERIOD.	GROUP A.	GROUP B.	GROUP C.	GROUP D.
I.....	* Basal ration.	* Basal ration.	* Basal ration.	* Basal ration.
II.....	Basal ration.	Basal ration.	Basal ration.	Basal ration.
III.....	Basal ration.	Basal ration.	Basal ration.	Basal ration.
IV.....	Basal + 20 gm. Concentrate.	Basal + 50 gm. Concentrate.	Basal + 85 gm. Concentrate.	Basal + 170 gm. Concentrate.
V.....	Basal + 20 gm. Concentrate.	Basal + 50 gm. Concentrate.	Basal + 85 gm. Concentrate.	Basal + 170 gm. Concentrate.
VI.....	Basal + 20 gm. Concentrate + 200 gm. green feed.	Basal + 50 gm. Concentrate + 200 gm. green feed.	Basal + 85 gm. Concentrate + 200 gm. green feed.	Basal + 170 gm. Concentrate + 200 gm. green feed.

* The basal ration consisted, for all groups and periods, of 400, 500, or 600 grams of poor grass hay per sheep.

The concentrate was composed of 76 parts by weight of starch, 15 parts of casein, 5 parts of dried brewer's yeast and 4 parts of a complete mineral mixture according to Hubbell *et al* (1937). This supplement was specially prepared by mixing the ingredients and adding boiling water whilst stirring until the mass attained the consistency of a dough. It was then kneaded for about 5 minutes in an electric mixing machine. The dough was next rolled out into $\frac{1}{4}$ inch thick sheets and placed in pans to dry in the sun. After about 6 hours the sheets were broken up by hand into $\frac{1}{2}$ to 1 inch pieces. After a further 6 to 8 hours in the sun the material was usually found to be sufficiently dry to allow of storage without spoiling. The sheep were found to be extremely fond of these crisp " biscuits ". Lucerne was used as green feed in period VI.

On starting a collection period the pens were thoroughly cleaned and the faeces-bags closed at a definite hour, say, 9 o'clock in the morning. The daily rations were weighed out each morning and samples taken at the same time for analysis. The moisture contents of the grass hay and green feed were determined daily and usually found to vary but little under the prevailing weather conditions in the course of an experimental period.

Composite samples of the feeds were obtained for each period from the daily samplings and reserved for chemical analysis. Feed refused or scattered on the floor of the pen was collected each morning, dried in the sun, if necessary, and reserved in a paper bag. At the end of a collection period the combined orts were weighed and sampled for analysis. These consisted for all periods of the coarser stems of the grass hay only. Except for the green feed which was fed only in the morning, the daily rations were offered in two portions, about half in the morning and the rest in the afternoon.

The faeces of each sheep were collected twice daily, at 8 p.m. and 4 p.m. Those collected in the afternoon were stored in the cold in a canned fruit bottle containing a little formalin until the next morning when they were thoroughly mixed with the morning's collection, weighed, and a 10 per cent. aliquot transferred to a galvanized iron pan for immediate drying in the sun or in an electric oven, should weather conditions be unfavourable. After about 5 hours in the sun the faeces were usually found to be sufficiently dry to check any further decomposition. The dry aliquots were composited in a linen bag. After the conclusion of a collection period the composite sample of faeces was weighed and a sample taken for a moisture determination, the remainder being finely ground and a representative sample of it stored in a suitable bottle for chemical analysis.

Cellulose was determined by the method of Crampton and Maynard (1938).

The sheep were weighed at the beginning and at the end of each collection period.

Results.

Relevant features in the chemical composition of the basal ration of grass hay and of the concentrate and green feed are presented in Table 2. A glance at the figures reveals that the composition of the basal ration remained virtually the same for all the periods. An essential requirement for work of this nature has thus been satisfied. A more detailed analysis of a composite sample of the grass hay used as basal ration yielded the following results in percentages on the basis of the dry matter: Ash, 8·4; Crude fat, 1·0; Crude protein, 2·2; water soluble substances, 5·9; cellulose, 41·8; lignin, 14·0; and hemicelluloses, by difference, 26·7. From these figures it may be calculated that no less than 90 per cent. of the organic matter of the grass was composed of the cell-wall constituents cellulose, hemicelluloses and lignin. The nature of the water-soluble constituents were not investigated except that a small fraction, 0·7 per cent. on the basis of the dry matter, was found to be reducing sugars. The grass hay contained no starch. The moisture contents of the feeds as fed were on an average 8·0 per cent. for the hay and concentrate, and 70·0 per cent. for the green feed.

The main collection data together with the coefficients of digestibility of the dry matter of the rations are given in an Appendix by Tables I, II, III and IV for Groups A, B, C and D, respectively. Under the same heading the digestion coefficients of cellulose have been calculated in Tables V, VI, VII and VIII. Group averages which will form the basis of the following discussion are set forth in Table 3. For the sake of economy of space the data relating to the daily consumption of phosphorus and protein and to the digestibility of the latter are given in the summarized form

only in this table. The average figures for live weight, hay consumption, and percentage cellulose digested are presented graphically in Figures 1, 2 and 3, respectively.

TABLE 2.

Percentage Composition of the Dry Matter of the Feeds used.

Period.	Grass Hay.			Concentrate.			Green Feed.		
	Cellulose.	Protein.	P.	Cellulose.	Protein.	P.	Cellulose.	Protein.	P.
I	40·9	2·29	0·049	—	—	—	—	—	—
II	41·2	2·33	0·045	—	—	—	—	—	—
III	40·7	2·44	0·047	—	—	—	—	—	—
IV	41·6	2·10	0·041	—	16·20	0·456	—	—	—
V	41·3	2·15	0·042	—	16·20	0·456	—	—	—
VI	41·1	2·16	0·044	—	16·20	0·456	30·3	16·78	0·153

TABLE 3.

Summary of Group Averages for Collection Data and Digestion Coefficients.

