

GRAZING MANAGEMENT OF NATIVE PASTURES IN THE NEW ENGLAND REGION OF NEW SOUTH WALES

II. THE EFFECT OF SIZE OF FLOCK ON PASTURE AND SHEEP PRODUCTION WITH SPECIAL REFERENCE TO INTERNAL PARASITES AND GRAZING BEHAVIOUR

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Summary

The effect of flock size on pasture and animal productivity, on parasitic infection, and on grazing behaviour was investigated in a grazing experiment over a period of 3 years. Merino sheep, undrenched, and stocked at the rate of one sheep per acre on native pasture dominated by *Bothriochloa ambigua* S.T. Blake, were used in five flock sizes, viz. 2, 4, 8, 16, and 30 animals.

Flock size did not significantly affect the forage available or the botanical composition of the pastures, but liveweight gains and wool production were significantly lower in the flock of two sheep than in the other flocks. Observations indicated that the reduced productivity of the smallest flock was associated with reduced grazing time consequent on changes in grazing behaviour.

No consistent significant differences in worm egg counts were observed in faecal samples from the different flocks.

The results indicate that although under fairly extensive grazing conditions a unit of two sheep may be unsatisfactory in some respects, flocks of four sheep could give information on pasture or animal production or on parasitism comparable with that from larger flocks of up to 30 animals.

I. INTRODUCTION

Workers on pasture and animal problems have used sheep flocks of varying sizes in their experiments. The flock size adopted appears to have been determined arbitrarily, within certain statistical, economic, and spatial limits, but without enquiry as to the possible consequences of unit size alone on pasture or animal productivity. Apparently there is no information available to indicate whether a small flock of sheep is comparable with a larger flock, not only in its effect on the grazed pasture, but also in the productivity and behaviour of the flock as a whole, and in the interrelationships of sheep within the flock. Interrelationships within a flock could be of considerable importance in the development of infections with worm parasites. For instance, small flocks with fewer potentially susceptible animals may provide less favourable conditions for an increase in parasitism than larger flocks.

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The present experiment compares the productivity, parasitic worm burden, and grazing behaviour of Merino sheep in flock sizes of 2, 4, 8, 16, and 30, under conditions of measured pasture productivity.

The experiment was located on "Chiswick", the Research Station of the Pastoral Research Laboratory, C.S.I.R.O., Armidale, N.S.W. It was run concurrently with, and adjacent to the site of, another experiment on the management of native pasture already reported (Roe, Southcott, and Turner 1959). The general procedures were similar in both experiments.

II. DESIGN

Flocks (treatments) of 2, 4, 8, 16, and 30 sheep were grazed in paddocks (plots) arranged in a randomized block design. There were three replications of the first four treatments and two replications of the last. For comparisons of the five flocks, only a two-replication randomized block analysis was possible. In the text and tables treatments (T) are identified by the appropriate flock number.

Sheep in each treatment were grazed at the rate of one per acre. They were 1-year-old fine-wool Merino ewes and wethers selected for uniformity of live-weight pre-experimentally. A fresh group of sheep was used in each of the three years of the experiment.

No regular anthelmintic treatment was given but in 1951 a few sheep were drenched to prevent undue losses from worm infections.

III. EXPERIMENTAL PROCEDURES

(a) Pastures

The total forage available and the botanical composition of the pasture by weight were determined by the methods previously described (Roe, Southcott, and Turner 1959). The former was measured at monthly intervals; the botanical composition and green forage were determined on six occasions selected to cover the extremes of seasonal conditions.

(b) Sheep

(i) *Sheep Production*.—Measurements were made of liveweight, body size, wool production, and wool fibre diameter by procedures previously described (Roe, Southcott, and Turner 1959).

All the sheep from the smaller (2, 4, 8) flocks, and 10 sheep from the flocks of 16 and 30 sheep, were weighed, and sampled for fibre diameter measurements at regular intervals. At shearing in November, greasy wool weights were obtained from the sampled sheep, and midside wool samples were taken for the determination of clean scoured yield. Body dimensions were recorded at the commencement and conclusion of each 12-month period.

(ii) *Parasitic Infection*.—The level of nematode infection was assessed by means of worm egg counts and species differentiation in larval culture. The species present and the techniques used were the same as previously reported (Roe, Southcott, and Turner 1959).

