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AFRC Institute for Grassland and Animal Production,
Pig Department, Shinfield Research Station[1]
PHLS, Centre for Applied Microbiology
and Research Bacterial Metabolism Research Laboratory,
Porton Down, Salisbury[2]
AFRC Institute of Food Research,
Reading Laboratory, Shinfield[3]

EVA A. LATYMER[1], A. G. LOW[1], KATHLEEN FADDEN[2], I. E. SAMBROOK[3], SUSAN C. WOODLEY[3] and H. D. KEAL[1]

Measurement of transit time of digesta through sections of gastrointestinal tract of pigs fed with diets containing various sources of dietary fibre (non-starch polysaccharides)

1. Introduction

Interest in transit time stems from the view that if transit time is accelerated, then less time is available for digestion of the diet by host enzymes in the small intestine, or for fermentation of undigested dietary residues by microbes in the large intestine, resulting in poorer use of the diet. This hypothesis has very rarely been tested in animals, but it is supported by the work of CHAPMAN et al., (1985), who found that increasing transit time (using loperamide) or decreasing transit time (using magnesium citrate) led to proportionately more or less total starch respectively, in human ileostomates.

The transit time (TT) of dietary residues through the gut has frequently been measured in pigs, rats and in man: it is clear that TT can change as a result of dietary alteration, and fibre, defined here as non-starch polysaccharides (NSP), can be an important determinant (WRICK et al., 1983; FLEMING & LEE, 1983). However, it is evident that different types of fibre may exert different effects (WRICK et al., 1983) and FLEMING & LEE (1983), and also different levels of fibre inclusion can modify the TT (WRICK et al., 1983). Furthermore, the results obtained have often been conflicting.

Numerous studies have indicated that there is an inverse relationship between TT through the colon and stool weight in man (READ, 1986). The increased bulk induced by some NSP sources tend to increase colonic motility, but whether it is the NSP source itself, or other factors contributing to the overall bulk which may affect TT is not known; READ (1986) points out that the following factors could all be important (a) retention of fluid in the NSP matrix, (b) bile acid transport into the colon, (c) volatile fatty acid production, (d) low pH inhibiting water and electrolyte absorption, (e) increased bacterial cell mass, (f) increased mucus production, (g) distension due to gas production. In addition, stress, exercise and colonic anatomy may also modify TT.

Information on the effect of NSP on TT in the pig is limited to studies of transit measured either overall *in vivo*, or in different parts of the gut after slaughter. There is very little information on this topic within different regions of the gut of the pig *in vivo*. Thus, the aim of the studies described here was to examine the effect of a contrasting range of sources of NSP on transit time from mouth to ileum, caecum, colon and rectum in pigs fitted with multiple cannulas, as part of a wider study on the effect of NSP on small and large intestinal function.

The solid and liquid phases of digesta were separately marked in order to assess the possibility that these two phases moved at different rates.

Evidence about the correct time course of adaptation to dietary changes in pigs, before sampling of digesta for investigations, is rather limited. It is known that changes in the output of gastric and pancreatic juice and of their constituent enzymes is usually complete in under 48 h (PARTRIDGE et al., 1982). It is also known that the response of a pig in terms of blood glucose and insulin to a single meal containing sources of NSP such as pectin, guar gum or sugar beet pulp is as large as it is after several weeks of adaptation (LOW, personal communication). The thermic effect of a change from a diet of low NSP content to high content is marked for 1–2 days. By 3 days after a change there is no further response in terms of heat output. Similarly methane output adapts completely in less than 3 days after such a dietary change providing an indication, that adaption of microbial activity occurs rapidly (CLOSE, personal communication). Transit time is a generalised measure of a series of changes, some of which may take longer to occur than 3 days. Hower, it was considered that the above points are an indication that determinants of transit time adapt rapidly to a change in dietary NSP type or level. The measurements in this paper show the effects on transit time seen under the specific circumstances stated here. Measurement of the transit phenomena in pigs apapted over a period of several weeks to each diet would have led to very largeage effects.

The significance of measurements of TT has frequently been discussed (READ, 1986; LOW, 1988): among the problems in interpreting data is the question of the most meaningful way of expressing the results. We have chosen to express the results in terms of the times of the first arrival of the markers used and their peak concentration.

