

Factors affecting the voluntary intake of food by cows

7*. The behaviour and reticular motility of cows given diets of hay, dried grass, concentrates and ground, pelleted hay

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To understand the close relationship between the voluntary intake of roughages by ruminants and the rate of disappearance of digesta from the reticulo-rumen recently demonstrated by us (Campling, Freer & Balch, 1961, 1962) it is necessary to study the factors influencing the rate at which food particles are reduced to a size suitable for transfer to the omasum. The rate of reduction in particle size largely determines the time of retention of food residues in the digestive tract and is therefore an important factor influencing the voluntary intake of roughages. Reduction in particle size comes about mainly through chewing during eating and ruminating and by microbial digestion. The study now presented is of the eating and ruminating behaviour of cows given diets of hay, dried grass, concentrates and ground, pelleted hay. It supplements that recently conducted with cows given diets of hay, straw and oat straw with urea (Freer, Campling & Balch, 1962). The effects of diets of hay, dried grass or concentrates on the voluntary intake of food, digestion and time of retention of food residues in the gut were described by Freer & Campling (1963) and of the diets of long hay and ground, pelleted hay by Campling, Freer & Balch (1963). Throughout the present report the term ground hay will be used to describe the diet of ground, pelleted hay.

EXPERIMENTAL

Plan of experiments

Expt 1. The behaviour and frequency of reticular contractions of three cows (A, B and C) were compared when they were offered long hay, artificially dried grass or concentrates (i) *ad lib.* and (ii) restricted to 10 lb daily and with the diet of dried grass only, (iii) at 20 lb daily. A 3 × 3 Latin-square experimental design was used.

Expt 2. The same observations were made when four cows (D, E, F and G) received long hay or ground, pelleted hay *ad lib.* A 2 × 2 Latin-square experimental design was used.

Cows and housing

Three adult Friesian cows (A, B and D) and four Shorthorn cows (C, E, F and G) were used in the non-pregnant and non-lactating states. Each of the cows had a permanent rumen fistula which was closed by means of the rubber cannula and bung

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described by Balch & Johnson (1948). The cows were kept in a metabolism shed in individual standings. Water and salt licks containing trace minerals were accessible at all times.

Foods

Expt 1. The hay was mainly ryegrass cut on 22 June 1960. The dried grass was made by cutting ryegrass from the sward by cylinder mower in the autumn and drying it in a commercial grass drying plant (Nottingham Crop Dryers Ltd). The concentrates were prepared from a dairy concentrate mixture composed of barley 17, maize 20, wheat bran 20, decorticated groundnut meal 15, copra cake 10, palm kernel 5, molasses 10, dicalcium phosphate 1, calcium carbonate 1 and salt 1% with 5×10^6 i.u. vitamin A and 1×10^6 i.u. vitamin D added per ton. The mixture was in the form of pellets with square section (14 mm side) and 18–22 mm in length. The chemical composition of the foods is given in Table 1. When given hay or dried grass each cow received daily 40 g of a proprietary mineral mixture (Churn 105, British Glues and Chemicals Ltd) together with a weekly supplement of a concentrate of vitamins A and D (Drivite; Boots Pure Drug Co. Ltd).

Table 1. *Chemical composition of the foods*

Expt no.	Food	Dry matter	Crude protein	Ether extract	Crude fibre	Nitrogen-free extract	Ash
			As percentage of food dry matter				
1	Hay	83.8	8.4	4.2	33.2	46.3	7.9
	Dried grass	84.8	19.7	2.5	18.6	45.3	13.8
	Concentrates	87.0	19.8	3.2	6.4	63.1	7.5
2	Long hay	85.2	7.8	1.5	31.5	51.9	7.2
	Ground hay	91.1	6.8	1.2	30.6	53.4	7.6

Expt 2. A batch of ryegrass hay was divided into two parts; one part was ground commercially in a large hammer mill with a screen with apertures of 0.049 in. diameter and then pelleted with the addition of steam only (Nottingham Crop Dryers Ltd). As described in Expt 1, supplements of a proprietary mineral mixture and a concentrate of vitamins A and D were given with both the long hay and the ground, pelleted hay. The chemical composition of the long and ground hay is given in Table 1. The digestibilities of the diets and distribution of the size of particles of the ground hay was given by Campling *et al.* (1963).