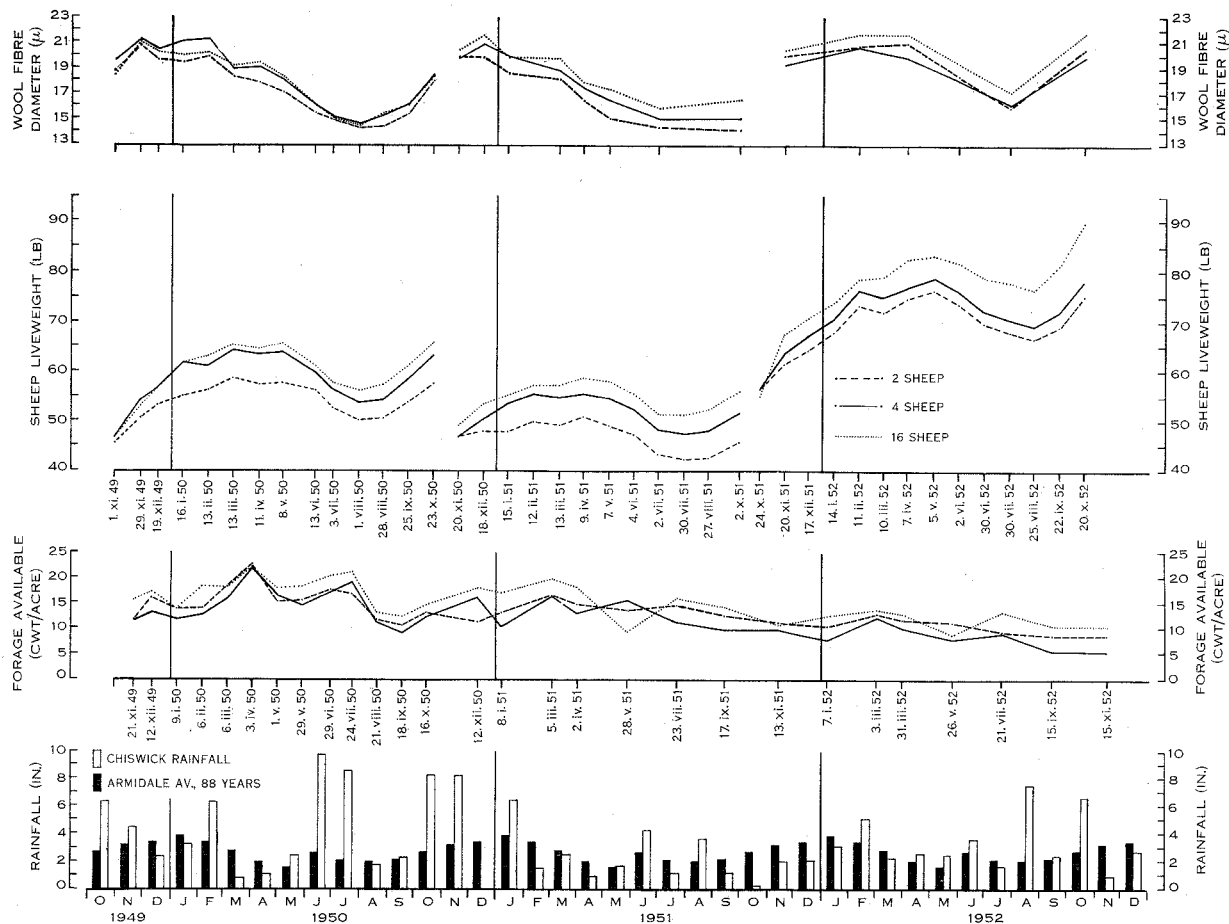


Fig. 1.—Forage available, sheep liveweights, and wool fibre diameters for sheep in flocks of 2, 4, and 16 animals. Mean monthly rainfall at Armidale compared with monthly rainfall at "Chiswick" during the course of the experiment is included.

For the first year faecal samples were taken at monthly intervals from all sheep in the flocks of 2, 4, and 8 and from 10 sheep in the flocks of 16 and 30 animals. In the following two years the number of sampled sheep, in the flocks of 8, 16, and 30 animals, was reduced to five per group.

(iii) *Grazing Behaviour*.—Direct observations of the grazing behaviour of each flock in one replication were made on 12 occasions during the experiment. On seven occasions the observations were for a continuous 24-hr period. The remaining observations were made during daylight for a period of 12 hr.

Two observation sites were used. One observer commanded a view of the flocks of 2, 4, 8, and 16 sheep from a tower 20 ft high. The other observer watched the flock of 30 sheep from a natural vantage point. Both observers were equipped with field-glasses. The activities of one sheep, selected at random on each occasion and marked with a white girth band, were recorded continuously to the nearest minute. Notes were also made on the flock activity as a whole, and subsequent inspection of the data indicated that the one marked sheep was a reliable indicator of group activity. Activities were classified as grazing, resting, and idling, as defined by Tribe (1949). The distance walked was calculated from a graph of the movements of the marked sheep. Orientation of the animal within the paddock was by reference to stakes set out on a 2 chain grid.

The 24-hr periods of observation were made on moonlit and partially moonlit nights, as otherwise it would have been difficult to observe the sheep in the larger paddocks. Apart from this the days selected were typical for the time of the year, with maximum and minimum temperatures close to the mean monthly figures.

IV. RESULTS

(a) *Pasture Production and Composition*

The total forage available showed the same seasonal trends in all treatments, and these trends were comparable with those reported previously (Roe, Southcott, and Turner 1959). Total forage available for sheep in flocks of 2, 4, and 16 sheep is shown in Figure 1.

At no time were there any significant differences between treatments in the amounts of total forage available or in the botanical composition and green forage. This was so, even when the treatment means were adjusted for the amounts of forage available on each treatment at a pre-experimental sampling.

(b) *Sheep Production*

(i) *Liveweight*.—The mean monthly liveweights of the sampled sheep in treatments 2, 4, and 16 are shown in Figure 1. The mean liveweights of sampled sheep in treatments 8 and 30 generally lay within the limits set by treatments 4 and 16, and have been excluded from the graph for the sake of clarity.

The overall pattern of liveweight changes was similar from year to year and from treatment to treatment, with a characteristic seasonal rise and fall already described (Roe, Southcott, and Turner 1959). In the third year the higher initial

weight of the sheep was due to the provision of better post-weaning nutrition than had been possible in previous years, and to more rigid selection.

The mean liveweight gain for each treatment in each experimental year was adjusted for the mean total forage available for that treatment in that year, with the use of the regression coefficient of liveweight gain on forage available, calculated from the treatment \times block interaction in the analysis of covariance of the three replications of treatments 2-16. The adjustment was not made if this coefficient was less than its error. This adjustment would not have been reasonable had there been any effect of treatment on the amount of forage available, but in the absence of such effects the adjustment should reduce the error variance for liveweight.

TABLE 1
MEANS OF LIVEWIGHT GAINS, ADJUSTED FOR MEAN TOTAL FORAGE FOR EACH YEAR

Year	Mean Liveweight Gains, Adjusted for Forage					S.E.* of Differences between Means	Regression Coeff. of Liveweight Gain on Forage
	T2	T4	T8	T16	T30		
1949-50	+12.0	+16.7	+20.2	+18.2	+17.4	1.93	+0.0555 \pm 0.0308
1950-51	- 1.2	+ 4.8	+ 4.4	+ 6.8	+ 5.6	2.92	-0.0054 \pm 0.0583
1951-52	+17.1	+23.4	+26.2	+31.6	+23.8	4.60	+0.2680 \pm 0.0903
Mean	+ 9.3	+15.0	+16.9	+18.9	+15.6		

* Generalized standard error proposed by Finney (1946).

The adjusted treatment means are recorded in Table 1, together with the regression coefficients and their errors. The means for treatment 30 were adjusted by the coefficients calculated from treatments 2-16.

In the second year the regression coefficient of liveweight gain on total forage was not significant (Table 1). This may have been due to the effects of worm infestation.

Each year the mean liveweight gain in treatment 2 was less than in the other treatments and this was the only significant treatment effect; liveweight gains in treatments 4, 8, 16, and 30 were never significantly different.

(ii) *Size Index*.—Size indices* were calculated from the body measurements taken at the beginning and end of each experimental year. The final size index was adjusted for the initial size index from a regression coefficient calculated within subgroups. The adjusted subgroup means were then further adjusted for the mean total forage available, from a regression coefficient calculated from the treatments \times block interaction (see Table 2). The sets of regression coefficients recorded were from the analysis of covariance of the three replications of treatments 2, 4, 8, and 16.

* Size index = length \times chest depth $\times \frac{1}{2}$ (width at shoulders + width at hips).

The only important treatment effect was the difference between treatment 2, which had the smallest size index, and the other treatments.

(iii) *Wool Production and Wool Fibre Diameter.*—The mean final greasy and clean scoured wool weights were adjusted for initial greasy wool weight and for mean forage available each year.

