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Studies on intestinal digestion in the sheep

2.* Digestion of some carbohydrate constituents in hay, cereal and hay-cereal rations

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1. In seven experiments sheep were given diets ranging from all-hay to all-barley, and also a diet comprising one part hay to two parts flaked maize. Each sheep was equipped with a cannula into the rumen and a re-entrant cannula in the proximal duodenum; six of the ten also had a re-entrant cannula in the terminal ileum. Paper impregnated with chromic oxide (Cr_2O_3) was given twice daily by rumen fistula.

2. Amounts of α-linked glucose polymer entering and leaving the small intestine and excreted in the faeces were measured. Some values for a fraction designated non-glucose reducing polymer for cellulose and for gross energy were also obtained. The amounts passing the proximal duodenum and the terminal ileum were adjusted to give 100% recovery of Cr_2O_3 and the values were used to measure the extent of digestion in various parts of the alimentary tract.

3. When rolled or whole barley was given alone or was the major feed constituent the amount of α-linked glucose polymer entering the small intestine was $6\cdot0 \pm 0\cdot76$% of that ingested (range 2·6–8·1%). The value was significantly lower than that found for the diet of hay and flaked maize ($10\cdot4 \pm 1\cdot3$%, range 8·0–13·6%). The α-linked glucose polymer which entered the small intestine was almost completely digested there.

4. The digestibility of the non-glucose reducing polymer, which included much of the hemicelluloses present, ranged from 51 to 73% and almost all the digestible fraction (93–97%) was digested before the small intestine when hay or predominantly hay diets were given. On high-cereal diets only 71–85% of the digested fraction disappeared before the small intestine and appreciable amounts were digested in the large intestine.

5. On the all-hay diet 91% of the digestible cellulose and 67% of the digestible energy were lost before the small intestine, 0 and 21% in the small intestine and 9 and 12% in the large intestine.

6. Mean digestibility coefficients determined in sheep fed solely on either whole or rolled barley were: for dry matter 88·1 and 87·9%, for nitrogen 83·5 and 82·1%, for crude fibre 53·7 and 56·6% and for gross energy 87·7 and 88·0%.

The conventional picture of carbohydrate digestion in ruminants is one in which the major part of digestion takes place in the rumen under the influence of microbial fermentation to yield principally volatile fatty acids (VFA) and also lactic acid, methane and carbon dioxide (Armstrong, Blaxter & Graham, 1957). Very little potentially digestible carbohydrate material is thought to escape from the reticulo-rumen and enter the small intestine via the abomasum.

For animals fed roughage diets there is evidence to support this view. Thus Hogan & Phillipson (1960), using hay-fed sheep, showed that 70% of the digestible dry matter of the ration disappeared before the pylorus. Ridges & Singleton (1962), working with goats given hay and concentrates, found that 81% of the soluble carbohydrate (measured as total dry matter less fat, nitrogen ×6·25, crude fibre and ash)

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and 93% of the crude fibre that were digested disappeared before the duodenum. With steers, Sineshchekov (1953) reported that 80% of the carbohydrate (measured as the sum of crude fibre and nitrogen-free extractives) that was digested disappeared before the duodenum, 10% was lost in the small intestine, and the remainder in the caecum and colon.

More detailed analyses of digesta entering the small intestine of hay-fed sheep have been made by Heald (1951) and by Weller & Gray (1954) and of hay-fed goats by Porter & Singleton (1965). These workers recognized that, of the carbohydrate entering the small intestine, only that present as α-linked glucose polymer would be likely to yield glucose under the action of the intestinal carbohydrases. Accordingly they measured the amounts of glucose of microbial origin entering the duodenum and in all instances found only very small amounts.

In present-day feeding practice, however, high levels of cereals are frequently fed to ruminant animals. With steers given rations of ground maize and ground lucerne hay, Karr, Little & Mitchell (1966) reported that some 35–40% of the starch intake reached the abomasum and of this quantity only some 65% was digested within the small intestine. Recently, however, Topps, Kay, Goodall, Whitelaw & Reid (1968) in experiments with 6-month-old steers, gave a concentrate diet consisting mainly of barley and reported that only the equivalent of some 5% of the starch in the feed entered the duodenum.

The studies reported in the present paper were designed to measure the amounts of α-linked glucose polymer entering the small intestine of sheep given high-energy diets and to determine the extent to which such polymers are digested in their subsequent passage through the small intestine and through the caecum and colon. Some results are also presented for the digestion of cellulose, gross energy and of a fraction termed the non-glucose reducing polymers. Since these studies were completed, Topps, Kay & Goodall (1968) have reported similar experiments with sheep given diets of barley and hay.