Period.	Group A.	Group B.	Group C.	Group D.
		Live weight (lb.).		
I	70·0	69·3	67·7	69·8
II	66·9	65·5	64·5	66·5
III	60·8	60·6	60·9	61·8
IV	58·7	59·7	59·5	62·4
V	57·5	59·0	59·5	63·7
VI	55·5	58·3	59·2	64·8
		Hay consumed (gm. dry matter).		
I	363·0	346·1	413·8	407·4
II	400·8	344·5	414·1	400·7
III	371·9	319·2	389·5	383·9
AVERAGE FOR I–III	*378·6*	*335·1*	*405·8*	*397·3*
IV	347·4	323·6	395·4	394·4
V	353·1	315·5	380·8	409·0
AVERAGE FOR IV–V	*350·3*	*319·6*	*388·1*	*401·7*
VI	325·8	327·7	393·3	381·9
		Hay refused (gm. dry matter).		
I	116·1	69·1	72·9	77·4
II	68·0	77·4	54·7	68·1
III	58·4	65·5	40·8	45·6
AVERAGE FOR I–VII	*80·8*	*70·7*	*56·1*	*63·7*
IV	87·3	65·3	42·1	40·3
V	80·7	72·6	50·7	24·7
AVERAGE FOR IV–V	*84·0*	*69·0*	*46·4*	*32·5*
VI	110·2	68·0	48·9	62·7

TABLE 3 (*continued*)

Period.	Group A.	Group B.	Group C.	Group D.
		Percentage dry matter digested.		
I.	31·7	35·0	36·3	35·9
II.	31·2	32·4	32·2	34·7
III.	30·2	35·4	36·6	33·4
AVERAGE FOR I–III.	*31·0*	*34·3*	*35·0*	*34·7*
IV.	32·3	42·6	45·3	49·8
V.	31·6	40·7	42·6	47·2
AVERAGE FOR IV–V.	*32·0*	*41·7*	*44·0*	*48·5*
VI.	38·3	46·1	45·4	51·6
		Percentage cellulose digested.		
I.	46·7	49·8	51·8	51·9 (50·0)
II.	44·5	47·5	47·3	50·1 (47·4)
III.	42·3	48·4	50·6	47·1 (47·1)
AVERAGE FOR I–III.	*44·5*	*48·6*	*49·9*	*49·7*
IV.	43·9	50·0	49·9	46·4
V.	41·9	47·5	47·6	42·4
AVERAGE FOR IV–V.	*42·9*	*48·8*	*48·8*	*44·4*
VI.	49·3	51·8	49·1	48·5
		Protein consumed (gm. per day).		
I.	8·3	7·8	9·5	9·3
II.	9·3	8·0	9·6	9·3
III.	9·0	7·8	9·5	9·4
AVERAGE FOR I–III.	*8·9*	*7·9*	*9·5*	*9·3*
IV.	10·3	14·2	20·9	33·5
V.	10·6	14·2	20·7	34·1
AVERAGE FOR IV–V.	*10·5*	*14·2*	*20·8*	*33·8*
VI.	19·9	25·0	31·5	44·0
		Percentage protein digested.		
I.	N*	N	N	N
II.	N	N	N	N
III.	N	N	N	N
AVERAGE FOR I–III.	—	—	—	—
IV.	N	13·8	27·2	46·7
V.	N	13·0	23·7	42·8
AVERAGE FOR IV–V.	—	*13·4*	*25·5*	*44·8*
VI.	19·5	27·9	41·7	50·7
		Phosphorus consumed (gm. P per day).		
I.	0·18	0·17	0·20	0·20
II.	0·18	0·16	0·20	0·18
III.	0·17	0·15	0·18	0·18
AVERAGE FOR I–III.	*0·18*	*0·16*	*0·19*	*0·19*
IV.	0·22	0·34	0·52	0·88
V.	0·23	0·34	0·52	0·89
AVERAGE FOR IV–V.	*0·23*	*0·34*	*0·52*	*0·89*
VI.	0·32	0·45	0·62	0·97

* N signifies that coefficients of digestibility were negative.