TABLE 2

MEAN FINAL SIZE INDICES, AFTER ADJUSTMENT FOR INITIAL SIZE INDICES AND MEAN FORAGE AVAILABLE EACH YEAR

Year	Adjusted Treatment Means					S.E.* of Difference	Regression† Coeff. of Final on Initial Size Index	Regression‡ Coeff. of Adjusted Size Index on Forage
	T2	T4	T8	T16	T30			
1949–50	1061	1199	1197	1185	1132	67.8	+0.8514±0.1355	+0.4759±1.2297
1950–51	914	980	976	1109	991	57.8	+1.0017±0.1232	–2.4171±0.9992
1951–52	1470	1538	1548	1600	1523	90.3	+0.6740±0.1158	+2.1605±1.7728
Mean	1148	1239	1240	1298	1215			

* Generalized standard error proposed by Finney (1946).

† Calculated within subgroups.

‡ Calculated on treatments×blocks interaction.

TABLE 3

MEAN FINAL CLEAN WOOL WEIGHT, AFTER ADJUSTMENT FOR INITIAL CLEAN WOOL WEIGHT AND MEAN FORAGE AVAILABLE EACH YEAR

Year	Adjusted Treatment Means					S.E.* of Difference	Regression Coeff. of Final on Initial Clean Wool Wt.†	Regression Coeff. of Adjusted Clean Wool Wt. on Forage‡
	T2	T4	T8	T16	T30			
1949–50	3.9	4.5	4.6	4.3	4.4	0.20	+1.1967±0.2049	+0.0064±0.0032
1950–51	3.0	3.5	3.3	3.6	3.4	0.27	+0.2905±0.0940	+0.0007±0.0055
1951–52	5.6	5.9	5.6	6.1	5.8	0.26	+0.8794±0.1152	+0.0101±0.0052
Mean	4.2	4.6	4.5	4.7	4.5			

* Generalized standard error.

† Calculated within subgroups.

‡ Calculated on treatments×blocks interaction.

The statistical analyses of the greasy wool weight and clean wool weight were of the same type as those on size index. Again treatment 2 consistently had a lower wool production than the other treatments. For the mean greasy wool weight per head

over the 3 years, treatment 2 produced 0.6 lb less than the treatment next in rank, but for the clean wool weight this mean difference was reduced to 0.3 lb. The adjusted clean wool weights are shown in Table 3.

Wool fibre diameter measurements of sampled sheep in treatments 2, 4, and 16 are graphed in Figure 1. Analyses showed that no significant differences due to any of the five treatments occurred at any time.

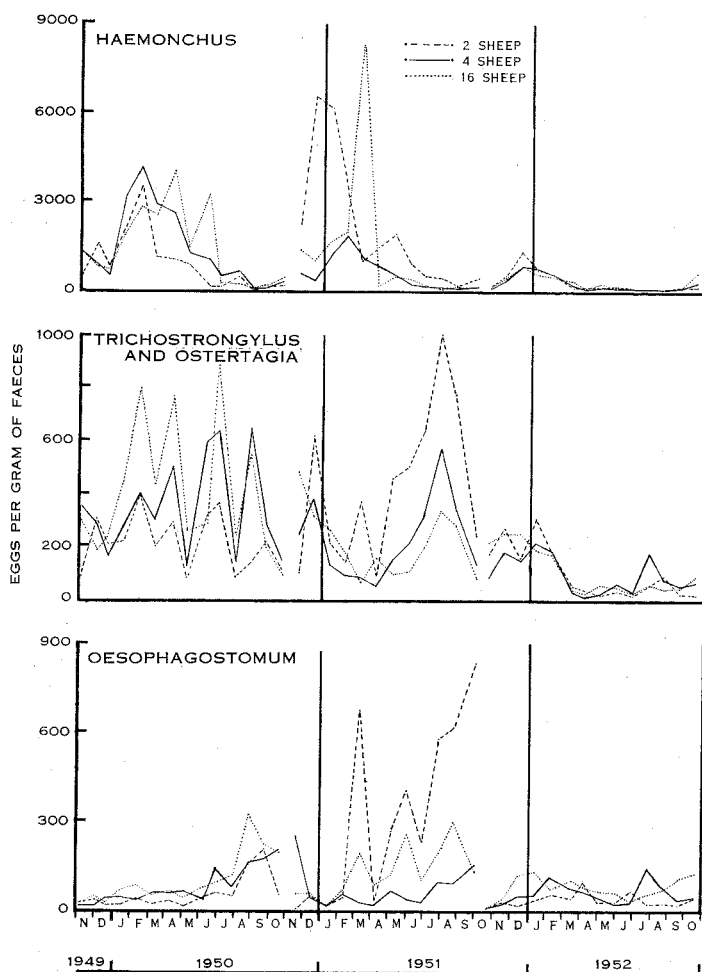


Fig. 2.—Levels and fluctuations of worm egg counts for sheep in flocks of 2, 4, and 16 animals.

(c) Parasitic Infection

After logarithmic transformation, separate analyses were made for each sampling on the worm egg count data for the most important helminths present in the experimental animals, namely, *Haemonchus contortus*, *Trichostrongylus-Ostertagia* spp., and *Oesophagostomum* spp. A two-replication analysis was used for a comparison of

TABLE 4

WORM EGG COUNTS OF HAEMONCHUS CONTORTUS, TRICHOSTRONGYLUS AND OSTERTAGIA SPP., AND OESOPHAGOSTOMUM SPP. AT SELECTED DATES
Geometric mean of the number of worm eggs per gram of faeces. Three replications, treatments 2, 4, 8, and 16; two replications, treatment 30

Treatment	1. xi. 49	13. ii. 50	8. v. 50	1. viii. 50	23. x. 50	20. xi. 50	12. ii. 51	9. iv. 51	2. vii. 51	2. x. 51	24. x. 51	17. xii. 51	5. v. 52	30. vii. 52	25. viii. 52	20. x. 52
<i>Haemonchus contortus</i>																
Flock size 2	399	2827	141	111	64	695	703	754	163	277	45	289	79	16	33	59
Flock size 4	914	2505	528	366	196	296	731	389	42	45	14	412	35	18	8	63
Flock size 8	519	1257	366	174	83	874	764	992	22	51	40	152	89	17	7	177
Flock size 16	731	1139	390	108	181	565	399	601	30	9	32	352	39	13	4	167
Flock size 30	1109	1028	459	109	156	310	288	432	12	38	37	668	37	14	24	34

Significant differences: 23.x.50, T4, T16>T2 (3-replication analysis); 2.vii.51, T2>T4, T16 (3 rep.), T2>T4, T8, T16, T30 (2 rep.); 2.x.51, T2>T16 (3 rep.)