EXPERIMENTAL

Sheep. The sheep used were adult wethers each fitted with a rumen cannula and a re-entrant cannula in the proximal duodenum; all but four (sheep Br, E, K and S) were also equipped with a re-entrant cannula in the terminal ileum. For further details see MacRae & Armstrong (1969).

Experimental design and rations. Seven experiments were carried out. The first four were designed to compare diets ranging from all-hay to all-barley. Each ration was given to provide the same daily intake of dry matter except in Expt 4 when sheep B was given the all-barley ration at a lower level of intake. The hay was chopped, the barley rolled. In Expt 5 the sheep were given a diet comprising one part chopped hay to two parts flaked maize and it was intended that both the ratio of hay to cereal and total daily dry-matter intake would be the same as in Expt 3, thus permitting a comparison of flaked maize and rolled barley. In the event two of the four sheep used failed to consume the amount offered and their rations were accordingly reduced although the ratio of hay to flaked maize was kept the same as originally planned. In

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order to provide further information on all-barley diets two further experiments were done. In the first of these (Expt 6) the barley was rolled before use; in the second (Expt 7) it was given whole. Small amounts of a mineral supplement were given with all the rations containing cereals. Details of the rations and animals used in the seven experiments are given in Table 1.

Table 1. *Sheep and rations used in the experiments*

		Rations given (g/24 h)			
Expt no.	Sheep	Feed	Fresh weight	Dry weight	Total dry weight
1	B, Rg	Hay	900	743	743
2	B, C, R	Hay	600	499	751
		Rolled barley	300	252	
3	B, C	Hay	300	254	750
		Rolled barley	600	496	
4	Br	Rolled barley	900	750	750
	B	Rolled barley	600	489	489
5	C, E	Hay	300	266	780
		Flaked maize	600	514	
	Ri, Ro	Hay	240	213	619
		Flaked maize	470	406	
6	K, S	Rolled barley	1050	850	850
7	K, S	Whole barley	1050	864	864

Management of sheep. Each ration was given for a preliminary period of at least 2 weeks. Daily collections of faeces for 7-day periods were then made, followed by 24 h collections of digesta at the terminal ileum and, 2 days later, at the proximal duodenum. Details of the day-to-day management of the sheep including the daily administration of chromic oxide (Cr_2O_3) and the procedures adopted for collecting the intestinal samples have been given by MacRae & Armstrong (1969).

Preparation of samples for analysis. Representative samples of the feeds were collected during the preparation of the rations and after being dried under reduced pressure at 50° they were ground through the 1 mm sieve in a Christy and Norris hammer mill and stored for analysis.

During the 7-day faecal collection periods a subsample of wet faeces was taken daily from each sheep and stored at −20°. From these a representative bulk sample for each animal was prepared on a fresh-weight basis, dried at 50° under reduced pressure, ground through a 1 mm sieve in a Christy and Norris mill and stored for analysis.

The method used in obtaining cumulative 24 h samples of duodenal and of ileal contents has been described by MacRae & Armstrong (1969).

Analyses. All samples were analysed for their content of α-linked glucose polymer by the method of MacRae & Armstrong (1968), the result being expressed as mg glucose yielded/g dry matter. Some were also analysed for their content of total reducing polymer by hydrolysing with 0·36 N-H_2SO_4 for 8 h at 100°, followed by precipitation of protein in the hydrolysates and estimation of reducing sugars present by a copper-reduction method (Somogyi, 1945). For further details see MacRae &

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Armstrong (1968). Total reducing polymer less α-linked glucose polymer has been designated non-glucose reducing polymer. Work in this laboratory (D. E. Beever, unpublished observations) has shown that the last-mentioned fraction contains a considerable part of the hemicellulose fraction. Some samples were also analysed for their content of cellulose by the method of Barnett (1957) and of gross energy using an adiabatic bomb calorimeter (A. Gallenkamp & Co. Ltd, London). The components of the rations were also analysed for the proximate constituents using the conventional methods of feeding-stuffs analysis. Their composition is shown in Table 2.