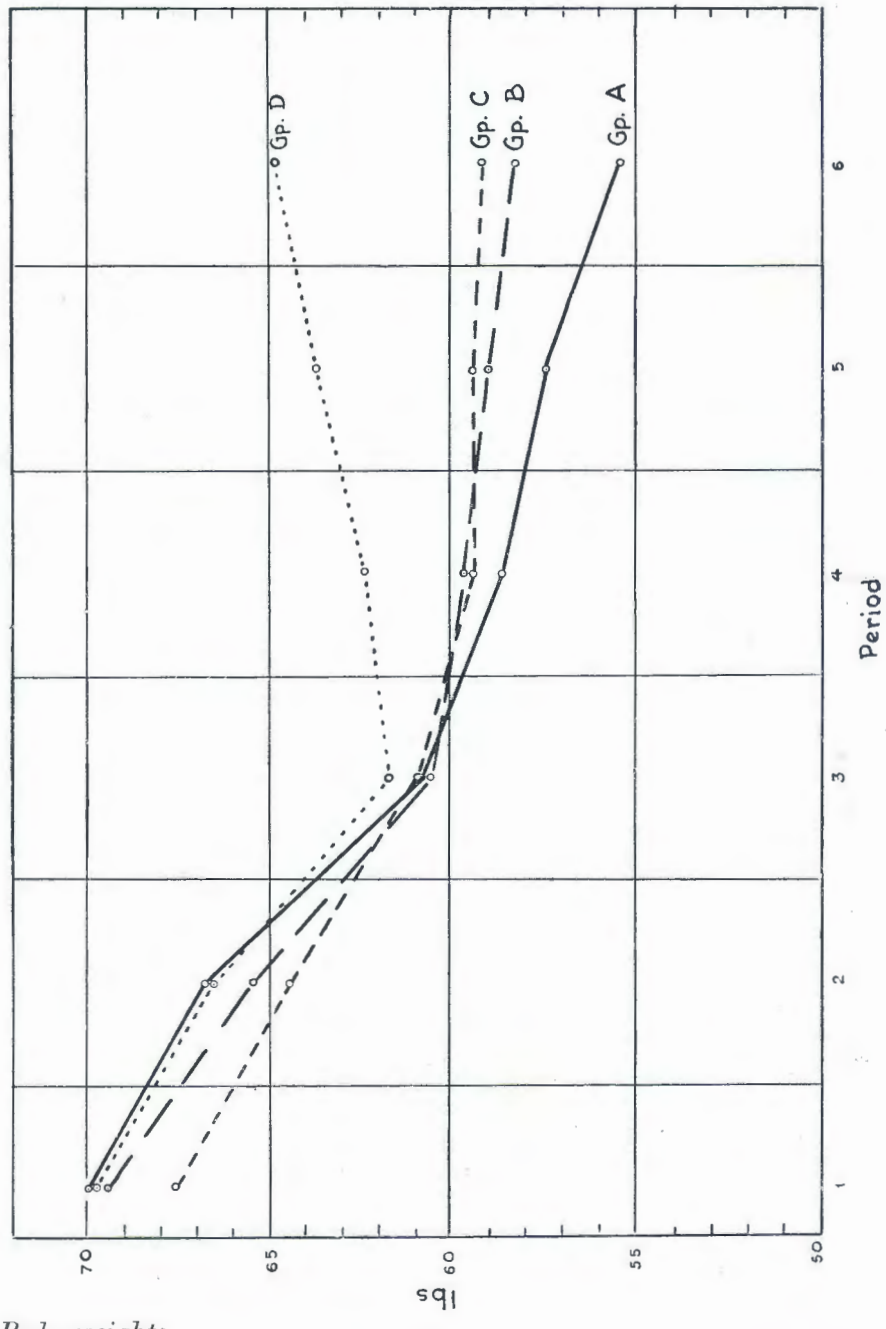


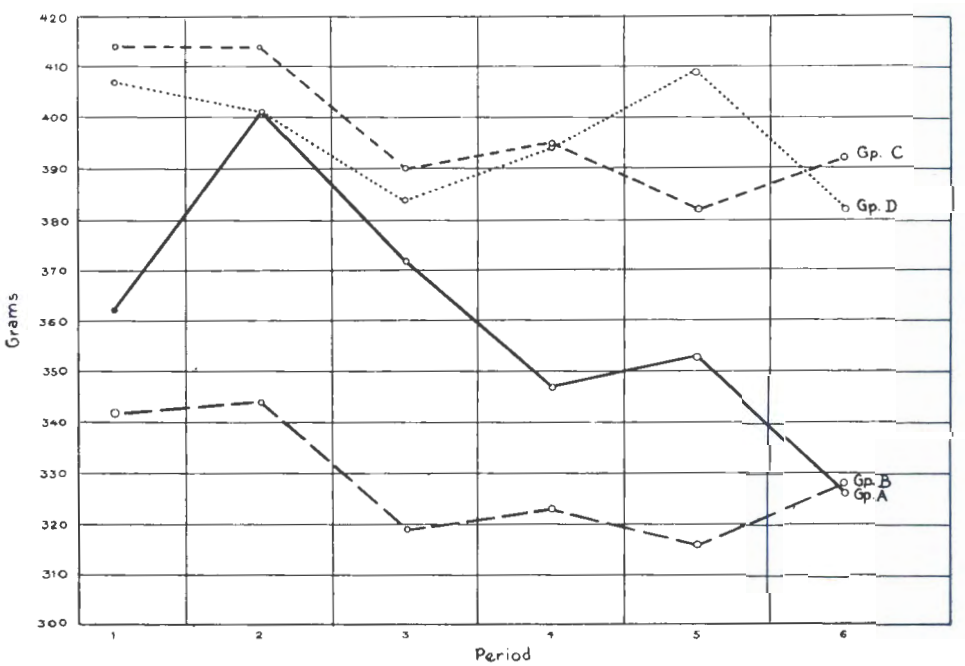
Fig. 1.—Bodyweights of Animals (Group Means).

(*a*) *Body weights.*

The variations in the live weights of the sheep in the several groups may be taken to reflect the nutritive value of the rations consumed. During the first three periods, when all the animals were offered the basal ration

only, a progressive loss in weight occurred in all the groups. Thus the individual sheep of Group A lost on an average 9 lb. during the 41 days covering these periods. The subsequent course of the weight curves were apparently determined by the size of the supplement offered. A supplement of 20 grams of concentrate together with one of 200 grams of green feed had, for instance, virtually no influence on the downward run of the graph for Group A; the loss of weight was considerably reduced in the case of group B receiving 50 grams of the concentrate, and practically arrested in the case of the animals of Group C offered 85 grams of the concentrate per head daily. Only in Group D (170 grams concentrate per sheep) has the initial decrease in live weight been changed into an increase by the supplements. With the exception of these animals, and then only in Periods IV, V and VI, all the sheep were thus at a more or less sub-maintenance level of nutrition during the whole of the investigation.

Fig. 2.—Average Daily Hay Consumption.



(*b*) *Hay consumption.*

Inspection of Figure 2 reveals only minor fluctuations in the average basal feed intake of the animals in Groups B, C and D for Periods I to VI. Those of Group A apparently consumed progressively less hay from Period II to Period VI, the intake in the latter period being only 80 per cent. of that in Period II.

The determination of the digestibility of a feed requires that no change be made in the amount of feed offered at any time during an experimental period, and that orts are, as far as possible, reduced to a minimum. For these reasons the grass hay could not be offered *ad. lib.*,

as required by a consumption trial, so that the question of the possible influence of the supplements on basal feed intake falls, strictly speaking, outside the scope of this study. Certain features relating to the amounts of hay offered and consumed call, however, for comment.

Whilst the supplements were at all times completely consumed the sheep refused varying amounts of the basal ration in all periods of the experiment, the amount offered remaining, apart from a few minor adjustments in the earlier periods, essentially unchanged. Orts were almost invariably composed of the coarser stems which were presumably the least palatable portions of the hay, but which cannot be considered inedible, in view of the not inconsiderable variations in the size of the orts left by animals receiving hay of uniform composition. For instance, in Period I sheep No. 1 refused daily 114 grams of dry matter from a ration of 500 grams of hay whilst sheep No. 16 completely consumed 600 grams of the same material. Again, sheep No. 9 left only 29 grams over in Period III, but no less than 125 grams in Period VI, the amount offered being 500 grams in both cases. Further examples of this nature may be cited from Tables I, II, III and IV, in the Appendix. At the same time the actual consumption of grass hay described in Figure 2 was at all times very much below the capacity of these animals for a roughage [c.f. Smuts and Marais (1940)]. These considerations seem to justify the conclusion that an improvement in the appetite of the sheep for the poor veld hay, following on the supplements of concentrate and green feed could have been reflected in a consistent reduction in the amounts of the refused feed in the relevant periods. Since this did not happen it would appear that the supplements fed in Periods IV, V and VI had no influence on the consumption of grass hay, or, at most, prevented a progressive decrease such as that which the supplements of Group A were apparently unable to stay.