Feeding

Each diet was offered once daily at 10.00 h and, with diets given *ad lib.*, the uneaten food was removed and weighed after 5 h. Each cow received each diet for at least 18 days before recordings of behaviour were made; in Expt 1 particular attention was given to allowing sufficient time for the change to a diet of concentrates.

Recording apparatus

The apparatus used was that described by Freer *et al.* (1962) and Balch, Kelly & Heim (1951) and consisted of a small, lightly inflated balloon retained by a brass

weight in the reticulum. The balloon was connected to a tambour in an Evershed and Vignoles recorder. Also, a similar balloon was placed under a side strap on a leather head-stall to record jaw movements. Each tambour operated a pen and provided a continuous record of the frequency of pressure changes at 0.5 in./min. Records of reticular motility and jaw movements were made simultaneously with all cows with each diet, starting immediately before a meal and continuing for 72 h. The records were analysed to determine the time the cows spent eating, ruminating, resting, standing and lying; resting was the residual state during which the cows were neither eating nor ruminating. The frequency of the contractions of the reticulum during each activity was calculated and for this purpose each double or triple contraction of the reticulum was counted as one contraction.

RESULTS

The mean time spent eating, ruminating, resting during 24 h, and the number and frequency of reticular contractions by each cow with each diet are shown for Expt 1 in Table 2 and for Expt 2 in Table 6. Results are presented for the individual cows to show the extent of differences between cows, as extremely few results of this type have been reported previously. Mean values for each diet calculated for all the cows in a particular experiment are also given. The values reported here of the amount of food eaten when food was offered *ad lib.* were those obtained on the 3 days during which the recordings were made; these values differ slightly from the mean voluntary intakes in the collection period of 10 days reported by Freer & Campling (1963) and Campling *et al.* (1963).

Expt 1

Eating. The mean daily time spent eating when each food was offered *ad lib.* varied from 263 min or 12.7 min/lb food with hay to only 66 min or 3.3 min/lb with concentrates; with dried grass the values were 194 min and 6.7 min/lb. There were no consistent differences between individual cows in the rate (min/lb food) at which the hay and dried grass were eaten when these foods were given *ad lib.* With hay, cow A ate more food more rapidly than cows B and C, but with dried grass cow B ate more slowly than the other two cows. Although there was a difference between the rate at which cow C ate *ad lib.* the diet of concentrates (4.1 min/lb) and those of cows B and A (2.2 and 3.5 min/lb respectively), there was little difference between the voluntary food intakes of cows C and B. The mean time spent eating 20 lb dried grass was 76 min or 3.8 min/lb, and the cows ate considerably more rapidly than when offered dried grass *ad lib.* (6.7 min/lb); cow C was the slowest eater and cow B the fastest.

When the amount of food given to the cow was restricted to 10 lb daily, hay, dried grass and concentrates were eaten considerably faster (7.3, 3.2 and 1.6 min/lb respectively) than when food was given *ad lib.* At this level of food intake (10 lb/day) cow B tended to eat both hay and dried grass faster than cows A and C, and cow C generally ate more slowly than cow A. Differences between the three cows in the time taken to eat 10 lb concentrates were small; cow A ate more slowly than cows B and C.

Table 2. *Expt 1. Mean time (min) spent daily in eating and ruminating and resting by cows receiving diets of hay, dried grass or concentrates, and the number and frequency/100 min (f) of reticular contractions during each activity*