<i>Trichostrongylus and Ostertagia</i> spp.																
Flock size 2	64	281	23	40	44	60	33	22	235	114	96	480	11	25	36	19
Flock size 4	267	195	94	56	74	35	35	22	67	69	53	128	15	42	50	53
Flock size 8	120	211	78	39	31	51	38	31	83	55	138	128	14	30	49	20
Flock size 16	220	424	109	42	18	91	68	46	65	18	159	161	22	42	23	21
Flock size 30	194	345	154	35	32	75	55	68	130	156	66	213	18	28	24	27

Significant differences: 1.xi.49, T4, T16>T2 (3-replication analysis), T4, T8, T16, T30>T2 (2 rep.); 17.xii.51, T2>T4, T8, T16 (3 rep.)

<i>Oesophagostomum</i> spp.																
Flock size 2	7	8	4	17	7	3	8	6	73	301	3	4	14	12	11	16
Flock size 4	4	2	15	17	68	17	17	6	10	94	5	16	8	25	25	19
Flock size 8	3	9	18	13	43	26	21	16	121	128	4	17	8	23	17	6
Flock size 16	5	7	14	28	32	14	32	30	21	104	4	28	32	27	36	13
Flock size 30	7	9	15	26	32	2	50	25	27	85	3	57	23	75	25	8

Significant differences: 30.vii.52, T30>T2, T8, T16 (2-replication analysis); T4>T2, T8; T16>T2

treatments 2, 4, 8, 16, and 30, and a three-replication analysis for comparison of treatments 2, 4, 8, and 16. There was no outstanding or consistent trend in worm egg counts as a result of treatment, and significant differences were recorded on isolated occasions only.

The levels and fluctuations of worm egg counts in treatments 2, 4, and 16 are shown in Figure 2, and the geometric means of worm egg counts for all treatments at selected periods, including those periods when significant differences occurred, are presented in Table 4. As the worm egg counts for treatments 8 and 30 showed similar levels to those of other treatments they have been omitted from Figure 2.

During the period January 17 to March 12, 1951, four sheep in treatment 2, eight sheep in treatments 8 and 16, and two sheep in treatment 30 were anaemic and received anthelmintic treatment with carbon tetrachloride to reduce *Haemonchus contortus* infections. Other species would not have been affected by this drenching. No sheep in treatment 4 were drenched.

TABLE 5
REGRESSION COEFFICIENTS OF DISTANCE WALKED AND HOURS OF GRAZING,
IDLING, AND RESTING ON FORAGE AVAILABLE, FOR 12- AND 24-HR PERIODS

	12-hr Periods	24-hr Periods
Distance walked (yards)	-38.82 ± 15.68	-40.36 ± 16.97
Hours of grazing	-0.1084 ± 0.0343	-0.0957 ± 0.0521
Hours of idling	$+0.0440 \pm 0.0254$	$+0.0039 \pm 0.0806$
Hours of resting	$+0.0594 \pm 0.0236$	$+0.0984 \pm 0.0916$

Eight sheep died in the course of the experiment and most of these deaths were associated with heavy *Haemonchus contortus* infections. No sheep died in 1949-50, seven died in 1950-51 (one in treatment 2, two in treatment 4, and four in treatment 8, when worm egg counts and clinical signs indicated the highest levels of parasitism), and one sheep died in 1951-52 (treatment 30).

The worm egg count results, and the records of precautionary drenching and deaths, indicate that small flock size did not prevent the development of heavy worm infections.

(d) Grazing Behaviour

The observations on behaviour were made on the treatments in one replication only, and the treatment effect is confounded with the effect of the differences in productivity of the pastures in the five paddocks. An examination of the amounts of total forage available nearest the dates of the behaviour observations showed considerable variation between dates. Therefore, assuming that differences in forage available at different times in the same paddock would have the same effect on behaviour as differences in forage available between paddocks, the regression of hours of grazing on total forage available was calculated over dates within treatments, in analyses of covariance for the five 12-hr periods and the seven 24-hr periods. Similar

analyses were done on distance walked, hours of idling, and hours of resting. The regression coefficients on forage available (cwt/acre) are shown in Table 5.

The complete analyses of covariance on the 12 periods for hours of grazing and distance walked are shown in Table 6. The regression coefficient on the treatment means is not different from the regression coefficient within treatments for hours of grazing, but is significantly different for distance walked. This difference could be due to either the effect of treatments or that of paddocks.

TABLE 6
ANALYSES OF COVARIANCE OF HOURS OF GRAZING AND DISTANCE WALKED ON TOTAL FORAGE AVAILABLE (CWT/ACRE) FOR 12 PERIODS

(a) *Hours of Grazing*

Source of Variation	Sx^2	Sxy	Sy^2	D.F.	M.S.	F
Between treatments	1888.12	-121.20	27.0110	4	5.2091	3.102*
Within treatments	1453.26	-157.56	109.4308	54	1.7101	
Regression on treatment means				1	1.6058	—

(b) *Distance Walked (in 100-yd units)*

Source of Variation	Sx^2	Sxy	Sy^2	D.F.	M.S.	F
Between treatments	1888.12	-1708.57	3023.62	4	424.19	11.878***
Within treatments	1453.26	-564.16	2147.53	54	35.71	—
Regression on treatment means				1	219.25	6.139*

* $P < 0.05$. *** $P < 0.001$.

The treatment means of hours of grazing and distance walked were adjusted for forage available by means of the coefficients from the regression within treatments both in the 12-hr and 24-hr periods. Treatment 2 sheep grazed 1.5 hr less than those of any other treatment, but there were no significant differences between the other treatments in the time spent grazing. On the other hand, sheep in treatment 30 walked a significantly greater distance than the sheep in treatment 2, which in turn walked further than the sheep in treatments 4, 8, and 16.

Hours spent idling, i.e. not grazing and not lying down, were not dependent on the forage available. Over the 12-hr period the sheep of treatment 2 spent significantly more time idling than any other group (see Table 7). Over the 24-hr period only the differences between the mean for treatment 2 and the means for treatments 4 and 30 were significant.

For hours spent resting (lying down) there was a significant regression within treatments on forage available for the 12-hr period. After adjustment for forage available, there were no significant differences between the treatment means (see Table 7). Over the 24-hr period the regression within treatments on forage available was not significant; nor were there any differences between the treatment means.

TABLE 7

TREATMENT MEANS OF OBSERVATIONS OF BEHAVIOUR OVER 12-HR PERIODS AND 24-HR PERIODS

Treatment	Means of 12-hr Period				Means of 24-hr Period			
	Distance* Walked (yd)	Hours* of Grazing	Hours of Idling	Hours* of Resting	Distance* Walked (yd)	Hours* of Grazing	Hours of Idling	Hours* of Resting
2	2303	6.9	3.3	1.6	2967	7.6	5.4	11.0
4	1355	8.4	1.2	2.3	1523	9.2	2.5	12.2
8	1633	8.5	1.4	1.1	1810	9.4	4.3	10.3
16	1925	8.5	1.7	2.3	2186	8.9	4.0	11.9
30	3006	8.4	1.2	2.1	3712	9.5	3.1	11.3
Mean	2044	8.1	1.8	2.1	2439	8.9	3.8	11.2
S.E. of diff. between means	281†	0.61†	0.35	0.42†	267†	0.82†	0.85	1.44†

* Means adjusted for regression within treatments on total forage available.

