

Factors affecting the voluntary intake of food by cows

1. Preliminary observations on the effect, on the voluntary intake of hay, of changes in the amount of the reticulo-ruminal contents

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In farming practice it is often difficult to get animals to eat the amounts of the low-priced roughages which are desirable economically. Satisfactory levels of animal production can then be achieved only by the use of higher-priced foods. It is important, therefore, to understand the factors that control the voluntary intake of roughages. The probable importance of the filling effect of roughages in the reticulo-rumen has often been stressed (cf. Mäkelä, 1956; Crampton, 1957), but apart from a few brief remarks by Schalk & Amadon (1928) there appears to be little direct experimental evidence for this probable effect.

The experiments described here were carried out as a preliminary to the more detailed studies which will be discussed in later papers of this series. This paper deals with the effect, on the voluntary intake of food, of various increases or decreases in the contents of the reticulo-rumen. We wished to know whether changes in the amount of the reticulo-ruminal contents had a direct effect on the voluntary intake of hay. It appeared necessary to investigate: (1) the importance of the amount of digesta in the reticulo-rumen at different times relative to the offer of food, and (2) whether any effects observed were due to the amount of the contents *per se* or to the nature of the materials forming the contents.

EXPERIMENTAL

Cows and housing. Seven adult, non-lactating, non-pregnant Friesian and Shorthorn cows were used in four experiments. Each cow had a permanent rumen fistula which was closed by means of the cannula and bung described by Balch & Johnson (1948). The cows were kept in standings which prevented food being stolen by neighbours. Water and salt licks containing trace minerals were accessible at all times.

Determination of voluntary food intake. In all the experiments the diet consisted entirely of hay. The complete daily allowance was offered in one meal, the amounts offered being adjusted daily until the uneaten food remaining when the cow stopped eating was about 10% of the amount offered. Cows were judged to have stopped eating when they either lay down or began to ruminate, usually after they had been eating for 3–4 h; uneaten food was then removed and weighed.

Foods. The composition of the hays is given in Table 1. Hay A was used in Expts 1 and 2 and hay B in Expts 3 and 4.

Expt 1. Effect of removing swallowed hay as it entered the reticulo-rumen. In order to find whether, at any single meal, the intake of hay is limited by the accumulation of the newly ingested material in the reticulo-rumen, boluses of swallowed hay were caught by hand at the cardia and removed. On five isolated occasions, two with cow A and one each with cows B–D, each bolus was caught during the first 3 h of eating so that at the end of this period no newly ingested hay remained in the reticulo-rumen. After the collection of boluses the cows were allowed to continue eating hay until they either lay down or began to ruminate. The amount of hay eaten during the collection, the weight of boluses collected, the further amount of hay eaten after the collection had ended and the total time spent eating were recorded.

Table 1. *Chemical composition of the hay*

Hay	Expt nos.	Dry matter (%)	Crude protein	Crude fibre	Ether extract	Nitrogen-free extract	Ash
			(As percentage of dry matter)				
A	1, 2	84.0	7.8	39.2	1.7	42.7	8.6
B	3, 4	83.1	5.9	36.0	2.9	48.2	7.0

Expt 2. Effect of altering the amount of digesta in the reticulo-rumen immediately before, during or after a meal. The long-term effect of the amount of digesta in the reticulo-rumen at various times was investigated by manually removing digesta from, or adding them to, the reticulo-rumen daily for periods of 10–18 days. The treatments were as follows: (1) For 18 days 50 lb digesta were removed daily from cows that had just finished eating hay A and were added to the rumen contents of cows C and D immediately before they began their daily meal. (2) For the following 12 days cows C and D were given food in the usual way without further treatment. This period was followed by 12 days in which 50 lb digesta were removed daily from the rumen about 1½–2 h after the meal began. (3) A similar procedure was followed for 12 days with cows B and E, except that the 50 lb digesta were removed about 30 min after the cows stopped eating. (4) For 10 days 50 lb digesta were removed from cow F mid-way between meals, 11 h after the beginning of feeding, and added to the rumen of cow G. After a 12-day period of normal feeding the treatment was reversed, digesta from cow G being added to the rumen of cow F.

Expt 3. Effect of large water-filled bladders in the reticulo-rumen. To simulate increases in the volume of the reticulo-ruminal contents, large rubber bladders were placed in the ventral rumen and filled with a known weight of water at 35°. Each bladder contained up to 20 lb water and remained in the reticulo-rumen for periods of 14 days.

