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Rates of Passage of Digesta and Water Absorption along the Large Intestines of Sheep, Cows and Pigs

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Abstract

In 5 cows, the mean length of the large intestine was only slightly greater than that of 21 sheep and 3 pigs. At about one-fifth of the way along the large intestine of the sheep and cows, corresponding to the end of the proximal colon and start of the spiral colon, there were marked reductions in the amount of digesta present and in the lumen diameter. In pigs these parameters decreased gradually along the large intestine.

In all parts of the large intestine, the cows had more water in the digesta than did the sheep or the pigs. Nevertheless, the decrease in water content between the caecum and the rectum was similar for the cows and the sheep but less in the pigs. The rate of passage of digesta increased gradually along the large intestine of the pigs, but in the cows and sheep the rate was least in the caecum and proximal colon and greatest in the spiral colon. The total retention time for digesta in the large intestine was approximately 30, 20, and 9 h in the pigs, sheep, and cows respectively. The rate of water absorption from the large intestine was most rapid in the cows and slowest in the pigs. Differences in faecal water content between the species were not due to differences in retention times in the large intestine.

Introduction

Cattle usually excrete moister faeces than sheep but no reason has been proposed for this difference. The moisture content of pig faeces is normally between that for cattle and sheep.

In previous studies on the large intestine (Grovum and Hecker 1973; Hecker and Grovum 1971), a method was developed for investigating the rate of water absorption and other parameters along the large intestine of sheep. In the present experiment, this method has been used to study these parameters along the large intestine of cattle, sheep and pigs in an attempt to explain differences in faecal water content.

Experimental

Animals and Feeding

Sheep. The 21 sheep were previously used in the experiment reported by Grovum and Hecker (1973). Seven were given 400 g, eight were given 800 g and six were given 1200 g lucerne chaff per day in approximately equal hourly feeds. The mean results for all feed intakes are reported in this paper.

Cows. Five cows were used. One was a Jersey heifer (about 2 years old) of 125 kg body weight. The others were adult; their breeds (and body weights) were Hereford Jersey (320 kg), Friesian (736 kg), Hereford (408 kg) and Hereford (415 kg). They were kept in single stalls and for 7 days prior to slaughter were given 3800 g of lucerne chaff per day in two equal feeds 12 h apart.

Pigs. The three Landrace pigs were approximately 15 months of age and weighed about 55 kg. They had previously been given a restricted diet for several months as part of a separate experiment

for which permanent cannulae had been inserted into the caecum. For 14 days prior to slaughter, they were kept in metabolism cages. Two were given 1200 g of a 17·5% protein grower ration (Fielders Ltd, Tamworth, N.S.W.) per day and the third was given 900 g of the above ration plus 300 g of lucerne meal per day. These rations were given in two equal amounts per day at 0800 h and 1600 h.

All animals were given water *ad libitum*.

Experimental Procedure

The methods of slaughtering the sheep and preparing their large intestines have been described previously (Hecker and Grovum 1971).

The cows and pigs were shot through the forehead and their large intestines prepared as for the sheep. The daily outputs of faecal dry matter were determined from each cow and pig for 3 or more days prior to slaughter. After slaughter, the intestinal tract of each animal was removed from the abdominal cavity and the large intestine was stripped from its mesentery and divided into segments 15 cm long. The wet digesta in each segment were weighed and then dried to constant weight at 100°C. The weights of wet and dry digesta, water per gram dry matter, and the faecal excretion rate of dry matter were used to calculate the lumen diameter and the rate of passage of digesta along the large intestine (Hecker and Grovum 1971).

Table 1. Wet and dry matter in, retention time in, and water absorption from the large intestine of sheep, cows and pigs

Values are means ± standard deviations

Species	Section of the large intestine					
	0–20%	20–40%	40–60%	60–80%	80–100%	Total
			Wet matter (g)			
Sheep	794± 31	67± 4	50± 3	48± 3	106± 9	1064± 47
Cows	2335±970**	549±263**	484±423**	513±195	451±171**	4255±1385
Pigs	639± 67	660±225	502± 91	369±108	184± 14	2353± 436
			Dry matter (g)			
Sheep	101± 3	11± 1	11± 1	14± 1	38± 4	178± 8
Cows	189± 46**	49± 10**	49± 13**	72± 10**	106± 35**	459± 47**
Pigs	100± 8	123± 21	109± 16	84± 12	46± 9	416± 16
			Retention time (min)			
Sheep	694± 79	76± 7	76± 8	88± 8	241± 25	1179± 110
Cows	219± 52**	57± 10**	56± 16**	88± 8n.s.	127± 47**	548± 48**
Pigs	376±152	465±143	409± 49	346±125	173± 81	1768± 490
			Rate of water absorption (g per 100 cm² per min)			
Sheep	0·136	0·158	0·104	0·080	0·048	
Cows	0·62	0·191	0·186	0·255	0·217	
Pigs	0·064	0·037	0·015	0·010	0·020	

Comparison, cows and sheep: ** $P < 0·01$; n.s., not significant.