† Generalized standard error proposed by Finney (1946).

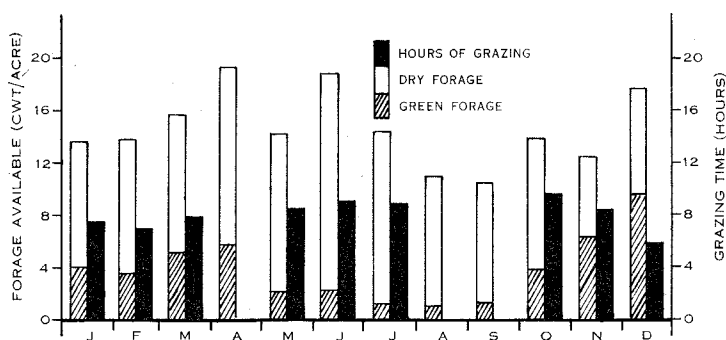


Fig. 3.—Relationship between grazing time and forage available.

The relationship between time spent grazing and the amounts of total and green forage available is shown in Figure 3. The figure represents a compilation of all available data, and indicates a tendency for the sheep to extend their grazing time in response to a decline in the amount of green forage available.

V. DISCUSSION

This experiment was in progress during the final 3 years of a grazing experiment reported by Roe, Southcott, and Turner (1959). They recorded seasonal fluctuations in sheep liveweight and wool fibre diameter which were related to the amount of green forage available in the pasture. In this experiment no significant differences in the amount of green forage, or of total forage, occurred as a result of the different grazing treatments (flock sizes). Despite this, liveweights and wool production were significantly reduced in the flock of two sheep in comparison with the flocks of 4, 8, 16, and 30 sheep. As the forage on offer to all sheep was comparable, the lowered production associated with the flock of two sheep may have resulted from a reduction in food intake, from less effective utilization of food, or from greater energy requirements associated with the grazing situation.

The two sheep spent significantly less time grazing than the larger flocks and this alone, by reducing food intake, may have accounted for the difference in production. There was no reason to suspect that differences in the effectiveness of food utilization were involved, e.g. as a consequence of possible differences in levels of parasitic infection; and, although the two sheep walked further than the sheep in the flocks of 4, 8, and 16 animals, they walked significantly less than the 30 sheep, which indicated that energy requirements for walking *per se* were not important. This does not preclude the possibility of additional energy requirements of the two sheep in response to a "stress" situation stemming from the enforced smallness of the social group.

Typical patterns of walking, including walking during grazing and idling, for sheep in the three smaller flocks for a 24-hr period are shown in Figure 4. The concentration of activity of the two sheep along the fence separating them from the flock of four sheep and the relatively small area of the paddock traversed during grazing are in marked contrast to the patterns shown by the larger groups.

Lines and Peirce (1931) measured the basal metabolism of the Australian Merino in pens and found that a restless or nervous animal had a metabolism enhanced out of all proportion to its muscular activity. Blaxter (1960) also suggests that environment may considerably affect the energy expenditure of sheep, and recently Lambourne (1961) has shown that under conditions of low pasture productivity, the free-grazing Merino sheep requires considerably more energy for maintenance than does its counterpart under pen conditions. If stress is the factor involved, it appears possible that the effect could be accentuated in the flock of two sheep by comparison with larger flocks.

The reduced grazing time and increased time spent idling by the flock of two sheep might indicate that, unless special precautions are taken, two sheep are unlikely to behave as a normal flock. Crofton (1958) found that during grazing, individuals tend to orientate themselves by reference to two other sheep and thus form an angle of 110° , which corresponds to the angle between the optical axes. This basis of interdependence suggested that five mature sheep was the minimum number which could constitute a flock. Thus two sheep alone would experience difficulty in grazing and satisfactorily maintaining contact with suitable reference

points, and this may explain why most of the additional time idling was spent in an aimless fence-walk which, because of the topography, kept the adjacent flock of four sheep continuously in view. Aimless walking was also a factor which increased the distance travelled by the two-sheep flock. Excluding this group, it should be noted that, with flocks of up to 30 sheep, distance walked appears to be a function of flock size, i.e. the significantly greater distance walked by the sheep in the flock of 30 animals

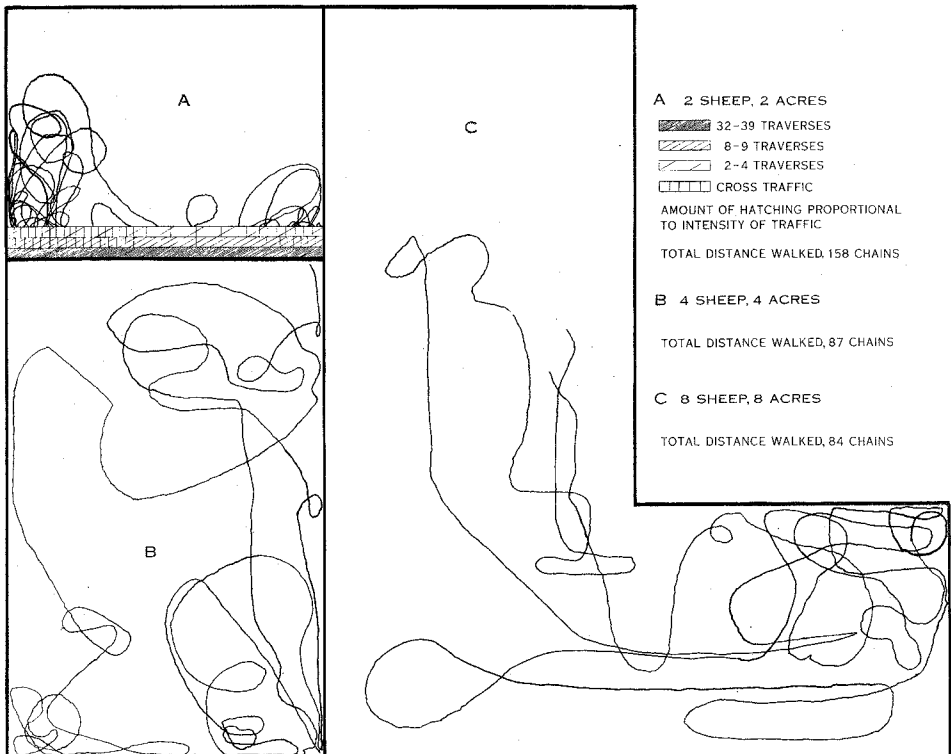


Fig. 4.—Typical movement patterns of sheep in flocks of 2, 4, and 8 animals during one 24-hr period.

was a genuine treatment effect; as there was no difference between the regression of hours of grazing on forage available between and within treatments, and the adjusted grazing time for the flock of 30 was not significantly different from the grazing times of the flocks of 4, 8, and 16 sheep. It was not possible to exclude paddock size as a determinant of distance walked in the present experiment, but other observations showed that 30 sheep in a 30-acre and a $7\frac{1}{2}$ -acre paddock respectively walked approximately the same distance.