The experiment was made with three cows which received the following treatments according to a 3 × 3 Latin square design: treatment 1, control, no additions to the rumen; treatment 2, the bladders contained 50 lb water; treatment 3, the bladders contained 75 lb water. There were no intervals between the 14-day periods.

Expt 4. Effect of adding large quantities of water to the contents of the reticulo-rumen. In this experiment the treatments were as follows: treatment 1, control, no additions

to rumen; treatment 2, bladders containing 100 lb water placed in the reticulo-rumen, as in Expt 3; treatment 3, 100 lb water added daily to the reticulo-rumen, through the fistula, during the first 50 min of the meal. The cows were those used in Expt 3 and they received the treatments, in 10-day periods, again according to a 3×3 Latin square design.

RESULTS

Expt 1. Effect of removing swallowed hay as it entered the reticulo-rumen

The results are given in Table 2 and show that the four cows normally ate 18.7–23.6 lb hay. On the five isolated days when swallowed hay was collected at the cardia they ate some 76–96% of their normal intake during the 3 h of collection. When the collection ceased the cows continued eating. The removal of swallowed food for 3 h prolonged eating from the usual 3–4 h to $6\frac{1}{2}$ –8 h and increased the total intake of hay by 70–85% to 31.8–39.2 lb.

This experiment suggested that the accumulation of recently swallowed food in the reticulo-rumen exerted a direct and immediate effect on the point in time at which the cow ceased to eat hay. On the isolated days when the food was removed as it was swallowed, the cows did not tend to cease eating after their meal had lasted for as long as it usually lasted on the non-experimental days. This finding suggests that, at any particular meal, the intake of the cows was governed less by habit formed while they were receiving the same diet on previous days than by the amount of digesta in the reticulo-rumen.

Expt 2. Effect of altering the amount of digesta in the reticulo-rumen immediately before, during or after a meal

As shown in Table 3, the mean normal voluntary daily intake of the cows varied between 18.3 and 22.9 lb hay. On average, 50 lb digesta contained 7.1 lb dry matter. To compensate directly for the addition or removal of 50 lb digesta it would have been necessary for the daily intake of hay to decrease or increase, respectively, by about 8.4 lb.

The daily addition of digesta to the reticulo-rumen always caused a decrease in the voluntary intake of hay. This decrease was never as great as 8.4 lb. When the addition was made immediately before the meal the mean decrease was 5.8 lb in cows C and D and 3.9 lb in cows B and E. When it was made 11 h after the beginning of the meal the decrease in cows F and G was 3.8 lb.

The daily removal of digesta from the reticulo-rumen usually caused an increase in the voluntary intake of hay. This increase was never as great as 8.4 lb. When the digesta were removed during the meal the increase was 2.4 lb in cows C and D, and when they were removed shortly after the meal the increase was 6.2 lb in cows B and E, but when they were removed 11 h after the meal began the increase in cows F and G was only 0.4 lb.

The daily addition or removal of digesta appeared, therefore, to be partially compensated for by decreases or increases in the voluntary intake of hay. However, the compensation was never complete; the results gave some slight indication that the

Table 2. *Expt 1. Effect of removing swallowed hay at the cardia on the voluntary intake of hay*

Cow	Normal voluntary daily intake (a) (lb)	Amount eaten during collection of swallowed hay (b) (lb)	Weight of swallowed hay and saliva collected in 3 h (lb)	Amount eaten after the collection of swallowed hay had ceased		Total voluntary intake (b+c) (lb)	Total time spent eating	
				Total (c) (lb)	Percentage of (a)		With normal feeding h min	When swallowed hay was collected h min
A	19.7	18.9	140.0	14.3	72.6	33.2	3 10	6 30
A	19.7	17.0	123.1	16.7	84.8	33.7	3 10	7 5
B	18.7	16.9	120.7	14.9	70.0	31.8	3 57	8 10
C	22.2	16.8	129.6	17.5	78.8	34.3	3 10	6 50
D	23.6	20.8	123.6	18.4	78.0	39.2	3 55	7 50

Table 3. *Expt 2. Effect, on the mean voluntary daily intake of hay (lb), of increasing or decreasing the amount of digesta in the reticulo-rumen at the beginning, during and after a meal*

Cows	Voluntary intake during the control period			Intake when 50 lb digesta (7.1 lb dry matter) were placed in the reticulo-rumen			Intake when 50 lb digesta (7.1 lb dry matter) were removed from the reticulo-rumen			
	Total	Dry matter		Immediately before eating	11 h after eating began	During eating	Shortly after the end of a meal	11 h after eating began	Dry matter	
C, D	22.9 (12)	19.2		17.1 (18)	—	25.3 (12)	—	—	—	—
B, E	18.3 (12)	15.4		14.4 (12)	—	—	24.5 (12)	20.6	—	—
F, G	21.5 (12)	18.1		—	17.7 (10)	—	—	—	21.9 (10)	18.4

Values in parentheses are the number of days for which the means for each pair of cows were calculated.

compensation was greater when the amount of digesta was changed immediately before, during or shortly after the meal than when it was changed midway between the meals. The critical times clearly need further definition.