The NSP sources were chosen because they are either ingredients of diets (beans, peas), or they may be supplementary NSP sources (bran, sugar beet pulp) or they may have pharmaceutical properties (pectin, guar gum). Lactulose, a derivative of lactose, was also used because of putatively similar properties to some soluble types of NSP. The pigs used for our studies were prepared with suitable cannulas which have been shown not to modify the bacterial flora of the large intestine (FADDEN et al., 1984) or energy balance (CLOSE et al., 1984).

The amounts of NSP sources used were chosen on the basis of other studies in progress in the department in which various effects or a lack of effects of NSP was observed. In the case of Solka-Floc (PARTRIDGE et al., 1982) had not found any significant difference in energy or N digestibility or N retention after long term feeding of additional NSP to the diet. RAINBIRD & LOW (1986; 1986a) and RAINBIRD (1986) found a small reducing effect of guar gum on gastric emptying which was confined only to the liquid phase of digesta. Inclusion of sources of NSP other than guar gum which increased the meal or gastric viscosity, reduced also the rate of gastric emptying, but only of that of the liquid phase. Decreased glucose and water absorption was detected by LOW et al. (1986) after feeding guargum and pectin as well as largely insoluble dietary fibres which do not increase viscosity such as bran and cellulose. A high degree of digestibility of NSP in wheat bran, sugar beet pulp and Solka Floc was shown by LONGLAND and LOW (1988). A cholesterol reducing effect of beans and peas was found by SHUTLER et al., (1988).

The 3 hours timing between individual sampling was chosen after consideration that if samples were to be taken at more frequent intervals, a substantial amount of digesta would be removed, leading to a considerable bias with unknown consequences for transit phenomena. It was the best possible compromise even though it led to a certain lack of precision.

2. Material and Methods

2.1. Animals and Surgery

Large white × Landrace boars from the Institute's own herd, and initially of 25 kg live weight were used. Each was equipped with simple cannulas in the ileum (ca. 20 cm cranial to the ileo-caecal valve), caecum (opposite the ileo-caecal junction), and mid-colon. The T-shaped cannulas were made in the Institute from a polyacetal rod (Kematal, ICI plc, London). The length of the barrel of the cannula was 45 mm, its internal diameter 16 mm, and the length of the base flange 74 mm. The whole length of barrel of the cannula was fixed with a solid plug except during sampling to stop the possibility of digesta lodging. After surgery, the pigs were left for about 14 days to recover and regain their full appetite. Particular attention was paid to keeping the pigs and cages as clean as possible. The skin surrounding the cannulas was washed and wiped dry daily and then dressed with Metanium ointment (Bengué & Co. Ltd., Maidenhead, Berks., U. K.) to treat and protect against possible irritation. The pigs were kept in metabolism cages in a room maintained at 20 ± 3 °C.

2.2. Diets

The composition of the diets is shown in Tables 1 and 2. The cereal-based control diet was used in experiments 1–3 and contained 155 g NSP/kg.

The beans and peas used in experiment 4 were soaked overnight before heating at 121 °C for 10 minutes. They were then stored at −20 °C until required for feeding.

2.3. Feeding

Pigs were fed equal amounts twice daily at 8.30 and 16.30 hours; the diet was mixed with water (1 : 2.5 w/v) immediately before feeding. All pigs were weighed weekly. The levels of feeding varied according to live weight, and also according to the NSP source given, so that the calculated daily ration for each treatment provided a similar intake of digestible energy to that of the control. Intakes of the control diet (g/kg live weight) were 41 for experiments 1 and 2, 35 for experiments 3, 4 and 5, (so that the pigs did not grow too large for the metabolism cages before completing the experimental treatments).

2.4. Experimental Plan

Four separate pigs were allocated to each experiment according to a Latin square design, except for experiment 1 where all pigs received the test diet after the control diet. Experiments 1–3 were done consecutively and 4 and 5 together. Each of the experimental diets was given to each pig for five days before measuring transit time.