(c) *The digestibility of the dry matter.*

Due to the fact that no supplements were given in periods I, II and III it was possible to determine the true digestibility of the dry matter of the grass hay in these periods. Inspection of the relevant tables in the Appendix reveals appreciable variations among the individual constituents. Considering all sixteen sheep the average digestibility of the dry matter was 33·75 per cent. The 46 coefficients on which this grand average is based ranged from 24·1 to 41·7 per cent., about 80 per cent. of the values falling within the range 30 to 40. An analysis of variance brought to light that there were no statistically significant differences in the digestibility of the dry matter among periods, groups, periods within groups, or groups within periods. Also, there was no correlation between the intake and digestibility of the dry matter.

The digestibility of the total dry matter of the rations improved in all subsequent periods, the extent of the improvement in different periods and groups depending on the size of the respective supplements (c.f. Tables 1 and 3). Considering the highly digestible nature of the concentrate offered this result was to be expected. At the same time it was not possible to determine the influence of the supplements on the digestibility of the grass hay as such, owing to the difficulties in the way of differentiating quantitatively between residues from the hay and the supplement, respectively, in the faecal dry matter. A useful indication is, however provided in this respect by the figures for the digestibility of the cellulose, a constituent

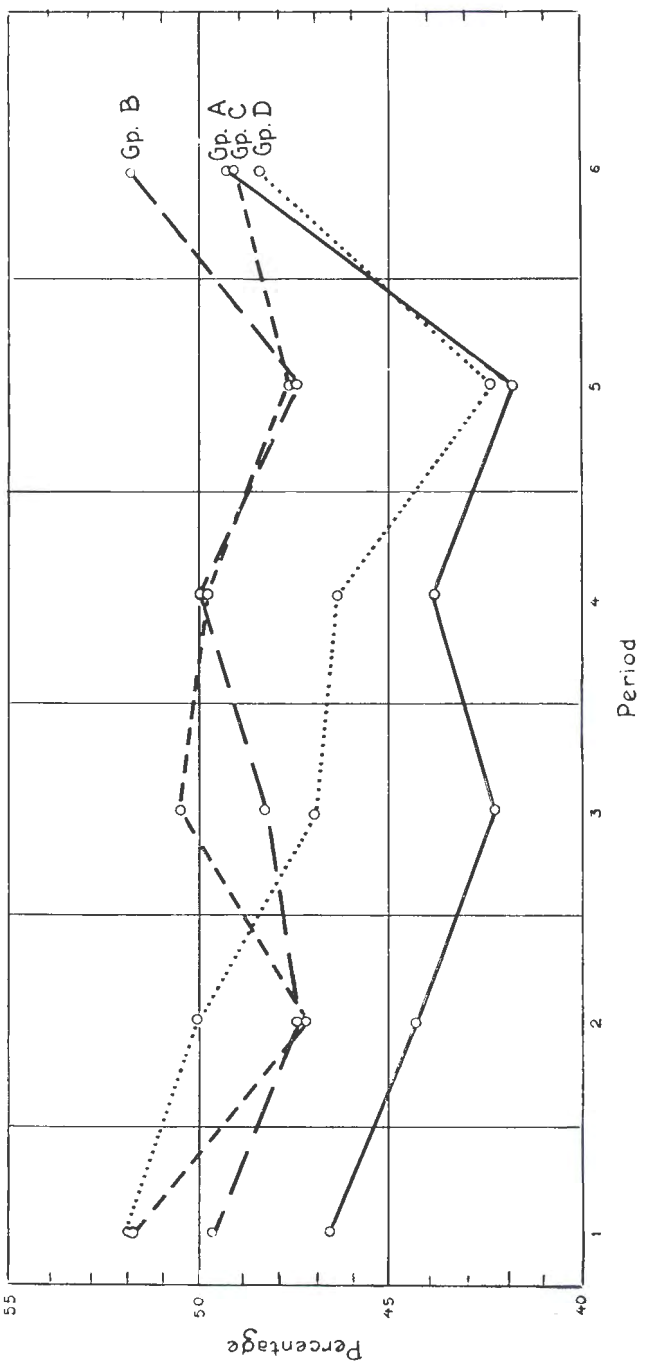


Fig. 3.—Average Digestibility of Cellulose.

of the hay not present in the concentrate fed in Periods IV and V during which the faeces should, therefore, have contained cellulose from the basal feed only.

(*d*) *The digestibility of the cellulose in the grass hay.*

The period means of cellulose digestion for the 16 sheep are given in brackets in the relevant part of Table 3. According to these figures the sheep digested the cellulose significantly better in Period I than in the following two periods, the values were 50·0, 47·4 and 47·1 per cent, for Periods I, II and III, respectively, giving a general mean of 48·2 for the three periods. Incidentally, it is of interest to note that this general mean is considerably higher than that of 33·75 obtained for the dry matter. From these figures it may be inferred that the cellulose of the type of mature plant material used is very much more digestible than its other fibrous constituents.

There was no difference in the efficiency with which the animals in Groups C and D digested the cellulose of the basal ration during the Periods I to III, the coefficients for the two groups being 49·9 and 49·7 per cent., respectively. The average coefficient for Group B, 48·6 per cent., was somewhat, and that for Group A, 44·5 per cent., appreciably lower than those for the other groups, all differences being, however, found to be statistically insignificant. If these group averages are now compared with those for Periods IV and V it is found that while the supplements had apparently no influence on the digestion of the cellulose in Groups B and C they had seemingly a depressing effect in the case of the remaining two groups, the decreases being from 44·5 to 42·9 per cent. and from 49·7 to 44·4 per cent. for Groups A and D, respectively. Only the latter decrease was, however, found to be statistically significant.

Apparently the additional supplement of green feed given in Period VI had also significant influence on the power of the animals in the two middle groups to digest cellulose. On the other hand, it seemed to have made good the decrease in digestive powers caused by the supplements of Periods IV and V in the case of the other two groups of animals. The improvements in the digestion coefficients for cellulose from 42·9 to 49·3 per cent. for Group A and from 44·4 to 48·5 per cent. for Group D were found to be highly significant.

General Discussion and Conclusions.

As pointed out earlier, considerable variations in the digestion coefficients obtained in the trials with sheep subjected to the same dietary treatment occurred (c.f. tables in Appendix). Thus in periods I to III, when all the sheep were ingesting the same basal ration of grass hay, the digestion coefficients of cellulose varied between 35·4 and 58·2, with a general mean of 48·2 per cent. The standard deviation, expressed as a percentage of this general mean, was found to be no less than 14·9. This is a quantitative measure of the variation which existed among different individuals.