The rate of water absorption (R; in grams per 100 cm² per min) from each fifth of the length of the large intestine was calculated using the equation

$$R = [100(W_s - W_e)a]/AT,$$

where W_s and W_e are the grams of water per gram of dry matter at the start and the end respectively of the section of intestine, and a, A and T are the amount of dry matter (g), the surface area (cm²) and the retention time of digesta (min) in the same section (Grovum and Hecker 1973). For the first section, W_s was the grams of water per gram of dry matter in the digesta in the terminal ileum.

Results

Lengths of the Large Intestine

The mean lengths of the large intestine ± standard deviations in the sheep, cows, and pigs were 491 ± 15, 549 ± 88, and 405 ± 15 cm respectively. In both sheep and cows, the caecum and proximal colon (to the start of the spiral colon) and the centripetal colon were both about 20% of the total length of the large intestine. The centrifugal colon was about 20% of the total length in the sheep but 30% in the cows. In the pigs, the only location that was clearly identified was the apex of the spiral colon, which was about halfway along the large intestine.

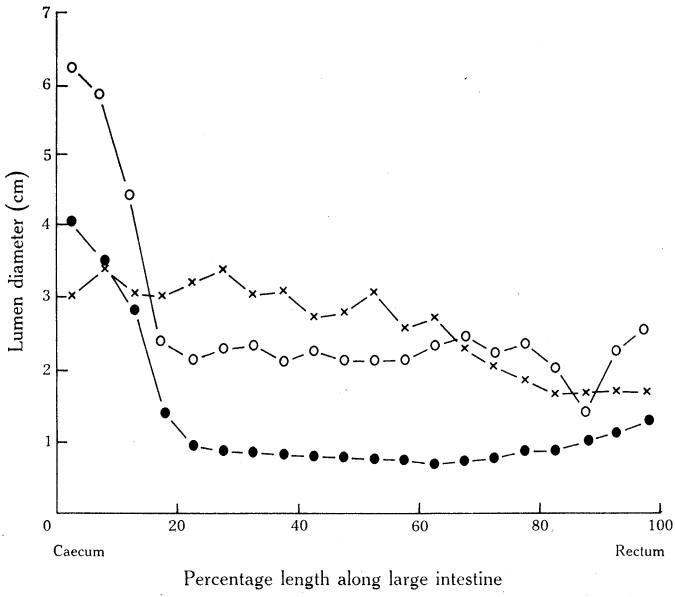

Fig. 1. Lumen diameter of the large intestine. ● Sheep. ○ Cows. × Pigs.

Weights of Digesta

The cows and pigs had greater weights of wet and of dry matter in the large intestine than did the sheep (Table 1). The distribution of the digesta along the large intestine in the cows and sheep was similar in that the caecum–proximal colon (0–20% of the total length) contained the greatest weights of contents, and the spiral colon (20–60%) the least. In the pigs, a large proportion of the large intestinal contents was found in the spiral colon (approximately 20–60%) and comparatively little in the terminal part of the large intestine.

Lumen Diameters

The lumen diameter of the large intestine was greater in the cattle than in the sheep ($P < 0{\cdot}01$ for each point) but in both species the caecum–proximal colon had the largest diameter and the spiral colon the smallest (Fig. 1). The diameter of the pigs' large intestine decreased gradually between the caecum and the rectum.

Water Content of Digesta

The amount of water per gram of dry digesta decreased between the caecum and the rectum in each species (Fig. 2), the mean difference being greatest in the sheep (5·4 g), slightly less in the cows (4·7 g) and least in the pigs (3·5 g).