2.5. Transit Time Measurements

The solid phase of the digesta was marked with ^{103}Ru – labelled tris – (1, 10-phenanthroline) – ruthenium II chloride and the liquid phase with ^{51}Cr complexed to EDTA. The radioisotopes were supplied by Amersham International plc, (Amersham, U. K). The ^{103}Ru was complexed by the method of TAN et al., (1971). The markers were used according to the principles set out by FAICHNEY (1975). In experiments 1 and 2 the

Table 1

Composition of diets (g/kg) for experiments "1", "2" and "3"
(The control diet was used in all three experiments)

Experiment	1		2			3		
Diet Code	Control	Solka Floc	Guar Gum 2.0	Guar Gum 4.0	Guar Gum 6.0	Bran	Lactulose	Pectin
Barley meal	493	419	483	473	463	444	468	468
Wheat meal	170	144	167	163	160	153	162	162
Soya bean meal	128	108	125	122	120	115	121	121
Fish meal	42	36	42	41	40	38	40	40
Limestone flour	1.7	1.4	1.7	1.6	1.6	1.5	1.6	1.6
Dicalcium phosphate	4.3	3.7	4.2	4.1	4.0	3.9	4.1	4.1
Mineral vitamin mix[1]	10.6	9.0	10.4	10.2	10.0	9.5	10.1	10.1
Beef tallow	75	64	74	72	70	68	71	71
Soyabean oil	75	64	74	72	70	68	71	71
Cholesterol	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Solka Floc[2]	–	150	–	–	–	–	–	–
Guar Gum[3]	–	–	20	40	60	–	–	–
Wheat Bran[4]	–	–	–	–	–	100	–	–
Lactulose[5]	–	–	–	–	–	–	50	–
Pectin[6]	–	–	–	–	–	–	–	50

[1] B P Nutrition UK Ltd, product code: 051700 (Wincham, Northwich, Cheshire, UK). The Min-Vit mix contained (g/kg): retinol 0.144, cholecalciferol 0.002, DL-α-tocopherylacetate 0.48, riboflavin 0.24, menadione 0.08, nicotinic acid 0.96, pantothenic acid 0.72, thiamine 0.08, pyridoxine 0.08, cyanocobalamin 0.001, iron 20.0, cobalt 0.08, manganese 2.4, zinc 8.0, iodine 0.08, selenium 0.008, calcium 270.0, sodium chloride 200.0.

[2] Brown & Co. Berlin, NH, USA.

[3] „Meyprogat" type 150, NSP 825 g/kg (Meyhall Chemical AG. CH - 8280 Kreuzlingen, Switzerland).

[4] Fine wheat bran, NSP 308 g/kg (Wilson King Mill, Liverpool, UK), NSP determined by method of Englyst and Cummings (30).

[5] Duphar BV, Amsterdam, Holland.

[6] USP pure high methoxy (H P Bulmer Ltd, Hereford, UK).

Table 2

Composition of semipurified diets (g/kg) used in experiments 4 and 5 providing 0.33 or 1.32 g non-starch polysaccharides (NSP) per kg of body weight per day

Experiment	4				5			
Diet code	Cooked beans		Mature peas (cooked)		Sugar beet pulp		Wheat bran	
NSP (g/kg body weight)	0.33	1.32	0.33	1.32	0.33	1.32	0.33	1.32
Maize starch	587	519	575	467	600	568	592	535
Soya bean oil	77	68	75	61	79	74	77	70
Beef tallow	77	68	75	61	79	74	77	70
Casein	173	153	169	138	177	167	174	158
Trace mineral mix	9.6	8.5	9.4	7.6	9.8	9.3	9.7	8.8
Vitamin mix[1]	1.9	1.7	1.9	1.5	2.0	1.9	1.9	1.8
Dicalcium phosphate	29.8	26.3	29.2	23.7	30.5	28.8	30.0	27.1
Choline hydrochloride	1.05	0.94	1.03	0.85	1.08	1.03	1.07	0.96
Sodium chloride	4.8	4.2	4.7	3.8	4.9	4.6	4.8	4.4
Cholesterol	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.5
Wheat bran[2]	–	–	–	–	–	–	31	124
Sugar beet pulp[3]	–	–	–	–	17.60	70.4	–	–
Cooked beans (as dry matter)[4]	38	150	–	–	–	–	–	–
Cooked mature peas (as dry matter)[5]	–	–	58	234	–	–	–	–

[1] The vitamin mix contained (g/kg): retinol 6.25, cholecalciferol 0.3, riboflavin 1.625, thiamin 1.0, nicotinic acid 7.875, pantothenic acid 8.0, pyridoxine 1.625, cyanocobalamin 0.015, DL-α-tocopheryl acetate 4.0, biotin 2.5, pteroylmonoglutamic acid 0.5, p-aminobenzoic acid 10.0, myo-inositol 97.5, ascorbic acid 15.0, menadione (sodium bisulphate) 1.0, starch 842.81.