Calculation of results. The values presented for duodenal and ileal digesta are mean 24 h quantities calculated by correcting the observed 24 h flows for 100 % recovery of Cr_2O_3. With one exception, the recoveries of Cr_2O_3 have been reported earlier (see Table 2 of MacRae & Armstrong, 1969). For sheep B in Expt 4 the recoveries of Cr_2O_3 in the 24 h duodenal and ileal collections as percentages of intake were 95·5 and 48·7 % respectively.

Table 2. *Composition of components of the rations (g/100 g dry matter except where stated)*

Constituent	Hay	Rolled barley	Flaked maize
Organic matter	88·7	97·3	99·4
Nitrogen	2·2	1·7	1·6
Ether extractives	1·8	1·8	2·1
Crude fibre	33·4	5·3	2·2
Nitrogen-free extractives	39·9	79·7	85·3
α-linked glucose polymer (mg glucose/g dry matter)	21·8	709·6	769·2
Non-glucose reducing polymer (mg glucose/g dry matter)	209·2	101·3	149·1
Cellulose	33·5	4·5	—
Gross energy (kcal/g dry matter)	4·244	4·376	4·333

RESULTS

Table 3 shows the amounts of α-linked glucose polymer in the feed, entering and leaving the small intestine, and in the faeces for sheep given rations of chopped hay, rolled barley or mixtures of both. Values for the disappearance of the digested polymer in three sections of the alimentary tract, expressed as a percentage of total digested polymer, are also shown. As increasing quantities of the polymer were given to the sheep the amounts reaching the duodenum also increased. However, expressed as a percentage of the amount ingested, there was little change; mean values were 18·2 % for hay, 9·3 % for two parts hay to one part barley, 7·5 % for one part hay to two parts barley, and 8·1 % for barley alone. It will be appreciated that the considerably higher value obtained for the all-hay diet is of little nutritional significance in view of the very small amounts of polymer contained in hay. From Table 3 it can be seen that there was virtually complete digestion of the polymer; only when the diet comprised one part hay to two parts barley were very small amounts detected in the faeces. Though the major part of the polymer was digested before the duodenum, that which did enter the small intestine was extensively digested there.

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Table 3. *Quantities of α-linked glucose polymer present in the feed, entering and leaving the small intestine and in the faeces of sheep given diets of hay, rolled barley or mixtures of the two*

(The values for digesta at the duodenum and ileum have been adjusted for 100 % recovery of chromic oxide. Values for the disappearance of digestible α-linked glucose polymer before and in the small intestine and in the caecum and colon are also given)

	900 g hay		600 g hay and 300 g barley			300 g hay and 600 g barley		900 g barley	600 g barley
	Sheep B	Sheep Rg	Sheep B	Sheep R	Sheep C	Sheep B	Sheep C	Sheep Br	Sheep B
Glucose polymer (g/24 h):									
In feed	16·2	16·2	189·5	189·5	189·5	357·3	357·3	532·5	347·0
At proximal duodenum	3·6	2·3	16·6	17·7	18·4	26·4	26·7	42·5	28·2
At terminal ileum	0·0	0·0	0·7	0·4	0·6	1·1	1·2	—	0·4
In faeces	0·0	0·0	0·0	ND	0·0	0·4	0·5	0·0	0·0
Glucose polymer entering the small intestine (% of that in the feed)	22·2	14·2	8·8	9·3	9·7	7·4	7·5	8·0	8·1
Apparent digestibility of the glucose polymer (%)	100·0	100·0	100·0	100·0*	100·0	99·9	99·9	100·0	100·0
Disappearance of digestible glucose polymer (%):									
Before small intestine	77·8	85·8	91·2	90·7*	90·3	92·6	92·5	92·0	91·9
In small intestine	22·2	14·2	8·4	9·1*	9·4	7·1	7·1	8·0 (small intestine, caecum and colon together)	8·1
In caecum and colon	0·0	0·0	0·4	0·2*	0·3	0·2	0·4		0·0

ND, not determined. * Values assuming 100 % digestibility.

The quantities of α-linked glucose polymer entering the small intestine of sheep given 1050 g/day of barley, either rolled or whole, are given in Table 4. When expressed as a percentage of the polymer in the diet, the amounts were again low; mean values for rolled and whole barley were 3·2 and 5·2% respectively.

Table 5 shows the quantities of α-linked glucose polymer ingested, entering and leaving the small intestine and excreted in the faeces of sheep receiving diets comprising one part hay to two parts flaked maize. The mean value for the amounts of polymer reaching the small intestine, expressed as a percentage of that ingested, was 10·4 and, as with the hay–barley diets, virtually all of this was digested before the terminal ileum.