The basal feed was of uniform composition. Collection periods lasted 8 days, preceded by preliminary periods of at least the same duration, so that the effect of irregular excretion could not have been large. There is, also, no reason for suspecting the accuracy of the observed weights and chemical analyses of the feeds and faeces. Of the possible causes to which

the variations in the coefficients obtained in the digestion trials may be due, we are thus left with variations in the actual digestive capacity of the individual animals. It is suggested that this high variability was due not so much to inherent differences in the digestive powers of the animals, but to causes associated with the fact that all the animals were for most of the time on a starvation diet (c.f. Figures 1 and 2 and Table 3). In this connection it should be pointed out that the hay consumption of the sheep was throughout only about 60 per cent. of their capacity for roughages, a circumstance which might have enhanced the effect of irregular excretion and thus necessitated a more extended collection period than the 8 days allowed in these trials. However, in spite of this disturbing feature in the individual results the mean values seem to justify certain provisional conclusions.

It was hoped that the supplements would on the one hand stimulate the appetite of the animals for the poor grass hay and at the same time improve the digestibility of its main energy-producing constituents, cellulose and hemicelluloses. Either improvement would have had the effect of increasing the value of the grass hay, as such, for maintaining life processes during times of feed scarcity. In neither case apparently, did the results of this investigation come up to expectations; no increase in hay consumption or improvement in the digestibility of the cellulose was observed on supplementing the hay with varying amounts of a concentrate mixture.

The results seem, at the same time, to suggest that the appetite and digestive powers of sheep subsisting on a ration of poor veld hay may deteriorate with time. The observed decrease in the coefficients of digestibility of cellulose from Period I to Period III might have been due to a phenomenon, referred to by Armsby (1917), according to which the percentage digestibility of the same feeding stuff by the same individual varied more or less at different times (a period effect). There is, however, the possibility that this decrease had been the outcome of an incipient weakening of digestive powers. The further decrease in cellulose digestion and hay consumption which took place in Periods IV and V in the case of Group A may then be explained on the ground that the small supplement (20 gm.) of concentrate fed these animals was not sufficient to oppose the effects of a progressive deterioration, reduced appetite and impaired digestive powers. The supplements given to the sheep in Groups B and C were, on the other hand, able to prevent these ill-effects. The significant decrease in the digestibility of the cellulose which occurred in Periods IV and V in the case of Group D may be ascribed to the fact, established by numerous experiments, that an undue proportion of easily digestible carbohydrate in a ration tends to reduce the digestibility of its fibrous constituents.

Whilst having apparently no effect on the animals of the two central groups, the addition of green feed in Period VI seemed, as pointed out previously, to have restored the capacity of the animals in groups A and D to digest cellulose to the previous level. In passing it should be pointed out that even if the cellulose in the green feed is assumed to be substantially more digestible than that in the grass hay, the amount thus introduced was too small (c.f. Tables V. VI VII and VIII in the Appendix) to account for the observed increases in the digestibility of the cellulose of the ration as a whole.

The results here presented confirm the earlier finding, quoted in the introduction of this paper, to the effect that old, dry winter grazing is apparently not deficient in nutrients required by the ruminal organisms responsible for the breakdown of the cellulose to a limit which is presumably set by the degree of lignification of the mature pasturage. They, however, raise new issues, such as that relating to the influence of varying amounts of a green, succulent feed on the nutritive value of mature dry grasses, which require further investigation.

Summary.

The influence of varying amounts of a supplement consisting of starch, casein, brewers yeast and minerals, alone and in conjunction with one of green feed, on the digestibility of the cellulose in a basal ration of poor veld hay, containing only 2·2 per cent. protein, has been tested in a series of digestion trials with sheep. It is concluded that:—

(1) The ability of sheep to digest cellulose was impaired when kept for any length of time on the basal diet of veld hay only.

(2) Daily supplements of 20, 50 or 85 grams of the concentrate mixture per sheep did not improve the digestion of the cellulose of the basal ration. Unlike the lowest one, the two higher supplements had, however, the effect of preventing deterioration of the digestive powers and appetites of the sheep.

(3) The highest supplement of concentrate, 170 grams per animal per day, more than compensated for the energy deficiency of the basal ration but depressed the digestion of its cellulose.

(4) Ability to digest cellulose, which had been temporarily weakened, as under (1) and (3) above, was restored by an additional supplement of green feed.

Acknowledgment.

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APPENDIX.

TABLE I.

Collection Data and Coefficient of Digestibility for Dry Matter (Group A).

Period.	Date of Collection.	Sheep No.	Weight (lb.).	Ration (gm.).			Orts. (gm. dry matter).	Dry Matter Intake (gm.).				Dry Matter Excreted.	Coefficient of Digestibility.
				Hay.	Supplement.	Green Feed.		Hay.	Supplement.	Green Feed.	Total.		
I.....	15–22/9/1944	1	63·3	500	—	—	114·0	342·3	—	—	342·3	342·3	31·5
		10	78·5	600	—	—	79·3	468·3	—	—	468·3	295·5	36·9
		11	72·8	500	—	—	103·0	353·3	—	—	353·3	240·0	32·1
		12	65·5	500	—	—	168·1	288·0	—	—	288·0	211·9	26·4
		AVERAGE..	70·0	—	—	—	116·1	363·0	—	—	363·0	—	31·7
II.....	4–11/10/1944	1	60·3	500	—	—	74·4	394·5	—	—	394·5	277·8	29·8
		10	74·5	600	—	—	53·5	509·0	—	—	509·0	352·5	30·7
		11	65·8	400	—	—	76·2	298·9	—	—	298·9	200·0	33·1
		12	—	—	—	—	—	—	—	—	—	—	—
		AVERAGE..	66·9	—	—	—	68·0	400·8	—	—	400·8	—	31·2
III.....	19–26/10/1944	1	57·0	500	—	—	67·5	385·0	—	—	385·0	274·5	28·7
		10	70·0	600	—	—	30·6	513·1	—	—	513·1	346·6	32·5
		11	61·0	400	—	—	49·6	312·9	—	—	312·9	205·0	34·5
		12	55·0	400	—	—	86·0	276·5	—	—	276·5	207·0	25·1
		AVERAGE..	60·8	—	—	—	58·4	371·9	—	—	371·9	—	30·2
IV.....	6–13/11/1944	1	56·3	500	20	—	53·5	404·0	18·3	—	422·3	279·4	33·8
		10	66·5	600	20	—	128·8	420·3	18·3	—	438·6	296·5	32·4
		11	59·5	400	20	—	61·5	304·5	18·3	—	322·8	215·7	33·2
		12	52·5	400	20	—	105·3	260·8	18·3	—	279·1	195·9	29·8
		AVERAGE..	58·7	—	—	—	87·3	347·4	—	—	365·7	—	32·3
V.....	21–28/11/1944	1	55·3	500	20	—	46·9	409·6	18·3	—	427·9	267·3	37·5
		10	65·5	600	20	—	91·1	456·6	18·3	—	474·9	337·0	29·1
		11	52·8	400	20	—	97·3	268·0	18·3	—	286·3	207·5	27·5
		12	56·5	400	20	—	87·3	278·0	18·3	—	296·3	199·8	32·2
		AVERAGE..	57·5	—	—	—	80·7	353·1	—	—	371·4	—	31·6
VI.....	7/14/12/1944	1	52·0	500	20	200	107·0	333·3	18·3	49·8	401·4	263·6	34·3
		10	63·3	600	20	200	103·8	454·5	18·3	62·3	535·1	340·0	36·5
		11	52·3	400	20	200	89·0	283·5	18·3	62·3	364·1	217·0	40·4
		12	54·5	400	20	200	140·8	231·8	18·3	62·3	312·4	181·3	42·0
		AVERAGE..	55·5	—	—	—	110·2	325·8	—	—	403·3	—	38·3