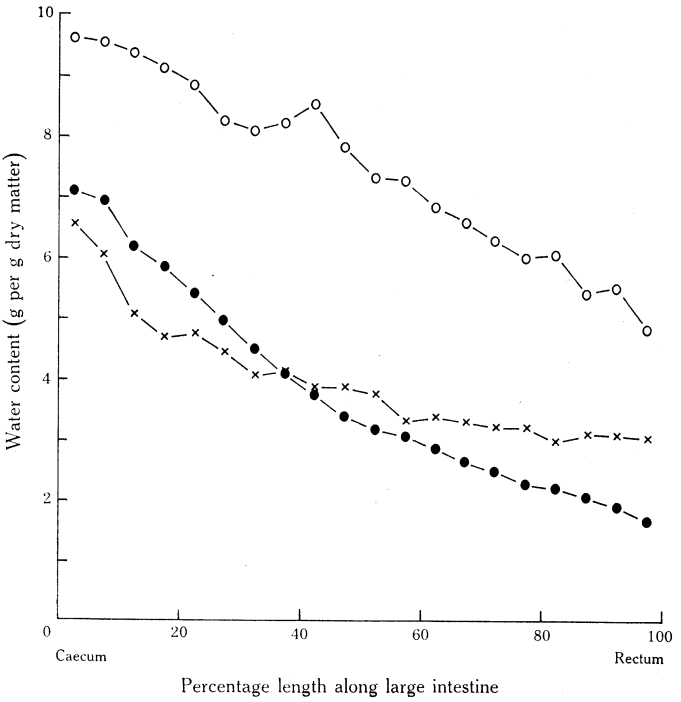

Fig. 2. Water content of digesta along the large intestine. ● Sheep. ○ Cows. × Pigs.

The digesta in parts along the large intestine in the cows contained 2·5–3 g more water per gram of dry matter than did the corresponding parts of the sheep's large intestine (Fig. 2) ($P < 0{\cdot}01$ for each point). The digesta in the caecum–proximal colon of the pig were drier than in that of the sheep, but those in the distal 40% of the large intestine were wetter in the pig than in the sheep.

The water content of ileal digesta (in grams per gram of dry matter) was $11{\cdot}6 \pm 1{\cdot}4$, $15{\cdot}3 \pm 5{\cdot}7$, and $6{\cdot}7 \pm 0{\cdot}6$ for the sheep, cows, and pigs respectively.

Rates of Passage of Digesta and Retention Times

There was a similar trend in the rates of passage of digesta along the large intestines of the sheep and the cows (Fig. 3) but the data were more variable in the cows. These had in general greater rates than the sheep ($P < 0{\cdot}05$ for 0–30, 60–70, and 75–95% length). In both species, the rates of passage were slowest in the caecum–proximal colon and fastest in the spiral colon. In any part, the rate was faster in the cows than in the sheep. The rate of passage in the pigs gradually increased between the caecum and the rectum.

The digesta were retained in the large intestine for total periods of about 30 h in the pigs, 20 h in the sheep, and 9 h in the cattle (Table 1). The retention times in the

20–80% region were much greater in the pigs than in the sheep or cows. The smaller total retention time in the cows as compared with that in the sheep was mainly due to the smaller retention times in cows in the caecum–proximal colon.

Rates of Water Absorption

The rates of water absorption along the large intestine were greatest in the cows and least in the pigs (Table 1).

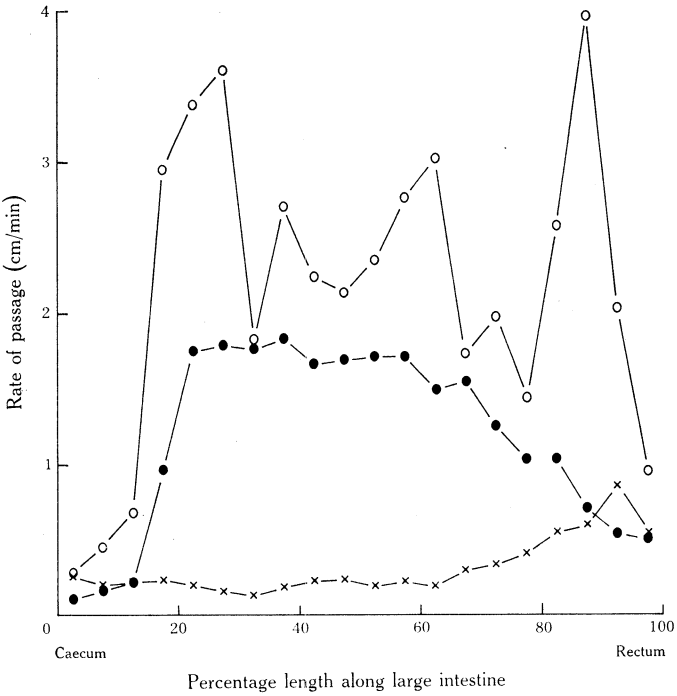

Fig. 3. Rate of passage of digesta along the large intestine. ● Sheep. ○ Cows. × Pigs.