Records of pasture and sheep productivity and direct observations of grazing behaviour all suggest that flocks of four sheep and more would be suitable units in grazing experiments involving the study of pasture and animal production under "moderately extensive" grazing conditions, i.e. with stocking at about one sheep per acre. With a flock size of two sheep, results may differ from those obtained with

larger flocks and may not be applicable to farm or station conditions. With such a small flock, behaviour is abnormal, and in this experiment this resulted in lower liveweight gains and wool production. Although the two sheep flock did not show any consistent significant differences in worm egg counts in comparison with the larger flocks, other observations suggest that this small unit was generally less suitable for parasitological studies. For instance, the reduction in grazing time observed when the two sheep grazed alone could reduce the risk of infection, and by lowering the nutritional level could perhaps indirectly affect the development or maintenance of resistance. Further, the restricted pattern of grazing shown by the two sheep would affect pasture contamination and exposure to reinfection. Records of deaths from parasitic infection and precautionary drenching also support the view that the two sheep were at a disadvantage by comparison with the larger flocks and so were less suitable for parasitological studies.

There was no suggestion from the present study that flocks of two sheep reduced the risk of parasitism by virtue of the lessened chance of including susceptible animals, although in some circumstances this factor could be important experimentally. Thus Gordon and Turner (1946), who estimated levels of parasitism under different grazing systems with two sheep per paddock, commented on the undesirable variations in the levels of infection with *Haemonchus contortus* between paddocks, attributable to individual variations in susceptibility.

Within the limits of the present experiment it may be concluded that flocks of four sheep would give information on pasture or animal production or on parasitism fully comparable with that from larger flocks of up to 30 animals. Although two sheep would be unsatisfactory for measuring absolute levels of production or in parasitological investigations, this is not to say that the undesirable effects noted could not be offset by careful design, or that comparison of two sheep with two sheep are necessarily undesirable or invalid.

VI. ACKNOWLEDGMENTS

The work reported was made possible through the collaboration and assistance of a number of C.S.I.R.O. officers whose individual contribution has been indicated in a previous paper (Roe, Southcott, and Turner 1959). We take this opportunity again to acknowledge gratefully the help received from these people.

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THE EFFECTS OF PREGNANCY ON THE PASSAGE OF FOOD THROUGH THE DIGESTIVE TRACT OF SHEEP

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Summary

The rate of passage of food residues through the digestive tract of pregnant and non-pregnant Merino ewes was measured at four levels of feeding.

The passage of digesta became more rapid as the level of feeding was increased, or, the intake being constant, as pregnancy advanced. The mean retention time fell by 3 hr per 100 g increase of food intake, and by 1 to 1½ hr per 100 g increase of estimated weight of concepta at constant intake.

The digesta increased by about 150 g dry matter (depending on level of feeding) per 100 g increase of daily food intake and fell by about 150 g per 1000 g increase of estimated weight of concepta.

Two alternative explanations of the changes of rate of passage during pregnancy are discussed. While reduction of the quantity of digesta by the increasing bulk of the uterus would tend to curtail appetite, increase of the flow of digesta as a physiological side-effect of pregnancy would tend to enhance appetite. In either case, more rapid passage of digesta would depress the digestibility of some rations and so contribute to undernutrition in late pregnancy.

I. INTRODUCTION

It has been claimed that expansion of the gravid uterus restricts the capacity of the digestive tract of ruminants, and eventually curtails their appetite (Mäkelä 1956). Such restriction could increase the rate of passage of food residues through the digestive tract of an animal on a high level of feeding (i.e. with a full gut) and so depress the digestibility of some types of food (Blaxter, Graham, and Wainman 1956). Aside from the question of appetite limitation, the problem of undernutrition in late pregnancy (Reid 1958) would be aggravated by progressive decrease of efficiency of food utilization concurrent with progressive increase of foetal requirements.

The present experiments were designed to determine whether these changes do occur in the digestive tract of the pregnant sheep.

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II. EXPERIMENTAL METHODS

The rate of passage of food residues through the digestive tract was measured by the method of Balch (1950) as modified by Blaxter, Graham, and Wainman (1956). Briefly, the excretion of a meal containing dyed food was followed by counting dyed particles in the faeces. Faeces were collected each 6 hr for 3 days, each 12 hr for a further 3 days, and each 24 hr thereafter until no dyed material was observed. A composite sample of faeces representing 14 days of excretion was used to determine the digestibility of the dry matter eaten.

Fifteen Merino ewes, which were 3 years old and weighed between 27 and 35 kg at the start of the experiment, were held in metabolism cages and given a mixture of equal parts of chopped lucerne hay and wheaten chaff; the mixture contained 14% crude protein and 27% crude fibre. They were divided into three equal groups. The ewes in one group were each given 400 g food/day throughout the experiment, those in the second group 700 g, and those in the third group 1000 g. The food was given in one meal at 11 a.m. each day. The lowest level was just enough to enable a ewe to carry its lamb to full term, and the highest was about the most a pregnant ewe would eat at full term.

After a month on these regimes three sheep from each group were mated. The measurement of rate of passage and digestibility was attempted with all sheep after a further 1 to 2 months and also after 3 to 4 months, corresponding to early and mid or late pregnancy in the sheep which were mated. However, both experiments with one non-pregnant and one pregnant sheep on 1000 g food per day, and one experiment with a non-pregnant sheep from each other group, had to be abandoned because the animals refused to eat part of their ration on a few occasions.

Each pregnant ewe produced one live lamb, the birth weight of which was recorded. Immediately after parturition two lactating ewes (previously given 700 or 1000 g/day) were offered food *ad lib.*, and approximately 1500 g was eaten per day. They were then given exactly 1500 g/day and the measurements repeated: dry sheep would not eat this amount of food.

III. RESULTS

(a) Cumulative Excretion Curves

The number of coloured particles which appeared in the faeces between the time of giving the dyed meal and any subsequent time was expressed as a percentage of the total number excreted during the particular experiment. This was plotted against time to obtain the cumulative excretion curve.

The mean cumulative excretion curves for non-pregnant animals on four levels of feeding are given in Figure 1. The dyed material first appeared in the faeces 6–18 hr after the dyed meal was consumed. Thereafter, the rate of passage of the food residues through the digestive tract was greater at the higher levels of feeding, although complete excretion of a marked meal always occupied about 14 days.