TABLE II.

Collection Data and Coefficient of Digestibility for Dry Matter (Group B).

Period.	Date of Collection.	Sheep No.	Weight (lb.).	Ration (gm.).			Orts. (gm. dry matter).	Dry Matter Intake (gm.).				Dry Matter Excreted.	Coefficient of Digestibility.
				Hay.	Supplement.	Green Feed.		Hay.	Supplement.	Green Feed.	Total.		
I.....	15–22/9/1944	6	59·3	400	—	—	107·0	258·0	—	—	258·0	173·5	32·8
		7	66·5	500	—	—	47·8	408·5	—	—	408·5	254·0	37·8
		14	65·8	400	—	—	53·5	311·5	—	—	311·5	208·4	33·1
		18	85·5	500	—	—	68·0	388·3	—	—	388·3	246·9	36·4
		AVERAGE..	69·3	—	—	—	69·1	341·6	—	—	341·6	—	35·0
II.....	4–11/10/1944	6	54·8	400	—	—	88·8	286·3	—	—	286·3	184·8	35·4
		7	65·3	500	—	—	53·5	415·3	—	—	415·3	286·5	31·0
		14	62·0	400	—	—	50·9	324·1	—	—	324·1	233·0	28·1
		18	79·8	500	—	—	116·5	352·3	—	—	352·3	228·8	35·0
		AVERAGE..	65·5	—	—	—	77·4	344·5	—	—	344·5	—	32·4
III.....	19–26/10/1944	6	52·0	400	—	—	55·3	306·1	—	—	306·1	192·5	37·1
		7	61·5	500	—	—	40·0	412·5	—	—	412·5	268·8	34·8
		14	57·0	400	—	—	56·1	306·4	—	—	306·4	220·6	28·0
		18	72·0	400	—	—	110·6	251·9	—	—	251·9	147·3	41·6
		AVERAGE..	60·6	—	—	—	65·5	319·2	—	—	319·2	—	35·4
IV.....	6–13/11/1944	6	50·8	400	50·0	—	71·5	294·5	45·8	—	340·3	194·3	42·4
		7	60·3	500	50·0	—	46·0	411·5	45·8	—	457·3	270·0	41·0
		14	56·3	400	50·0	—	41·8	324·3	45·8	—	370·1	215·8	41·7
		18	71·3	400	50·0	—	102·0	264·0	45·8	—	309·8	169·3	45·4
		AVERAGE..	59·7	—	—	—	65·3	323·6	—	—	369·4	—	42·6
V.....	21–28/11/1944	6	50·0	400	50·0	—	81·4	283·9	45·8	—	329·7	192·5	41·6
		7	59·8	500	50·0	—	55·3	401·3	45·8	—	447·1	267·9	40·1
		14	57·0	400	50·0	—	46·8	318·5	45·8	—	364·3	237·1	34·9
		18	69·3	400	50·0	—	107·0	258·3	45·8	—	304·1	163·5	46·2
		AVERAGE..	59·0	—	—	—	72·6	315·5	—	—	361·3	—	40·7
VI.....	7–14/12/1944	6	49·5	400	50·0	200	76·5	296·0	45·8	62·3	404·1	228·1	43·5
		7	59·0	500	50·0	200	52·9	412·4	45·8	62·3	520·5	289·1	49·4
		14	56·3	400	50·0	200	37·0	335·5	45·8	62·3	443·6	256·5	42·2
		18	68·3	400	50·0	200	105·5	267·0	45·8	62·3	375·1	190·3	49·2
		AVERAGE..	58·3	—	—	—	68·0	327·7	—	—	435·8	—	46·1

TABLE III.

Collection Data and Coefficient of Digestibility for Dry Matter (Group C).