[2] Fine grade wheat bran (Wilson King Mill, Liverpool, UK) NSP 308 g/kg, NSP determined by method of Englyst and Cummings (30).

[3] Fibrex, Sockerbolaget AB, Arlov, Sweden NSP 536 g/kg.

[4] Haricot beans (H J Heinz & Co Ltd, Hayes Park, Middlesex, UK), cooked before use (without tomato sauce), NSP 252 g/kg.

[5] Marrowfat peas (Wherry and Sons, Bourne, Lincolnshire, UK), cooked before use, NSP 161 g/kg.

markers were mixed with 30 ml of previously collected and homogenized caecal digesta and injected into the ileal cannula three hours after the morning feed. In experiments 3, 4 and 5 the markers were given orally with the morning feed. The markers were given at a level of 2 μCi ^{103}Ru and 10 μCi ^{51}Cr per g of digesta (the weight of digesta in the caecum was estimated to vary between 500 and 800 g) directly into the ileum in experiments 1 and 2. They were given at these levels per kg of air-dry diet and water in experiments 3, 4 and 5. Samples of digesta and faeces were taken for 30 minute periods every 3 h after marker administration for a total of 48 h in experiments 1 and 2 and 51 h for experiments 3, 4 and 5. Digesta samples were collected into a ca 30 cm length of colostomy tubing. The concentration of radioactivity was then measured in a γ-counter.

2.6. Expression of Results and Statistical Analysis

The results for TT were expressed as the time of first arrival (FA) of the markers at each site, and the time of peak concentration (PC) at each site.

The results were assessed by analysis of variance.

3. Results

3.1. Animals

Although each experiment began with four pigs, one pig was lost in experiments 1 and 2. All of the other pigs remained in good health throughout the studies.

Table 3

Effect of Solka-Floc supplementation[1] on transit times (h) of solid and liquid phase markers[2] through the digestive tract of three pigs (experiment 1)[3]

	First Appearance		Peak Concentration	
	Solid	Liquid	Solid	Liquid
Ileum to caecum				
Control	3.0	3.0	5.0	4.0
+ Solka-Floc	3.0	3.0	4.0	4.0
SED[4]	0.0	0.0	1.0	1.7
CV[5] % between pigs	0.0	0.0	33.3	21.7
Ileum to colon				
Control	8.0	8.0	18.0	18.0
+ Solka-Floc	5.0	5.0	9.0	8.0
SED	1.7	1.7	12.1	11.5
CV % between pigs	74.2	74.2	96.2	103.4
Ileum to faeces				
Control	19.0	17.0[6]	32.0	32.0
+ Solka-Floc	26.0	26.0	31.0	31.0
SED	1.0	1.7	11.8	11.8
CV % between pigs	11.5	17.6	23.8	23.8

[1] For details of diets see Table 1.
[2] For details of markers see 2.4.
[3] For details of pigs see 2.1.
[4] Standard error of difference[8] of means between the diets within a phase.
[5] CV Coefficient of variation
[6] The only significant difference between the diets ($P<0.001$) was the first appearance of markers of both phases.

3.2. Transit Time

Tables 3–7 show the mean transit time of the markers for experiments 1–5 respectively. Although there were clearly longer mean values as the distances from administration via the ileum or mouth increased, there were virtually no statistically different times when dietary treatments were compared in any of the experiments; this applied to both solid and liquid phase markers, when expressed in terms of time of first arrival and of peak concentration of markers.

The transit times observed in experiments 1–3 were generally faster than those in experiments 4 and 5, this corresponds with the change from a cereal-based to a semi-purified diet.