Excretion curves representative of those obtained with the pregnant ewes are given in Figure 2. In every case, the rate of passage was markedly faster in late than in early pregnancy.

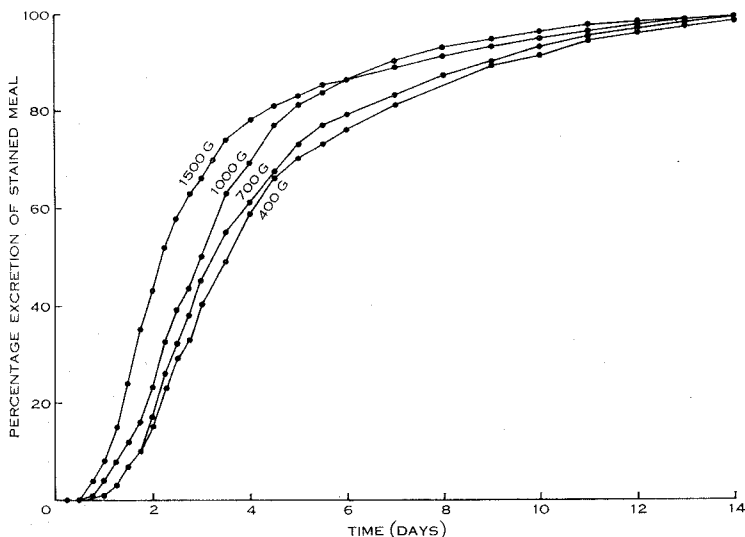


Fig. 1.—Mean cumulative excretion curves for a dyed meal given to non-pregnant ewes; the levels of feeding were 400, 700, 1000, and 1500 g/day as marked on the curves.

(b) *Mean Retention Times*

The curves can be evaluated in terms of \bar{t} , the mean retention time of a marked particle of food (Blaxter, Graham, and Wainman 1956). This was calculated as:

$$\bar{t} = \frac{1}{N} \sum [\frac{1}{2} n(t' + t)],$$

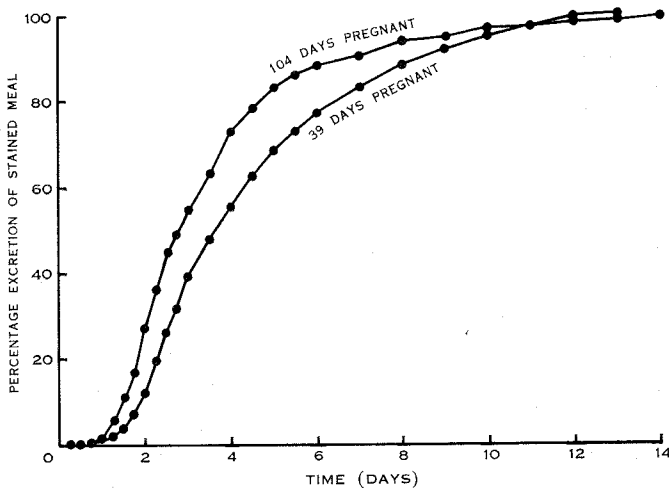


Fig. 2.—Cumulative excretion curves for a dyed meal given to a sheep (ewe 12) in early and late pregnancy; the level of feeding was 700 g/day.

where n is the number of coloured particles excreted between times t and t' , Σ signifies the sum of such quantities for successive intervals ($t'-t$) of 6 hr until n becomes zero, and N is the total number of coloured particles excreted.

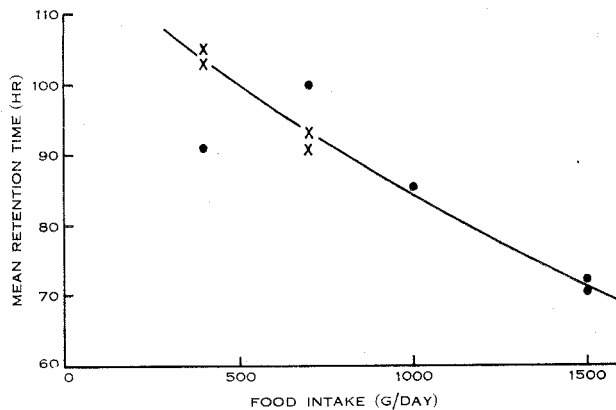


Fig. 3.—Mean retention times for a dyed meal given to non-pregnant ewes, in relation to level of feeding. The line of best fit is given. The values marked \times represent duplicate determinations with the same sheep.

The effect of level of feeding on the mean retention time for the non-pregnant ewes is shown in Figure 3. The time decreased by about 3 hr per 100 g increase of food intake.

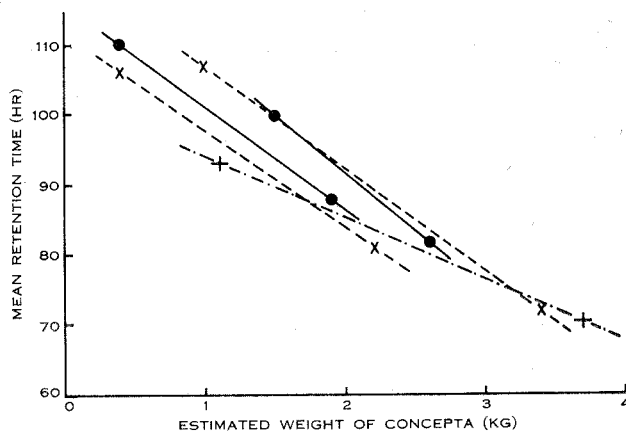


Fig. 4.—Mean retention times for a dyed meal given to sheep at various stages of pregnancy, in relation to estimated weight of concepta. The levels of feeding were 400 (•), 700 (x), or 1000 (+) g/day; the two values for each ewe are joined by a straight line.

The weight of concepta at the time of each experiment was estimated from the data of Cloete (1939), the actual weights of the lambs at birth being used. As shown in Figure 4, the retention time always decreased as pregnancy advanced,

by 1 to $1\frac{1}{2}$ hr per 100 g increase of concepta. Thus, an increase of weight of concepta had one-third to one-half the effect on retention time of the same weight of extra food.