Table 4. *Quantities of α-linked glucose polymer present in the feed and entering the small intestine of sheep given rolled or whole barley*

(The values for digesta at the duodenum have been adjusted for 100% recovery of chromic oxide)

	Rolled barley		Whole barley	
	Sheep K	Sheep S	Sheep K	Sheep S
Glucose polymer (g/24 h):				
In feed	603·2	603·2	613·1	613·1
At proximal duodenum	15·4	23·1	38·7	25·5
Glucose polymer entering small intestine (% of that in feed)	2·6	3·8	6·3	4·2

Table 5. *Quantities of α-linked glucose polymer present in the feed, entering and leaving the small intestine and in the faeces of sheep given a diet comprising one part hay to two parts flaked maize.*

(The values for digesta at the duodenum and ileum have been adjusted for 100% recovery of chromic oxide. Values for the disappearance of digestible α-linked glucose polymer before and in the small intestine and in the caecum and colon are also given)

	300 g hay and 600 g flaked maize		240 g hay and 470 g flaked maize	
	Sheep C	Sheep E	Sheep Ri	Sheep Ro
Glucose polymer (g/24 h):				
In feed	401·2	401·2	316·9	316·9
At proximal duodenum	45·2	34·0	25·3	43·1
At terminal ileum	2·3	—	0·4	1·8
In faeces	0·5	0·0	0·0	0·5
Glucose polymer entering small intestine (% of that in feed)	11·3	8·5	8·0	13·6
Apparent digestibility of glucose polymer (%)	99·9	100·0	100·0	99·8
Disappearance of digestible glucose polymer (%):				
Before small intestine	88·7	91·5	92·0	86·4
In small intestine	10·7	} 8·5	7·9	13·0
In caecum and colon	0·6		0·1	0·6

In Table 6 similar measurements for non-glucose reducing polymer are presented for sheep receiving diets of chopped hay, rolled barley or mixtures of the hay with either rolled barley or flaked maize. Apparent digestibilities of this fraction ranged

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Table 6. *Quantities of non-glucose reducing polymer present in the feed, entering and leaving the small intestine and in the faeces of sheep given diets of hay, rolled barley and mixtures of hay and rolled barley or flaked maize*

(The values for digesta at the duodenum and ileum have been adjusted for 100 % recovery of chromic oxide. Values for the disappearance of digestible non-glucose reducing polymer before and in the small intestine and in the caecum and colon are also given)

	900 g hay		600 g hay and 300 g barley		300 g hay and 600 g barley		600 g barley	300 g hay and 600 g flaked maize	240 g hay and 470 g flaked maize	
	Sheep B	Sheep Rg	Sheep B	Sheep C	Sheep B	Sheep C	Sheep B	Sheep C	Sheep Ri	Sheep Ro
Non-glucose reducing polymer (g/24 h):										
In feed	155·4	155·4	129·9	129·9	103·3	103·3	49·5	132·2	105·1	105·1
At proximal duodenum	58·4	58·4	46·5	45·2	53·9	50·8	31·6	50·4	51·4	38·9
At terminal ileum	57·8	52·0	44·3	44·2	54·6	43·7	34·4	52·0	53·1	45·0
In faeces	51·4	55·7	40·6	41·3	41·7	40·8	24·2	35·8	37·4	34·4
Apparent digestibility of polymer (%)	66·9	64·2	68·7	68·2	59·6	60·5	51·1	72·9	64·4	67·3
Disappearance of digestible polymer (%):										
Before small intestine	93·3	97·3	93·4	95·6	80·2	84·0	70·8	84·9	84·9	79·3
In small intestine	0·5	6·4	2·5	1·1	−1·1	11·4	- 11·1	−1·7	−1·7	−2·5
In caecum and colon	6·2	−3·7	4·1	3·3	20·9	4·6	40·3	16·8	16·8	23·2

from 51 % to 73 %. When all or a major part of the ration was hay, 93–97 % of that which was digestible was digested before the small intestine. On the other hand, when cereals formed a major part of the ration or when rolled barley was given alone only 71–85 % of the digested fraction was lost before the small intestine, and in five of the six observations appreciable amounts were digested in the caecum and colon. However, with the exception of sheep C receiving 300 g hay and 600 g barley, the amounts of non-glucose reducing polymer measured at the ileum were all higher than those recorded at the duodenum, thus increasing values for the loss of the digestible fraction in the caecum and colon. Though part of the apparent increase in the fraction occurring during passage through the small intestine may have arisen from errors in measurement of the amounts of digesta flowing into and out of the small intestine, the consistency of the apparent increase suggests that it may have resulted from an artifact in the fraction isolated at the ileum.