Some of the mouth-faeces marker transit times in experiments 4 and 5 were longer than 51 h. This time of collection had previously been found to be sufficient for marker first arrival and peak concentration times and the problem was not detected until the

Table 4

Effect of guar gum supplementation[1] on transit times (h) of solid and liquid phase markers[2] through the large intestine of three pigs (experiment 2)[3]

	First Appearance		Peak Concentration	
	Solid	Liquid	Solid	Liquid
Ileum to caecum				
Control	3.0	3.0	5.0	4.0
+20 g/kg guar gum	3.0	3.0	5.0	3.0
+40 g/kg guar gum	3.0	3.0	6.0	3.0
+60 g/kg guar gum	3.0	3.0	4.0	3.0
SED[4]	0.0	0.0	2.0	0.7
CV[5] % between pigs	0.0	0.0	8.7	13.3
Ileum to colon				
Control	3.0	3.0	9.0	9.0
+20 g/kg guar gum	4.0	3.0	7.0	7.0
+40 g/kg guar gum	3.0	3.0	9.0	9.0
+60 g/kg guar gum	3.0	3.0	9.0	9.0
SED	0.7	0.0	0.0	0.0
CV % between pigs	13.3	0.0	45.3	45.3
Ileum to faeces				
Control	16.0	16.0	30.0	30.0
+20 g/kg guar gum	18.0	18.0	25.0	25.0
+40 g/kg guar gum	16.0	16.0	30.0	30.0
+60 g/kg guar gum	16.0	14.0	22.0	22.0
SED	3.8	2.4	4.8	4.8
CV % between pigs	16.4	16.5	8.6	8.6

[1] For details of diets see Table 1.
[2] For details of markers see 2.4.
[3] For details of pigs see 2.1.
[4] Standard error of differences of means between the diets within a phase.
[5] *CV* Coefficient of variation

Table 5

Effect of wheat bran, lactulose and pectin supplementation[1] on transit times (h) of solid and liquid phase markers[2] through the digestive tract of four pigs (experiment 3)[3]

	First Appearance		Peak Concentration	
	Solid	Liquid	Solid	Liquid
Mouth to ileum				
Control	3.0	3.0	3.8	4.5
+Wheat bran	3.0	3.0	3.0	3.0
+Lactulose	3.0	3.0	6.8	3.0
+Pectin	3.0	3.0	3.8	5.3
SED[4]	0.0	0.0	2.7	1.2
CV % between pigs	0.0	0.0	50.0	18.2
Mouth to caecum				
Control	3.0	3.0	7.5	7.5
+Wheat bran	3.0	3.0	8.3	9.0
+Lactulose	3.0	3.0	8.3	6.0
+Pectin	3.0	3.8	9.8	9.0
SED	0.0	0.5	0.9	2.1
CV % between pigs	0.0	11.8	13.3	16.5
Mouth to colon –				
Control	8.3	7.5	22.5	19.5
+Wheat bran	8.3	9.0	23.3	18.0
+Lactulose	6.0	6.0	21.8	20.3
+Pectin	6.8	6.0	24.8	21.0
SED	1.7	2.1	2.1	3.1
CV % between pigs	9.8	6.1	16.9	10.0
Mouth to faeces				
Control	30.0	30.0	42.0	42.0
+Wheat brsn	33.0	35.3	43.5	42.8
+Lactulose	32.3	31.5	46.5	45.0
+Pectin	30.0	30.8	44.3	44.3
SED	4.8	4.8	4.5	5.0
CV % between pigs	19.6	21.3	16.9	18.5

[1] For details of diets see Table 1.
[2] For details of markers see 2.4.
[3] For details of pigs see 2.1.
[4] Standard error of differences of means between the diets within a phase.
[5] *CV* Coefficient of variation

samples were counted at the end of these two experiments which were done simultaneously. Defaecation from pigs in these experiments was much less frequent than for those in experiments 1–3.

There were some indications that individual animals had inherently different transit times, irrespective of the dietary treatments applied. In addition sampling tended to be more rapid from animals of a more active disposition and these animals defaecated rather more frequently.