Cow	Diet	Mean daily food intake (lb)	Total contractions		Eating		Ruminating		Resting	
			No.	f	Time (min)	No.	f	Time (min)	No.	f
A	Hay	22.0*	1835	127	258	374	145	577	728	120
		10.0	1619	112	71	105	148	361	488	135
	Dried grass	31.2*	1615	112	209	333	159	410	821	814
		20.0	1496	104	78	121	155	230	267	116
	Concentrates	10.0	1279	89	37	58	157	137	137	139
		23.8*	1367	95	83	163	196	93	99	106
B	Hay	10.0	1201	83	19	46	242	64	102	159
		20.7*	1732	120	253	376	149	544	628	115
	Dried grass	10.0	1423	99	57	93	163	287	298	104
		28.5*	1634	113	206	294	143	397	455	115
	Concentrates	20.0	1385	96	60	98	163	233	284	122
		10.0	1203	84	23	43	187	157	158	101
C	Hay	18.6*	1377	96	41	86	210	128	159	124
		10.0	1302	90	14	36	257	119	117	98
	Dried grass	19.4*	1592	110	278	411	148	541	540	100
		10.0	1539	107	90	135	150	319	267	84
	Concentrates	26.9*	1567	109	166	254	153	400	390	98
		10.0	1438	100	90	138	153	301	293	97
Means	Hay	10.0	1270	88	37	58	157	148	137	93
		18.0*	1240	86	73	140	192	60	69	115
Means	Hay	10.0	906	63	14	31	221	105	124	118
		20.7*	1719	119	263	387	147	554	635	115
	Dried grass	10.0	1527	106	73	111	152	322	351	109
		28.9*	1606	112	194	294	152	402	438	109
	Concentrates	20.0	1439	100	76	119	157	255	281	110
		10.0	1251	87	32	53	166	147	162	110
Means	Concentrates	20.1*	1328	92	66	130	197	94	109	116
		10.0	1136	79	16	38	238	96	114	119

* Food offered *ad lib.*

The mean frequency of contraction of the reticulum during eating was higher than during any other activity and differed little between hay and dried grass at any level of food intake; a marked increase in frequency occurred with concentrates (197 and 238 contractions/100 min). Differences in the frequency of reticular contractions in individual cows and with different amounts of food were slight.

Rumination. When offered hay *ad lib.* the cows ruminated, on average, for 554 min daily or 26.8 min/lb hay; with dried grass *ad lib.* the time spent ruminating dropped to 402 min/day or 13.9 min/lb. Although triple contractions of the reticulum, normally characteristic of rumination, were observed in all three cows given concentrates, the concomitant regular jaw movements were rarely observed. Almost all the periods of triple reticular contractions were found when the cows were lying and between the hours of 01.00 and 06.00 h. The total duration of the periods was greater for cows B and C when they received 10 lb concentrates daily than with concentrates *ad lib.* Also

Table 3. *Expt 1. Mean daily number of periods of rumination, and the mean time spent in eating and ruminating per lb food for individual cows receiving diets of hay and dried grass*

Cow	Diet	Mean daily food intake (lb)	No. of periods of rumination	Time spent/lb food (min)		
				Eating	Ruminating	Eating and ruminating
A	Hay	22.0*	12	11.7	26.2	37.9
		10.0	9	7.1	36.1	43.2
	Dried grass	31.2*	10	6.7	13.1	19.8
		20.0	9	3.9	11.5	15.4
		10.0	8	3.7	13.7	17.4
B	Hay	20.7*	16	12.2	26.3	38.5
		10.0	17	5.7	28.7	34.4
	Dried grass	28.5*	14	7.2	13.9	21.1
		20.0	13	3.0	11.7	14.7
		10.0	12	2.3	15.7	18.0
C	Hay	19.4*	15	14.3	27.9	42.2
		10.0	16	9.0	31.9	40.9
	Dried grass	26.9*	14	6.2	14.9	21.1
		20.0	13	4.5	15.1	19.6
		10.0	10	3.7	14.8	18.5
Means	Hay	20.7*	14	12.7	26.8	39.5
		10.0	14	7.3	32.2	39.5
	Dried grass	28.9*	13	6.7	13.9	20.6
		20.0	12	3.8	12.8	16.6
		10.0	10	3.2	14.7	17.9

* Food offered *ad lib.*

the mean daily total time of the periods of triple reticular contractions was 3.6 min/lb food in cows A and C and 6.9 min/lb in cow B when they received concentrates *ad lib.* We have shown that undigested particles of concentrates probably remained in the reticulo-rumen of cow B much longer than in the other two cows (Freer & Campling, 1963). Kick, Gerlaugh, Schalk & Silver (1937) reported that young steers given diets without roughage and consisting of shelled maize and a protein supplement ruminated for about 80 min daily, and their rumination was slow and listless.

The frequency of contractions of the reticulum tended to increase slightly when the cows were given dried grass compared with that when they were given hay. Cow C was observed to chew the regurgitated boluses of hay and dried grass for a slightly longer time than cows A and B. The frequency of contractions was similar whether the cows were lying or standing.