Period.	Date of Collection.	Sheep No.	Weight (lb.).	Ration (gm.).			Orts. (gm. dry matter).	Dry Matter Intake (gm.).				Dry Matter Excreted.	Coefficient of Digestibility.
				Hay.	Supplement.	Green Feed.		Hay.	Supplement.	Green Feed.	Total.		
I.....	15–22/9/1944	3	—	—	—	—	—	—	—	—	—	—	—
		15	66·8	500	—	—	92·8	363·5	—	—	363·5	225·5	38·0
		16	78·8	600	—	—	—	547·5	—	—	547·5	368·1	32·8
		17	57·5	500	—	—	125·8	330·5	—	—	330·5	204·4	38·1
		AVERAGE..	67·7	—	—	—	72·9	413·8	—	—	413·8	—	36·3
II.....	4–11/10/1944	3	65·0	500	—	—	36·9	431·9	—	—	431·9	325·0	24·7
		15	63·3	500	—	—	101·5	367·3	—	—	367·3	245·0	33·3
		16	76·5	600	—	—	10·6	551·9	—	—	551·9	262·5	34·3
		17	53·3	400	—	—	69·8	305·3	—	—	305·3	194·4	36·3
		AVERAGE..	64·5	—	—	—	54·7	414·1	—	—	414·1	—	32·2
III.....	19–26/10/1944	3	62·5	500	—	—	24·0	428·5	—	—	428·5	289·1	32·5
		15	58·5	400	—	—	41·3	321·3	—	—	321·3	195·6	39·1
		16	73·0	600	—	—	35·4	508·4	—	—	508·4	340·0	33·1
		17	49·5	400	—	—	62·6	299·9	—	—	299·9	175·0	41·7
		AVERAGE..	60·9	—	—	—	40·8	389·5	—	—	389·5	—	36·6
IV.....	6–13/11/1944	3	61·3	500	85·0	—	17·8	439·8	77·8	—	517·6	296·5	42·8
		15	56·8	400	85·0	—	55·0	311·0	77·8	—	388·8	208·0	46·5
		16	72·0	600	85·0	—	5·5	543·5	77·8	—	621·3	341·0	45·2
		17	48·0	400	85·0	—	90·1	287·1	77·8	—	364·9	194·8	46·6
		AVERAGE..	59·5	—	—	—	42·1	395·4	—	—	473·2	—	45·3
V.....	21–28/11/1944	3	61·0	500	85·0	—	35·8	420·8	77·8	—	498·6	293·4	41·2
		15	56·8	400	85·0	—	55·3	310·0	77·8	—	387·8	214·9	42·0
		16	71·5	600	85·0	—	30·6	517·1	77·8	—	594·9	366·3	38·4
		17	48·5	400	85·0	—	81·1	275·1	77·8	—	352·9	181·6	48·6
		AVERAGE..	59·5	—	—	—	50·7	380·8	—	—	458·6	—	42·6
VI.....	7–14/12/1944	3	61·3	500	85·0	200	15·5	449·8	77·8	62·3	589·9	342·8	41·9
		15	56·5	400	85·0	200	57·9	314·6	77·8	62·3	454·7	241·4	46·9
		16	72·0	600	85·0	200	10·3	548·0	77·8	62·3	688·1	394·4	42·7
		17	46·8	400	85·0	200	112·0	260·8	77·8	62·3	400·9	200·5	50·0
		AVERAGE..	59·2	—	—	—	48·9	393·3	—	—	533·4	—	45·4

TABLE IV.

Collection Data and Coefficient of Digestibility for Dry Matter (Group D).

Period.	Date of Collection.	Sheep No.	Weight (lb.).	Ration (gm.).			Orts. (gm. dry matter).	Dry Matter Intake (gm.).				Dry Matter Excreted.	Coefficient of Digestibility.
				Hay.	Supplement.	Green Feed.		Hay.	Supplement.	Green Feed.	Total.		
I.....	15–22/9/1944	4	61·5	400	—	—	48·9	338·6	—	—	338·6	232·5	31·4
		5	70·5	600	—	—	49·5	498·0	—	—	498·0	292·8	41·2
		9	70·8	600	—	—	89·9	457·6	—	—	457·6	290·4	36·6
		13	76·3	500	—	—	120·9	335·4	—	—	335·4	220·8	34·2
		AVERAGE..	69·8	—	—	—	77·4	407·4	—	—	407·4	—	35·9
II.....	4–11/10/1944	4	58·0	400	—	—	44·1	330·9	—	—	330·9	217·5	34·3
		5	70·0	600	—	—	59·3	503·3	—	—	503·3	315·4	37·3
		9	66·8	600	—	—	92·6	469·9	—	—	469·9	310·0	34·0
		13	71·0	400	—	—	76·3	298·8	—	—	298·8	200·0	33·1
		AVERAGE..	66·5	—	—	—	68·1	400·7	—	—	400·7	—	34·7
III.....	19–26/10/1944	4	53·0	400	—	—	49·4	313·1	—	—	313·1	204·4	34·7
		5	67·0	600	—	—	59·0	484·8	—	—	484·8	297·1	38·7
		9	61·0	500	—	—	29·4	419·8	—	—	419·8	268·8	36·0
		13	66·0	400	—	—	44·5	318·0	—	—	318·0	241·3	24·1
		AVERAGE..	61·8	—	—	—	45·6	383·9	—	—	383·9	—	33·4
IV.....	6–13/11/1944	4	54·3	400	170	—	46·0	320·0	155·5	—	475·5	244·8	48·5
		5	65·8	600	170	—	62·5	486·5	155·5	—	642·0	330·4	48·5
		9	62·0	500	170	—	32·1	425·4	155·5	—	580·9	295·1	49·2
		13	67·5	400	170	—	20·4	345·6	155·5	—	501·1	236·9	52·8
		AVERAGE..	62·4	—	—	—	40·3	394·4	—	—	549·9	—	49·8
V.....	21–28/11/1944	4	55·8	400	170	—	19·0	346·3	155·5	—	501·8	270·8	46·0
		5	67·3	600	170	—	46·6	501·1	155·5	—	656·6	350·9	46·6
		9	62·5	500	170	—	19·6	436·9	155·5	—	592·4	317·5	46·4
		13	69·0	400	170	—	13·5	351·6	155·5	—	507·1	255·9	49·6
		AVERAGE..	63·7	—	—	—	24·7	409·0	—	—	564·5	—	47·2
VI.....	7–14/12/1944	4	57·3	400	170	200	64·0	308·5	155·5	62·3	526·3	250·0	52·5
		5	68·8	600	170	200	46·3	512·0	155·5	62·3	729·8	382·4	47·6
		9	62·8	500	170	200	124·6	341·6	155·5	62·3	559·4	257·3	54·0
		13	70·3	400	170	200	16·0	365·5	155·5	62·3	583·3	277·8	52·4
		AVERAGE..	64·8	—	—	—	62·7	381·9	—	—	599·7	—	51·6

Table V.

Digestibility of Cellulose (Group A).