Table 7. *Quantities of cellulose present in the feed, entering and leaving the small intestine and in the faeces of sheep given diets of hay and of hay and rolled barley*

(The values for digesta at the duodenum and ileum have been adjusted for 100 % recovery of chromic oxide. Values for the disappearance of digestible cellulose before and in the small intestine and in the caecum and colon are also given)

	900 g hay		600 g hay and 300 g barley		300 g hay and 600 g barley	
	Sheep B	Sheep Rg	Sheep B	Sheep C	Sheep B	Sheep C
Cellulose (g/24 h):						
In feed	248·9	248·9	178·5	178·5	107·4	107·4
At duodenum	85·0	84·1	62·9	66·9	75·7	64·8
At ileum	81·4	86·7	59·8	69·1	67·0	54·5
In faeces	66·1	70·5	45·8	40·8	45·8	37·5
Apparent digestibility of cellulose (%)	73·4	71·7	74·3	77·1	57·4	65·1
Disappearance of digestible cellulose (%):						
Before small intestine	89·6	92·4	87·1	81·0	51·4	60·9
In small intestine	2·0	−1·5	2·3	−1·6	14·1	14·7
In caecum and colon	8·4	9·1	10·6	20·6	34·5	24·4

Some results for the digestion of cellulose and of gross energy are given in Tables 7 and 8 respectively. It can be seen from Table 7 that when hay alone was given the major part (mean value 91 %) of the digestible cellulose disappeared before the small intestine and no digestion occurred there. When a ration of 2 parts hay to one part barley was given, slightly less of the digested cellulose was fermented in the rumen (mean value 84 %) and slightly more in the caecum and colon, although it must be noted that between-sheep differences were appreciable. Again there was no digestion in the small intestine. When barley was the major constituent of the diet, however, over-all digestibility of cellulose fell appreciably and a considerably smaller proportion (mean value 56 %) of that which was digested was lost before the duodenum. Digestion in the caecum and colon was of increased significance, but in addition there appeared to be appreciable digestion of this constituent in the small intestine.

As is to be expected, the apparent digestibility of gross energy increased with rises in the proportion of barley to hay in the ration (Table 8); for a given diet between-

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sheep differences in digestibility coefficients were small. Values for the the contribution of different parts of the alimentary tract to over-all energy digestion, however, differed considerably between sheep, and the cause warrants further study. Nevertheless from the mean values there appeared to be no effect of diet on the extent of disappearance of apparently digested energy before the duodenum. Mean values fell from 67% on the all-hay diet to 62% when barley alone was given.

Table 8. *Amounts of gross energy contained in the feed, entering and leaving the small intestine and in the faeces of sheep given diets of hay, rolled barley and mixtures of the two*

(The values for digesta at the duodenum and ileum have been adjusted for 100% recovery of chromic oxide. Values for the disappearance of apparently digested energy before and in the small intestine and in the caecum and colon are also given)

	900 g hay		600 g hay and 300 g barley		300 g hay and 600 g barley		600 g rolled barley
	Sheep B	Sheep Rg	Sheep B	Sheep C	Sheep B	Sheep C	Sheep B
Gross energy (kcal/24 h):							
In feed	3153	3153	3221	3221	3249	3249	2140
At proximal duodenum	1992	1809	1862	1733	1931	1667	1055
At terminal ileum	1558	1449	1170	1375	1181	1043	662
In faeces	1229	1333	1045	1085	875	960	378
Apparent digestibility of gross energy (%)	61·0	57·7	67·6	66·3	73·1	70·5	82·3
Disappearance of apparently digested energy (%):							
Before small intestine	60·3	73·8	62·5	69·7	55·5	69·1	61·6
In small intestine	22·6	19·8	31·8	16·8	31·6	27·3	22·3
In caecum and colon	17·1	6·4	5·7	13·5	12·9	3·6	16·1

DISCUSSION

In sheep given high-barley or all-barley diets only a small amount of α-linked glucose polymer entered the small intestine. The eight observations made on diets in which rolled or whole barley was given alone or was the major feed constituent gave a mean value of 6·0 ± 0·75 (SE) for the amount of the polymer which entered the small intestine when expressed as a percentage of that ingested (range 2·6–8·1%). This is in agreement with the findings reported by Topps, Kay & Goodall (1968) for sheep receiving a pelleted barley diet, by Sutton & Nicholson (1968) for sheep given diets containing hay, dairy cubes and flaked maize and by Ørskov & Fraser (1968) for 7-week-old lambs receiving a ration containing 80% rolled barley.