The mean daily number of periods of rumination for each cow tended to be an individual characteristic of the animal (see Table 3). Alterations in the total time spent ruminating associated with the type of roughage offered and the amount given, were due on the whole to alterations in the length of each period of rumination rather than to changes in the number of periods of rumination each day. Similar observations have been made by Kick *et al.* (1937) and ourselves (Freer *et al.* 1962). Table 3 also shows a complementary relationship between the times spent eating and ruminating so that the total time spent chewing during eating and ruminating per lb of each roughage was roughly of the same order at all levels of food intake.

Table 4. *Expt 1. Mean frequency of contractions of the reticulum/100 min by the three cows during standing resting and lying resting*

Food	Mean daily food intake (lb)	Frequency of contractions/100 min	
		Standing resting	Lying resting
Hay	20.7*	124	99
	10.0	114	85
Dried grass	28.9*	114	95
	20.0	110	77
	10.0	92	62
Concentrates	20.1*	99	71
	10.0	88	53

* Food offered *ad lib.*

Table 5. *Estimated mean weight of organic matter transferred per contraction from the reticulo-rumen to the omasum*

Expt no.	Food	Mean daily intake of organic matter (kg)	Weight of organic matter leaving reticulo-rumen/day (kg)	Total no. of reticular contractions/day	Weight of organic matter leaving reticulo-rumen/contraction (g)
1 (three cows)	Hay	7.25	5.03	1720	2.9
	Dried grass	9.58	5.69	1605	3.6
	Concentrates	7.34	4.51	1328	3.4
2 (four cows)	Long hay	8.46	4.42	1755	2.5
	Ground hay	9.01	6.74	1414	4.8

Resting. The time spent resting varied inversely with the time spent eating and ruminating and the frequency of contractions of the reticulum declined as the amount of food was reduced. Also, the habit of the cow affected markedly the frequency of reticular contractions: high frequencies were recorded while the cows were standing and low values when lying (Table 4), a tendency also reported by Balch (1952).

Mean frequency of reticular contractions. The mean daily frequency of contraction rose as the amount of food increased, owing to the increased time spent eating and ruminating. The mean amounts of organic matter passing from the reticulo-rumen to the omasum per reticular contraction are given in Table 5; the values have been estimated for each diet given *ad lib.* by subtracting from the intake of organic matter the amount estimated to have been digested in the reticulo-rumen (Freer & Campling, 1963). Comparison with results obtained with the same three cows in a previous experiment (see Expt 4, Freer *et al.* 1962) shows a direct relationship between the amount of undigested organic matter leaving the reticulo-rumen per reticular contraction and the daily intake of roughage organic matter (Fig. 1).

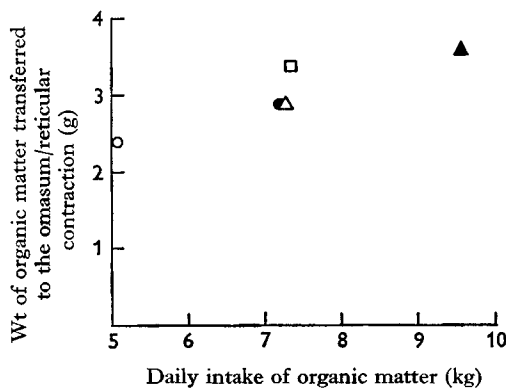


Fig. 1. Relationship between the mean daily intake of organic matter and the amount of organic matter transferred from the reticulo-rumen to the omasum during each cycle of reticulo-ruminal movements with a diet of oat straw (○), oat straw with urea (●), hay (△), dried grass (▲) or concentrates (□). Each value is the mean result for the same three cows offered each food *ad lib.* for 5 h daily. Details of the diets of oat straw and oat straw with urea were given by Freer *et al.* (1962, Expt 4). Details of the diets of hay, dried grass and concentrates are given on p. 196.