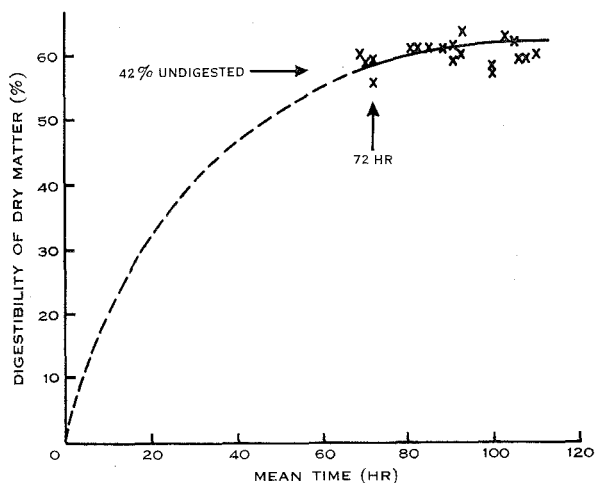


Fig. 5.—Probable relationship between digestibility of the dry matter of the food and mean retention time.

Because of the failure of some experiments (see above) the within-sheep variation of mean retention time for any one level of feeding cannot be established precisely, but inspection of Figure 3 suggests that it was small (S.D. approximately

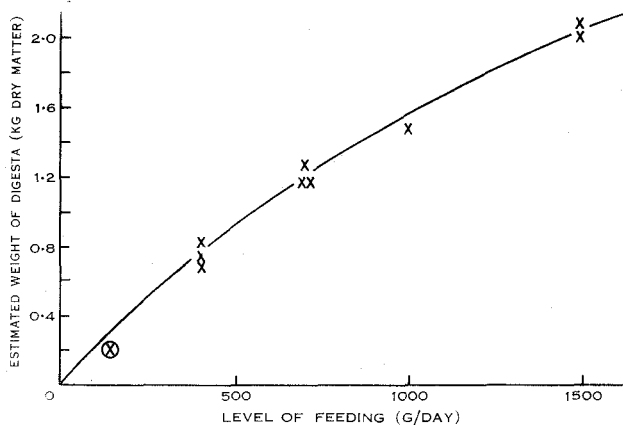


Fig. 6.—Weight of digesta, calculated from the passage and digestibility data for non-pregnant ewes, in relation to level of feeding. The line of best fit is given. The value circled was obtained by weighing the gut contents after slaughter.

± 1 hr). However, the corresponding between-sheep variation was quite large (S.D. ± 7 hr). In view of this, no significance can be attached to the apparent differences between the ewes in early pregnancy and the non-pregnant animals, but the large

within-sheep changes during pregnancy can be accepted with confidence. For the same reasons regressions were not calculated for any of the data.

(c) *Total Digesta*

The weight of food residues in the digestive tract may be estimated from the cumulative excretion curves and the curve relating digestibility of the ration to mean retention time (Blaxter, Graham, and Wainman 1956). The latter curve has not been defined fully for the present ration mixture, but it seems reasonable to use the approximate form given in Figure 5 for the purpose of making within-ration comparisons. Thus a cumulative excretion curve (Fig. 1) may show that 72 hr after a meal, 60% of the food has not been excreted, while the digestibility curve

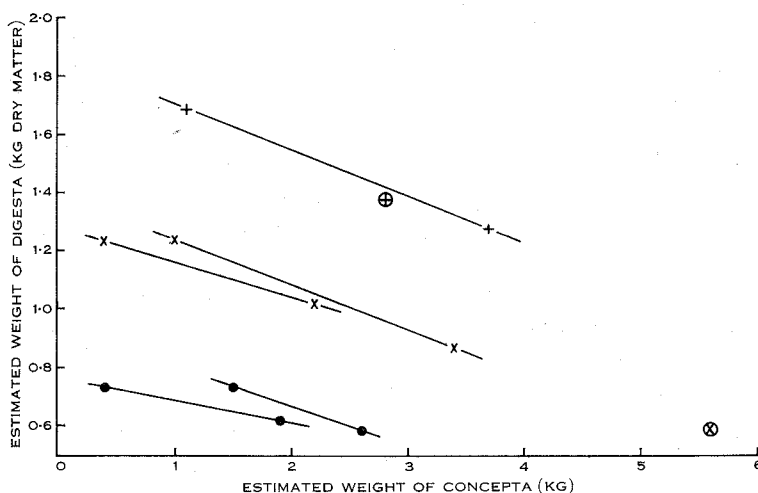


Fig. 7.—Weight of digesta, calculated from the passage and digestibility data, in relation to estimated weight of concepta at various stages of pregnancy. The levels of feeding were 400 (•), 700 (×), or 1000 (+) g/day; the two values for each ewe are joined by a straight line. The values circled were determined by weighing the gut after slaughter.

shows that approximately 42% of the food remains undigested at that time. Therefore, 72 hr after a meal, 25% ($= 60 \times 42/100$) of that meal remains as residues in the digestive tract: after 10 to 14 days, the amount is zero. Summation of such values (for 24, 48, 96 hr, etc.) to 14 days, gives an estimate of the total amount of solid digesta 24 hr after feeding, for an animal given a constant quantity of food at the same time each day. Such estimates are given in Figures 6 and 7, together with values determined directly after slaughter of three sheep not used in the main experiments. These sheep were larger animals than the others and their feeding prior to slaughter and the data were adjusted in proportion to body weight for comparative purposes. The values which were determined directly provide confirmation of the estimated values and of the trends observed in these. As shown in Figure 6, the weight of digesta in the non-pregnant ewes increased with level of feeding

by about 150 g dry matter per 100 g increase of dry food. With the pregnant animals, the digesta decreased on the average by 150 g dry matter per kg increase of concepta (Fig. 7). Thus, 1 kg increase of concepta had the same effect as a decrease of about 100 g dry matter in the food intake.

IV. DISCUSSION

There is considerable evidence (Blaxter, Graham, and Wainman 1956; Blaxter, Wainman, and Wilson 1961; Graham, unpublished data) that the rate of passage of fibrous foods through the digestive tract of sheep is largely determined by physical properties of the food and the dimensions of the digestive tract rather than by physiological factors. On these grounds it might be expected that pressure of the uterus on a fully distended rumen would reduce its capacity and so increase the rate of excretion of food residues. However, it seems unlikely that this could occur when both the tract and the abdominal cavity contain much less than they are capable of holding, for example, in the pregnant ewes on the two lower levels of feeding. On the other hand, pressure exerted on a particular section of the digestive tract may introduce a limiting factor in the overall rate of passage.

Although no physiological parameters relating to digestion were measured in these experiments, the possibility exists that some change of metabolism during pregnancy could increase the rate of flow of digesta and so decrease the amount of food residues in the digestive tract; for example, the water turnover may increase during pregnancy (Head 1953). However, this would tend to enhance appetite rather than depress it; in which case, inappetence must be considered to be unrelated to physical changes of the type observed.

Aside from the question of appetite control, progressive increase of the rate of passage during pregnancy would cause a large progressive decrease of the digestibility of some rations (Blaxter, Graham, and Wainman 1956) although not of the one used here. This, in turn, would reduce the energy available to the ewe at a time when the requirements of the foetus are high, and so contribute to the problem of undernutrition in late pregnancy.

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