In the first two of these studies the amounts of α-linked glucose polymer entering the small intestine, expressed as a percentage of that ingested, ranged from 2·0 to 11·7% and from 4·0 to 5·9% respectively. In the experiments of Ørskov & Fraser, mean values, similarly expressed, were 7·5% for the diet given on an 'estimated *ad lib.*' basis and 4·0% when only 70% of this intake was given. Ørskov & Fraser refer, however, to considerable between-lamb variation in values, particularly at the highest level of feeding, the highest value recorded being 18%.

In the present study the amount of α-linked glucose polymer passing the pylorus when a diet of 1 part hay to two parts flaked maize was given was equivalent to 10·4% ± 1·3

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(SE) of the amount ingested. This is significantly higher ($P < 0.001$) than the mean value obtained on the high-barley or all-barley diets and suggests that on diets high in flaked maize slightly greater amounts of α-linked glucose polymer enter the small intestine. The value is, however, markedly lower than those briefly reported by Tucker, Little, Mitchell, Hayes & Karr (1966) for sheep given diets containing 40–80 % ground maize. On these diets the amount of starch entering the duodenum as a percentage of that ingested ranged from 22·1 to 36·8. One explanation of the difference in findings may be that in the present studies flaked maize was given while in the experiments of Tucker *et al.* (1966) ground maize was used.

Virtually all of the α-linked glucose polymer entering the small intestine of our sheep was digested there, as was found by Topps, Kay & Goodall (1968). The same might not be true of younger animals, however, for appreciable amounts of the polymer, in one instance 6 % of that given, were detected at the terminal ileum of 7-week-old lambs by Ørskov & Fraser (1968).

End-products arising from digestion of the polymer within the small intestine have not been determined in this study. If, however, the end-product were glucose, then, in the adult sheep at least, the amount of polymer entering the small intestine on high-cereal diets would make a small though useful contribution to the glucose requirement of the animal. The daily requirement of a 55 kg non-pregnant sheep has been estimated to be 89 g glucose (Armstrong, 1965). Topps, Kay, Goodall, Whitelaw & Reid (1968) have pointed out however, that even on such diets propionate produced in the rumen is a much more important potential precursor of glucose.

The disappearance of more than 90 % of the digested cellulose before the duodenum and of the remainder in the large intestine on the all-hay diet is in agreement with the results of Bruce, Goodall, Kay, Phillipson & Vowles (1966). When the ration comprised 1 part hay to 2 parts barley, digestion in the large intestine assumed appreciably greater significance, presumably reflecting further fermentation in the caecum. It is difficult to account for the small apparent digestion of cellulose which occurred in the small intestine of sheep given this ration. Unfortunately no examination was made of the chemical nature of the fraction isolated as cellulose from digesta taken at the proximal duodenum and at the terminal ileum.

On the low-fat rations, such as were used in this study, the appreciable contribution of the small intestine to over-all gross energy digestion is largely a reflection of the digestion of nitrogenous constituents occurring there. The mean value for the apparently digested energy which disappeared before the small intestine on the all-hay diet, 67 %, was appreciably lower than the value of 81 % reported for a ration of hay pellets given to sheep by Topps, Kay & Goodall (1968); the single value of 62 % for the all-barley diet was also lower than the mean value of 72 % recorded by these workers for a pelleted barley diet.

It was surprising that when sheep were given all-barley diets the amounts of α-linked polymer which entered the small intestine were similar whether the grain was whole or rolled. With the former diet small numbers of intact barley grains were visible in the digesta collected at the duodenum, but their numbers were negligible relative to the number ingested. Whole barley was not fed to sheep fitted with re-

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entrant cannulas in the terminal ileum. The ability of the sheep's digestive system to digest barley grain with equal effectiveness, whether whole or rolled, is reflected in the close agreement in digestibility coefficients obtained for sheep K and S when given the grain alone. Mean coefficients relating to whole and rolled barleys respectively were: for dry matter 88·1 and 87·9%, for nitrogen 83·5 and 82·1%, for crude fibre 53·7 and 56·6%, and for gross energy 87·7 and 88·0%.

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