Expt 2

Eating. The mean time spent eating was 260 min with long hay or 11.0 min/lb and 126 min or 5.5 min/lb with ground hay; all four cows ate ground hay considerably faster than long hay (Table 6). Kick *et al.* (1937) and Keck, Hale, Schein & Miller (1962) reported that cattle and sheep ate ground hay faster than long hay. The mean frequencies of reticular contractions during eating were similar with both diets, 152 and 153 contractions/100 min. Differences between three of the four cows (D, E and F) in the time spent eating long hay were small, and their mean rate of eating was 11.5 min/lb, but cow G ate long hay faster at 9.7 min/lb. However, with ground hay cow G had the slowest rate of eating, 6.4 min/lb, whereas cow D ate the fastest at 4.6 min/lb; intermediate values for cows E and F were observed.

Ruminating. The mean time spent ruminating by the cows offered long hay was 566 min or 24.0 min/lb. Regular jaw movements were not observed with the diet of ground hay, although during considerable periods triple contractions of the reticulum and irregular jaw movements were recorded. Balch (1952) reported a similar finding with two cows given ground hay, and Kick *et al.* (1937), Cole & Mead (1943), Gordon

Table 6. *Expt 2. Mean time (min) spent daily in eating, ruminating and resting by cows receiving diets of long hay or ground hay ad lib., and the number, and frequency/100 min (f), of reticular contractions during each activity*

Cow	Food	Mean daily food intake (lb)	Total contractions		Eating		Ruminating		Resting				
			No.	f	Time (min)	No.	f	Time (min)	No.	f			
D	Long hay	24.7	1937	134	303	489	161	567	597	105	570	851	149
	Ground hay	24.6	1761	122	112	185	165	115	163	142	1212	1413	117
E	Long hay	19.6	1686	117	220	341	155	459	498	108	761	841	111
	Ground hay	25.5	1293	90	131	297	158	73	70	96	1236	1016	82
F	Long hay	23.8	1736	120	262	383	146	614	646	105	564	707	125
	Ground hay	21.7	1470	102	128	188	147	28	26	93	1284	1256	98
G	Long hay	26.1	1667	116	253	382	151	621	601	97	566	684	121
	Ground hay	22.7	1129	78	145	204	141	4	3	75	1291	922	71
Mean	Long hay	23.6	1755	122	260	399	153	566	586	104	614	770	125
	Ground hay	23.6	1415	98	126	196	156	55	66	120	1255	1153	92

(1958) and Keck *et al.* (1962) have all reported that diets of ground roughage were associated with greatly diminished periods of rumination in cattle and sheep. With long hay there was extremely little difference between cows D, E and G in the time spent ruminating per lb hay, but cow F ruminated for a slightly longer time per lb food. Differences between individual cows in the time spent chewing each bolus were small; cows D and F chewed for 57 sec per bolus and cows E and G for 63 sec per bolus. The number of periods of rumination during each day varied widely between cows, cow E having 24, cow D 18, cow G 16 and cow F 15 periods.

Resting. The mean time spent resting by the cows differed widely between diets, with long hay being 614 min and with ground hay 1255 min; the difference reflected the longer time spent eating and ruminating when long hay was offered. Also, the frequencies of reticular contractions were different, 125 and 97 contractions/100 min with long and ground hay respectively.

Mean frequency of reticular contraction. With long hay the mean frequency was 122 contractions/100 min and with ground hay 98 contractions/100 min. The mean amounts of organic matter passing from the reticulo-rumen to the omasum per reticular contraction were estimated to be 2.5 g with long hay and 4.8 g with ground hay (Table 5) and these amounts of organic matter were contained in 92 and 45 g digesta per contraction respectively. The amount of organic matter leaving the reticulo-rumen has been estimated from the intake and extent of digestion of organic matter in this organ (see Campling *et al.* 1963).

DISCUSSION

Eating. Differences in the rates of eating were associated with three factors, (i) the chemical and physical forms of the food, (ii) the amount of food offered and (iii) the individual animal. In Expt 1, comparison of two roughages of different chemical composition but similar physical form showed that hay was eaten more slowly than dried grass. The difference between the rates of eating when both foods were offered *ad lib.* could be related to differences between the rates of disappearance from the alimentary tract of digesta derived from each food and to differences between the amounts of digesta in the reticulo-rumen immediately before a meal. The rate of disappearance of dry matter from the alimentary tract was slower with hay than with dried grass and, on average, immediately before a meal the reticulo-rumens of the cows contained 40% more digesta and 84% more dry matter with the diet of hay than with dried grass (see Freer & Campling, 1963).