Expts 3 and 4. Effect of large water-filled bladders in the reticulo-rumen (Expt 3) and effect of adding large quantities of water to the contents of the reticulo-rumen (Expt 4)

The results of these experiments are given in Tables 4 and 5 which show that the addition of water in bladders to the reticulo-rumen reduced the voluntary intake of hay. As shown in Fig. 1, the reduction in the daily intake of hay was directly related to the weight of water in the bladders and amounted to about 0.54 lb hay/10 lb water. As the mean weight of digesta in the reticulo-rumen of these cows at the end of a meal was probably about 250 lb, the reductions caused, even by 100 lb of water, were surprisingly small. When 100 lb of water were poured daily into the reticulo-rumen during eating, the voluntary intake of hay did not change significantly.

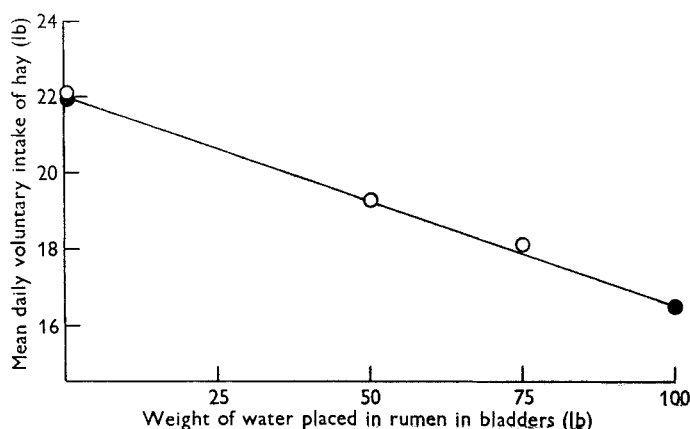


Fig. 1. Expts 3 and 4. Influence, on the voluntary daily intake of hay by cows, of water-filled bladders placed in the ventral sac of the rumen. Mean values are shown for Expt 3, O, and Expt 4, ●.

Table 4. Expt 3. Effect, on the mean daily voluntary intake of hay, of placing water-filled bladders in the reticulo-rumen

(Mean values for periods of 14 days with three cows)

Treatment	Mean daily voluntary intake	
	Hay (lb)	Water* (lb)
None	22.1	85
50 lb water in bladders	19.3	76
75 lb water in bladders	18.1	76
Standard error of difference between two means	± 0.46	—

* Excluding water in food.

The voluntary intake of water decreased slightly with the addition of water in bladders (Table 4) and virtually ceased when water was poured into the reticulo-rumen (Table 5).

Table 4. *Expt 4. Effect, on the mean daily voluntary intake of hay and on the amount of water drunk, of adding large quantities of water to the reticulo-rumen*

(Mean values for periods of 10 days with three cows)

Treatment	Mean daily voluntary intake	
	Hay (lb)	Water* (lb)
None	21.9	82
100 lb water in bladders	16.5	68
100 lb water poured into reticulo-rumen	22.3	2
Standard error of difference between two means	± 0.70	—

* Excluding water in food.

DISCUSSION

In these experiments the amount of the contents of the reticulo-rumen was changed by three techniques. Each technique provided evidence of a direct relationship between the amount of the contents and the voluntary intake of hay.

When the internal volume of the reticulo-rumen was reduced for periods of 10–14 days by means of water-filled bladders, the voluntary daily intake of hay was reduced by about 0.54 lb for every 10 lb water placed in the bladders. Pouring 100 lb water into the reticulo-rumen during the daily meal had no effect on intake, yet the addition or removal of digesta had certain direct effects. It follows that any changes due to the transfer of digesta were due to the dry matter, or to the volume associated with the dry matter, rather than to the water alone. The probable importance of dry matter and its associated water was stressed by Procter & Wright (1927). Blaxter, Wainman & Wilson (1960) recently produced evidence which suggested that the amount of digesta in the alimentary tract was an important factor controlling the voluntary intake of food by sheep which received several different types of hay.