Period.	Sheep No.	Cellulose Intake (gm.)			Cellulose Excreted. (gm.)	Coefficient of Digestibility.
		Hay	Green Feed.	Total.		
I.....	1	139·1	—	139·1	77·4	44·4
	10	188·8	—	188·8	92·5	51·0
	11	145·1	—	145·1	75·1	48·3
	12	118·0	—	118·0	67·1	43·2
	Average...	—	—	—	—	46·7
II.....	1	161·4	—	161·4	97·0	39·9
	10	208·0	—	208·0	117·0	44·8
	11	124·0	—	124·0	63·5	48·8
	12	—	—	—	—	—
	Average...	—	—	—	—	44·5
III.....	1	155·0	—	155·0	94·3	39·2
	10	207·0	—	207·0	110·1	46·8
	11	125·5	—	125·5	65·6	47·7
	12	109·5	—	109·5	70·8	35·4
	Average...	—	—	—	—	42·3
IV.....	1	168·3	—	168·3	90·8	46·1
	10	171·3	—	171·3	92·8	45·8
	11	126·0	—	126·0	70·3	44·2
	12	105·8	—	105·8	63·9	39·6
	Average...	—	—	—	—	43·9
V.....	1	168·8	—	168·8	86·9	48·4
	10	185·3	—	185·3	112·3	39·4
	11	109·6	—	109·6	67·5	38·4
	12	113·0	—	113·0	66·5	41·2
	Average...	—	—	—	—	41·9
VI.....	1	146·3	15·1	161·4	79·5	50·8
	10	183·0	18·9	201·9	107·5	46·8
	11	115·9	18·9	134·8	70·5	47·7
	12	96·1	18·9	115·0	55·3	51·9
	Average...	—	—	—	—	49·3

TABLE VI.

Digestibility of Cellulose (Group B).

Period.	Sheep No.	Cellulose Intake (gm.)			Cellulose Excreted. (gm.)	Coefficient of Digestibility.
		Hay.	Green Feed.	Total.		
I.....	6	105·9	—	105·9	54·1	48·9
	7	165·6	—	165·6	79·5	52·0
	14	128·1	—	128·1	68·5	46·5
	18	157·8	—	157·8	76·1	51·8
	AVERAGE...	—	—	—	—	49·8
II.....	6	117·4	—	117·4	58·0	50·6
	7	169·3	—	169·3	90·8	46·4
	14	134·5	—	134·5	77·3	42·5
	18	143·5	—	143·5	71·0	50·5
	AVERAGE...	—	—	—	—	47·5
III.....	6	124·0	—	124·0	64·9	47·7
	7	165·6	—	165·6	84·6	48·9
	14	123·4	—	123·4	74·5	39·7
	18	102·5	—	102·5	43·9	57·2
	AVERAGE...	—	—	—	—	48·4
IV.....	6	119·6	—	119·6	63·5	46·9
	7	169·0	—	169·0	85·3	49·6
	14	133·9	—	133·9	69·3	48·3
	18	107·1	—	107·1	48·1	55·0
	AVERAGE...	—	—	—	—	50·0
V.....	6	118·4	—	118·4	62·1	47·6
	7	163·3	—	163·3	81·0	50·2
	14	130·5	—	130·5	82·1	37·1
	18	104·8	—	104·8	47·3	54·9
	AVERAGE...	—	—	—	—	47·5
VI.....	6	123·0	18·9	141·9	73·8	48·0
	7	167·8	18·9	186·7	84·8	54·6
	14	137·0	18·9	155·9	81·9	47·5
	18	109·8	18·9	128·7	55·3	57·1
	AVERAGE...	—	—	—	—	51·8

Table VII.

Digestibility of Cellulose (Group C).

Period.	Sheep No.	Cellulose Intake (gm.)			Cellulose Excreted. (gm.)	Coefficient of Digestibility.
		Hay.	Green Feed.	Total.		
I.....	3	—	—	—	—	—
	15	147·1	—	147·1	66·5	54·8
	16	223·9	—	223·9	120·8	46·1
	17	134·6	—	134·6	61·1	54·6
	Average...	—	—	—	—	51·8
II.....	3	177·0	—	177·0	104·7	41·2
	15	148·5	—	148·5	72·3	51·4
	16	228·4	—	228·4	126·5	44·6
	17	124·4	—	124·4	60·0	51·8
	Average...	—	—	—	—	47·3
III.....	3	173·4	—	173·4	88·8	48·8
	15	128·8	—	128·8	61·0	52·6
	16	207·5	—	207·5	114·3	44·9
	17	121·8	—	121·8	53·6	56·0
	Average...	—	—	—	—	50·6
IV.....	3	183·0	—	183·0	93·5	48·9
	15	127·0	—	127·0	62·5	50·8
	16	226·8	—	226·7	112·0	50·6
	17	117·0	—	117·0	59·6	49·1
	Average...	—	—	—	—	49·9
V.....	3	172·4	—	172·4	95·0	44·9
	15	125·4	—	125·4	63·0	49·8
	16	216·0	—	216·0	119·8	44·6
	17	111·9	—	111·9	54·6	51·2
	Average...	—	—	—	—	47·6
VI.....	3	185·1	18·9	204·0	110·1	46·0
	15	127·3	18·9	146·2	71·0	51·5
	16	226·0	18·9	224·9	127·8	47·8
	17	105·0	18·9	123·9	60·8	51·0
	Average...	—	—	—	—	49·1

TABLE VIII.

Digestibility of Cellulose (Group D).

Period.	Sheep No.	Cellulose Intake (gm.)			Cellulose Excreted. (gm.)	Coefficient of Digestibility.
		Hay.	Green Feed.	Total.		
I.....	4	138·1	—	138·1	73·5	46·8
	5	201·9	—	201·9	84·0	58·2
	9	185·5	—	185·5	88·3	52·2
	13	137·6	—	137·6	68·5	50·2
	AVERAGE...	—	—	—	—	51·9
II.....	4	137·1	—	137·1	69·1	49·8
	5	204·4	—	204·4	94·8	53·6
	9	192·8	—	192·8	96·8	49·8
	13	123·1	—	123·1	65·0	47·2
	AVERAGE...	—	—	—	—	50·1
III.....	4	127·0	—	127·0	68·9	45·8
	5	194·6	—	194·6	91·5	53·0
	9	171·1	—	171·1	83·4	51·2
	13	129·0	—	129·0	79·4	38·5
	AVERAGE...	—	—	—	—	47·1
IV.....	4	132·8	—	132·8	77·5	41·7
	5	200·1	—	200·1	104·0	48·0
	9	175·9	—	175·9	90·9	48·3
	13	143·3	—	143·3	75·3	47·5
	AVERAGE...	—	—	—	—	46.4
V.....	4	143·0	—	143·0	88·3	38·3
	5	204·8	—	204·8	111·3	45·7
	9	179·6	—	179·6	102·3	43·1
	13	145·0	—	145·0	83·5	42·4
	AVERAGE...	—	—	—	—	42·4
VI.....	4	126·8	18·9	145·7	76·0	47·8
	5	209·1	18·9	228·0	119·7	47·5
	9	138·5	16·3	154·8	76·4	50·7
	13	146·4	18·9	165·3	86·1	47·9
	AVERAGE...	—	—	—	—	48·5