Of the three foods given in Expt 1 the rate of eating was fastest with concentrates, which in both physical and chemical composition differed markedly from the roughages. The results of Expt 2 suggest that the more important factor was the physical form, as the ground pelleted hay was eaten very much more rapidly than the long hay. The effect on the rate of eating of the amount of digesta in the reticulo-rumen could have been important with the diet of concentrates for there was very much less digesta in the reticulo-rumen immediately before a meal with this diet than with the roughages. However, in Expt 2, there was little difference between the amounts of digesta present in the reticulo-rumen before a meal of long hay and one of ground hay

(Campling *et al.* 1963). Thus it seems that the physical form of the hay was the most important factor determining the rate of eating.

Although when the diet of concentrates was given, the pH of digesta near the reticulo-omasal orifice fell within 1 to 2 h of feeding from 6.7 to a mean minimum of 4.7, eating still continued intermittently and the frequency of contraction of the reticulum was extremely high.

Decreasing the amount of food offered to the cows was associated with a more rapid rate of eating, which may have been related to smaller amounts of digesta in the reticulo-rumen.

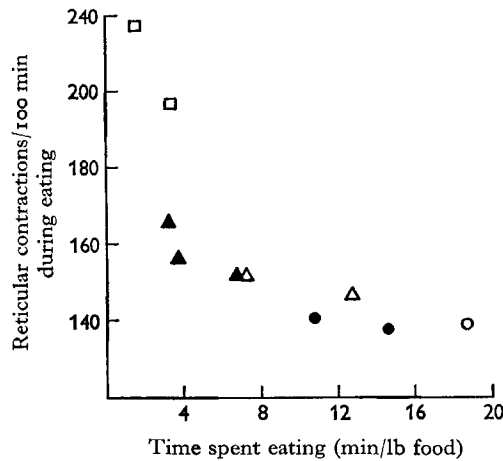


Fig. 2. Relationship between the mean time spent eating per lb food and the mean frequency of contractions of the reticulum during eating with diets of oat straw (O), oat straw with urea (●), hay (Δ), dried grass (▲) or concentrates (□). Each value is the mean for the same three cows. Details of the diets of oat straw and oat straw with urea were given by Freer *et al.* (1962, Expt 4). Details of the diets of hay, dried grass and concentrates are given on p. 196.

Differences between individual cows in their rates of eating were not consistent between foods. In Expt 1 cow C tended to eat the slowest and cow B the fastest but this was not always so. In Expt 2 the cow (G) which ate long hay fastest was not the fastest when offered ground hay. With diets of hay, dried grass and concentrates given *ad lib.* in Expt 1 and with long and ground hay in Expt 2, differences between the cows in rate of eating could not be related directly to the amounts of digesta (or dry matter) in their reticulo-rumens immediately before a meal. We have no information on the causes of differences between cows in rate of eating.

The cows used in Expt 1 were also used in Expt 4 of our earlier report (Freer *et al.* 1962), and Fig. 2 shows the relationship between the frequency of contraction of the reticulum during eating and the rate of eating with each of ten diets; each value is the mean for three cows. The frequency of contraction was about 150/100 min until the time spent eating fell below 4 min/lb. Recently we observed a frequency of reticular contractions of 150/100 min in cows allowed continuous access to concentrates throughout the day and eating at the rate of 6 min/lb (Freer & Campling, unpublished).

Rumination. Differences in the time spent ruminating could be related to three factors, the same as those associated with rate of eating.

The most striking result was that rumination did not occur with ground hay or with concentrates. It is well known that the regurgitation reflex can be initiated by tactile stimulation of parts of the walls of the reticulum and rumen (Schalk & Amadon, 1928; Balch, 1952; Ash & Kay, 1959) and, although with ground hay and concentrates short periods of regurgitation were observed, the regurgitated digesta were swallowed shortly after reaching the mouth and regular jaw movements were absent. Although several other workers (Kick *et al.* 1937; Cole & Mead, 1943; Gordon, 1958; Keck *et al.* 1962) have observed short periods of rumination in ruminants given diets of concentrates or ground hay, close comparison with their results is not possible because the size distributions of particles of food were not described adequately. The habit of chewing wood and other unusual materials reported by Cole & Mead (1943) in cattle given ground lucerne hay was also seen in several of our animals given diets of ground hay and of concentrates; precautions were taken to reduce this habit to a minimum.