It may be deduced, therefore, that if the mean dry-matter content of digesta is 10% (Balch & Line, 1957) and the mean specific gravity of digesta is 0.9 (Balch, 1958) every pound of dry matter removed from or added to the digesta would increase or decrease the voluntary intake by as much as the decrease when 11.1 lb water were added in bladders, that is by 0.6 lb hay. As shown in Fig. 2, the changes in intake resulting from both the isolated removal of swallowed hay and the long-term transfer of digesta approximated to the values to be expected according to these deductions. Closer agreement in general could hardly be expected in view of the use of mean values for the dry-matter content and specific gravity. This is strong evidence that the amount of the reticulo-ruminal contents had a direct effect on the voluntary intake of hay.

The results of Expts 1 and 2 support an earlier suggestion (Balch, 1958) that neither exhaustion of salivary secretion nor fatigue of the jaw or rumen muscles are likely to be important in determining the point at which a cow ceases eating a roughage offered *ad lib.*

The failure to alter the voluntary intake of hay by pouring 100 lb of water into the reticulo-rumen is not unexpected in view of the capacity of cows to utilize large

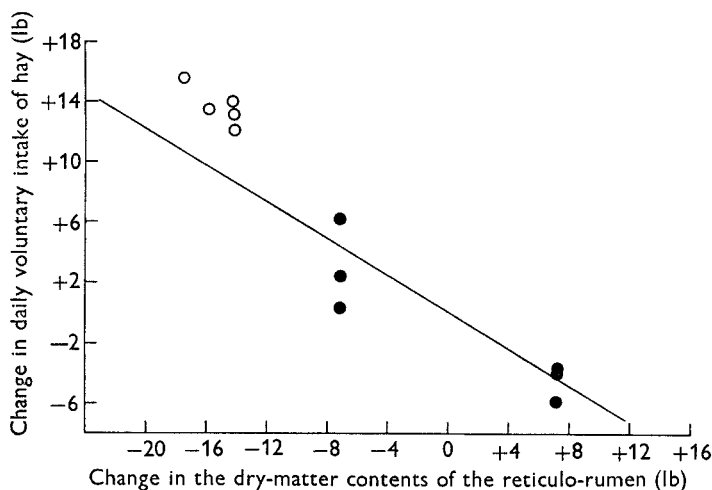


Fig. 2. Change, in the voluntary daily intake of hay by cows, caused by the removal of swallowed hay on isolated days (Expt 1, O), or by daily increases or decreases in the dry-matter contents of the reticulo-rumen (Expt 2, ●). The line represents the relationship expected when the removal or addition of 1 lb dry matter changes the voluntary intake of hay by 0.6 lb.

quantities of succulent foods, and Moore, Thomas & Sykes (1960) have recently reported a similar result. Also Hillman, Lassiter, Huffman & Duncan (1958) showed that the deliberate addition of large quantities of water to hay had no depressing effect on the amount of hay eaten. However, it is difficult to reconcile this result with the suggestion that excess water may be responsible for limiting the intake of grass and silage (McMeekan, 1958; Dodsworth & Campbell, 1953).

SUMMARY

1. The voluntary intake was measured in seven cows which were receiving only hay *ad lib.* in single daily meals lasting 3–4 h. The cows had rumen fistulas.

2. When, for 3 h on isolated days swallowed hay was collected and removed as it passed through the cardia, the length of the period of eating was almost doubled and the cows consumed about 177% of their normal voluntary daily intake of hay.

3. When several large bladders containing 50–100 lb water were kept in the reticulo-rumen for 10–14 days the mean voluntary intake of hay fell by 0.54 lb for every 10 lb water in the bladders.

4. Pouring 100 lb water into the reticulo-rumen during the daily meal did not affect the voluntary intake, but daily increases or decreases in the amount of the

reticulo-ruminal contents were compensated for by decreases or increases, respectively, in the voluntary intake.

5. It is concluded that the amount of the reticulo-ruminal contents has a direct effect on the voluntary intake of hay. It is provisionally concluded that in the reticulo-ruminal contents a change of 1 lb dry matter with its associated water results in an inverse change of 0.6 lb in the voluntary daily intake of hay.

6. The results support the suggestion that neither exhaustion of the salivary glands nor of the muscles of the jaw and reticulo-rumen are important in determining the point at which a cow ceases eating hay offered *ad lib*.

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