Table 6

Effect of bean or pea supplementation at low or high levels[1] on transit times (h) of solid and liquid phase markers[2] through the digestive tract of four pigs (experiment 4)[3]

	First Appearance		Peak Concentration	
	Solid	Liquid	Solid	Liquid
Mouth to ileum				
beans – low level	3.0	3.0	6.8	6.8
beans – high level	3.0	3.0	7.5	8.3
peas – low level	3.0	3.0	6.0	5.3
peas – high level	3.0	3.0	5.3	5.3
SED[4]	0.0	0.0	2.4	2.0
CV[5] % between pigs	0.0	0.0	52.6	45.1
Mouth to caecum				
beans – low level	4.5	3.8	15.0	14.3
beans – high level	3.0	3.0	14.3	13.5
peas – low level	3.0	3.8	16.5	9.8
peas – high level	3.8	3.8	9.0	9.0
SED	1.3	0.5	5.4	3.8
CV % between pigs	53.0	21.1	55.4	45.9
Mouth to colon				
beans – low level	10.5	12.0	50.3	48.8
beans – high level	3.0	4.5	45.3	45.0
peas – low level	6.0	8.3	35.3	31.5
peas – high level	4.5	6.0	36.0	35.3
SED	5.0	4.7	7.0	5.0
CV % between pigs	117.3	85.6	23.9	17.5
Mouth to faeces				
beans – low level	>51	>51	>51	>51
beans – high level	49.5	49.5	>51	>51
peas – low level	>51	>51	>51	>51
peas – high level	>51	>51	>51	>51
SED	–	–	–	–
CV % between pigs	12.0	12.0	–	–

[1] For details of diets see Table 2
[2] For details of markers see 2.4.
[3] For details of pigs see 2.1.
[4] Standard error of differences of means between the diets within a phase.
[5] *CV* Coefficient of variation

4. Discussion

The relatively small number of cases where supplements of NSP altered transit time of markers may either be a reflection of a lack of biological effects, or it may be the result of the experimental methods used.

Potential problems of experimental technique include the number of pigs used and the suitability of the markers used. With regard to the number of pigs used, it is clear that increasing the number to six per treatment, for example, would not have materially

Table 7

Effect of sugar beet pulp (SBP) or wheat bran (WB) supplementation at low or high levels[1] on transit times (h) of solid and liquid phase markers[2] through the digestive tract of four pigs (experiment 5)[3]

	First Appearance		Peak Concentration	
	Solid	Liquid	Solid	Liquid
Mouth to ileum				
SBP – low level	3.0	3.0	6.8	6.8
SBP – high level	3.0	3.0	7.5	8.3
WB – low level	3.4	3.4	5.8	3.4
WB – high level	4.1	4.1	12.2	7.5
SED[4]	0.6	0.6	1.2	1.8
CV[5] % 4	25.7	25.7	21.3	40.7
Mouth to caecum				
SBP – low level	5.3	4.5	14.3	10.5
SBP – high level	4.5	4.5	10.5	9.5
WB – low level	5.8	6.0	19.7	13.7
WB – high level	4.7	4.5	22.3	18.6
SED	0.6	0.8	3.0	3.1
CV % between pigs	16.6	21.8	25.1	33.4
Mouth to colon				
SBP – low level	14.3	15.0	43.5	39.8
SBP – high level	6.0	7.5	35.3	32.3
WB – low level	13.5	16.7	46.9	48.0
WB – high level	9.7	11.1	42.1	39.0
SED	5.7	6.5	10.2	8.4
CV % between pigs	74.3	73.0	34.2	30.0
Mouth to faeces				
SBP – low level	>51	>51	>51	>51
SBP – high level	46.2	46.2	>51	>51
WB – low level	44.7	44.7	>51	>51
WB – high level	43.2	40.5	>51	>51
SED	–	–	–	–
CV % between pigs	18.1	17.1	–	–

[1] For details of diets see Table 2
[2] For details of markers see 2.4.
[3] For details of pigs see 2.1.
[4] Standard error of differences of means between the diets within a phase
[5] *CV* Coefficient of variation

affected the results obtained, though some differences between treatments might have become significant. There is no comparable information in the literature about the variability of transit time measured within the gut regions studied here. Thus firm conclusions about the desirable number of pigs to be used in such work cannot be drawn.