The extent of rumination per lb long roughage was greater with hay than with dried grass and it would be expected that the hay would provide a greater amount of tactile stimulation per lb food than the dried grass. Also, the difference between the extent of rumination per lb hay or dried grass could be related to the digestibility of the foods and to the mean times of retention of food residues in the alimentary tract, the hay having a lower digestibility and remaining in the gut longer than dried grass (Freer & Campling, 1963). Freer *et al.* (1962) demonstrated a similar situation with cows given diets of hay, oat straw and oat straw with an intraruminal infusion of urea. Between foods, the differences in length of time spent masticating each regurgitated bolus were small and tended to be related directly to the time spent ruminating per lb food, i.e. slightly longer mastication with hay than with dried grass.

The complementary relationship between the time spent eating and the time spent ruminating described by us (Freer *et al.* 1962) was again observed with diets of hay and dried grass. The rate of eating roughage was fastest with small amounts of food, and rumination per lb food highest; with larger amounts of food opposite trends occurred so that the total amount of chewing per lb food was about the same. This nicely adjusted mechanism, ensuring reduction in size of particles of roughage, may reflect a greater amount of stimulation to rumination due to the large particle size of rapidly eaten food. Contrary to our earlier observations with coarse roughages (Freer *et al.* 1962) the results now presented confirm the finding of Hancock (1954) that the time spent ruminating per lb dried grass rose with decreasing intake.

Differences between individual cows in the time spent ruminating per lb food were small, often no more than 1–2 min. In Expt 1 cow C tended to ruminate longer than the other two cows and to chew each bolus of regurgitated digesta longest. Also, cow C ate roughages more slowly than cows A and B. The increased time spent chewing by cow C may have been associated with her age; she was 9 years old and $3\frac{1}{2}$ years older than cows A and B. We have no information on how chewing by any of the cows affected the particle size of the food.

Resting. The direct relationships between the intake of food and the mean frequency

of reticular contractions was possibly related to the amount of stimulation of the alimentary tract by the food residues passing through it. Support for this speculation is provided by the fact that with the diets of concentrates and ground hay the frequency of reticular contractions was lower than with a similar intake of long roughages.

In a previous report (Freer *et al.* 1962) we concluded that it seemed unlikely that, when hay or oat straw was given *ad lib.*, intake was limited by the amount of organic matter which could be transferred per reticular contraction to the omasum. Although the relationship between the diet and the motility of the reticulo-rumen is exceedingly complex (see Reid, 1963; Stevens, Sellers & Spurrell, 1960), the results of Expt 1 give further support to our earlier conclusion. However, in Expt 2 with the diet of ground hay, the high dry-matter content of the digesta (11.8%) leaving the reticulo-omasal orifice or the large amount of digesta in the remainder of the gut may have restricted the amount of digesta passing through the reticulo-omasal orifice per reticular contraction (see Campling *et al.* 1963).

SUMMARY

1. The behaviour and reticular motility of seven dry, non-pregnant cows was recorded on a variety of diets given *ad lib.* or in restricted amounts in one meal daily. Recordings were made by means of a small air-filled balloon in the reticulum and by a balloon strapped against the jaw; each balloon was connected to a tambour operating a pen to give continuous recordings for 72 h.

2. In Expt 1 a comparison was made between hay, dried grass and concentrates with three cows in a 3 × 3 Latin-square experimental design. The mean rate of eating food was fastest with concentrates and slowest with hay. The effect of decreasing the amount of food offered was to decrease the time spent eating per lb hay and per lb dried grass and to increase the time spent ruminating per lb of these foods. Rumination did not occur with the diet of concentrates, the cows ruminating longest with the diet of hay *ad lib.*

3. In Expt 2 a comparison was made between long hay and ground, pelleted hay when both foods were given *ad lib.* The rate of eating was much faster with ground, pelleted hay than with long hay. Rumination was not observed when the cows were given ground hay, although during short periods triple contractions of the reticulum were seen.

4. The times spent eating and ruminating by the cows are discussed in relation to the physical and chemical form of the food, the amount of food offered and the individual cow.

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