Discussion

One difficulty with an interspecies study such as this is deciding what are comparable rations for each species. Each sheep received one of three rations which were, respectively, above, approximately equal to, or below maintenance energy requirements. These different levels were shown (Grovum and Hecker 1973) to have marked effects on some of the parameters studied in this experiment, especially rate of passage of digesta (or retention times) and rate of water absorption. The first cow (320 kg) was given the equivalent of the sheep maintenance level per kilogram body weight$^{0.75}$ and subsequent cows were given the same weight of feed, even though their body weights differed. This level would have provided significantly less than maintenance requirements for the heaviest cow, significantly more for the lightest cow, and about maintenance requirements for the other three. Thus there would have been a range of feed intakes for the cows similar to that given to the sheep. In spite of these ranges in feed intakes in both cows and sheep, most differences between these species were statistically significant.

The rations given to the pigs supplied approximately maintenance energy requirements, as similar rations had maintained body weight for several months prior to the start of the experiment. Because of the small number of pigs and the supplementation of the diet of one with lucerne meal, no statistical comparisons were made. However, the differences in results between the pigs and the ruminants are sufficiently striking to indicate real differences in function.

Previously we showed that increased levels of feed intake in sheep were associated with slight increases in weight of digesta in the large intestine and with marked decreases in retention time (Grovum and Hecker 1973). The effects of level of feed intake on weight of digesta in the large intestine of cows and pigs have not been reported but they are almost certainly similar to the above. Retention times of digesta distal to the omasum in cattle are decreased when feed intake is increased (Campling *et al.* 1962). In the pig, Castle's *R* value (Castle 1956) and the time for 5% excretion of stained feed particles are decreased by increasing the level of feed intake (Castle and Castle 1957).

The retention times of digesta in the large intestine are of importance because cellulolysis is a comparatively slow process. In the cows, this retention time was relatively short and would restrict the amount of cellulose that potentially could be digested. In the sheep the mean time was longer, although those sheep given 1200 g of lucerne chaff per day (Grovum and Hecker 1973) had retention times almost as short as for the cows. In the pigs the mean retention time was much longer than that in the sheep or cows and was similar to the time that some roughages are retained in the rumen of sheep (Minson 1966; Weston 1968). This is probably of significance for the pig as in it, unlike ruminants, the large intestine is the only organ in which substantial digestion of cellulose can occur.

The lengths of the large intestines of the cows in this experiment were slightly shorter than those reported by Tulloh (1966) for cows and Ledger (1968) for zebu steers. It is possible that this difference may have been due to different degrees of stretching incurred when the large intestines were removed from their mesenteries.

The large intestines of the sheep and the cows were similar in anatomy, as they had a large diameter and contained most of the digesta in the caecum and proximal part of the colon. Digesta moved slowly through this part. The following part, the spiral colon, in both species had a small diameter and contained comparatively little digesta which moved rapidly. The pig also has a spiral colon, but the pig's large intestine did not show this differentiation as it had a more constant diameter and a slow rate of passage of digesta.

Another difference between the species was the change in water content per gram of dry matter between the ileum and the caecum. This change was greater than 4 g per gram dry matter in both the cows and the sheep but was negligible in the pigs. Such a change has been interpreted as indicating mixing of digesta in a pool in the caecum and first parts of the colon (Grovum and Hecker 1973; Hecker and Grovum 1971). In spite of the negligible change in this parameter in the pigs, mixing of digesta within pools must occur in the gastrointestinal tract of the pig, as there is a large difference between the times for 5% and 95% excretion in faeces of markers given in feed (Castle and Castle 1957).

Water was absorbed from digesta along the length of the large intestine of the three species, although the rates differed. In the pig, digesta entered the large intestine in a

comparatively dry state and, in spite of a long retention time, less water was absorbed there than in the cows or sheep. This indicates that the large intestine of the pig may have a low potential for water absorption. The large intestines of the cows were of similar lengths to those of the sheep and pigs but contained considerably more digesta. Also, the large intestine of the cows had a greater mucosal surface area but retained the digesta for a shorter time. Because of, or in spite of, these differences, the amount of water absorbed per gram dry matter in transit through the large intestine of the cows was similar to that in the sheep. As the digesta which entered the bovine large intestine were more moist, it would appear that the answer to the question of cattle passing comparatively moist faeces may lie in differences in small intestinal physiology.

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