The choice of markers used for measuring transit time is not straightforward. All markers have shortcomings as discussed by KOTB & LUCKEY (1972). It is desirable that a marker should not interfere with the acceptability of the diet, that it can be measured accurately in diet, digesta and faeces samples, and that it moves only with

the component of the diet which is of specific interest. In the present study we were interested to mark the movement of the liquid phase of digesta derived either from a single-shot administration in the ileum, or in the water given with the diet. Similarly, we were interested in marking the solid phase as a whole. Previous experience here with the markers used had shown that they could be measured easily and accurately, and that they were thoroughly mixed in the liquid (Cr) and solid (Ru) phases respectively. There was no evidence of marker exchange between the phases and both markers were fully recovered. Ruthenium associated tenaciously with the dietary and digesta solids as a whole and was not found on feeding equipment or the wall of the gut after washing. However, it is inevitable that some transfer of the marker from one component of digesta to another will occur as digestive hydrolysis proceeds (FAICHNEY, 1975). Particulate markers such as chromic oxide and rare earth oxides, polystyrene beads etc. do not adhere specifically to solids. On the other hand Cr and Ce have been mordanted specifically to plant cell walls (UDEN et al., 1980). Neither of these properties were considered desirable for the present work, in which we wished to mark solids and liquids as a whole. Interpretation of movement of any liquid phase marker is made more complicated by the fact that there are major fluxes of liquids throughout the digestive tract: movewent of the marker will inevitably be influenced by this.

Comparisons between the present results and those of other authors are only available for overall transit time. Our range of 30–49 h (peak marker activity) compares with 40–48 h found in pigs by EHLE et al., (1982) who used semi-purified diets including Cr-mordanted alfalfa, coarse bran, fine fran or cellulose at higher levels than in the present work. They also did not find treatment differences. KUAN et al., (1983) also used semi-purified diets containing 144, 262, 363 or 446 g lucerne leaf meal dry matter/kg. The two higher levels led to significantly shorter overall transit times in 4 pigs, assessed by appearance of stained particles or beads. A constant intake of NSP-free control diet with increasing levels of lucerne leaf meal were used: the range of NSP provided was much wider than in the present study. Several authors have measured the effects of adding wheat bran to milk powder or milk replacer based diets and have seen reduced mean transit times, again with high NSP inclusion levels (CANGUILHEM & LABIE, 1977; FIORAMONTI & BUENO, 1980; BARDON & FIORAMONTI, 1983) When wheat bran was added to a cereal-based diet by CANGUILHEM & LABIE (1977) there was no change in transit time, corresponding with the results in the present study. We conclude that the digestive tract of pigs accommodates marked changes in NSP intake without consequent alterations in transit time: other authors mentioned above have generally only found effects when more extreme differences between treatments have been applied.

While the suitability of pigs as a model for a wide range of aspects human metabolism has been frequently described, their comparability with regard to transit phenomena has not been directly assessed. The range of overall transit time of markers through the human gut was 24–72 h in studies by CUMMINGS (1978), while each subject exhibited a wide range of transit times, so that the average coefficient of variation for the subjects was 33 per cent. This suggests that transit times in pigs and in man are not dissimilar, in general terms. However, it is important to note that the pigs used in these studies were growing and received substantially more diet in proportion to their body size than the adult humans which have been used in most clinical studies. It is likely that transit is markedly influenced by total dietary intake as well as by its NSP con-

tent, and the former may be the main determinant of transit phenomena under the conditions of the present studies.

Direct comparison of data from the present study with other data for rates of flow through different regions of the gut is not possible. Comparisons of the transit time of similar diets in humans and pigs by FLEMING & WASILEWSKI (1984) from mouth to caecum, using breath hydrogen as an index of arrival time in the caecum indicated a range of 4–10 h for humans and 5–6 h for pigs (peak levels of hydrogen after the morning meal). These values correspond with those presented for first appearance of markers in the caecum, but peak concentrations of markers occurred considerably later. It is quite conceivable that peak hydrogen evolution could occur before peak concentration of the marker takes place.

The results presented provide an indication of the retention time of digestion in different regions of the gut. Mean times in the stomach and small intestine were 6–9 h for cereal-based diets, and 9–22 h for the semi-purified-cased diets (based on mouth-caecum peak concentration values).

The first apearance of marker values suggest that digesta may spend from under 1 hour in the caecum (high level of peas, solid phase, experiment 4) to 11 hours or more. Retention times in the colon appeared to be in the range of 30–40 h, as judged by the difference between caecum and faecal values. However these values can only be regarded as approximate because they relate to the nedt and thus are not representative of the situation in the organs as a whole. Nevertheless, KASS et al., (1980) found that 60–70% of the overall transit time was accounted for by residence in the colon, based on chromium time measurement in pigs given diets varying levels of alfalfa.

The transit time of a meal is known to vary greatly between different people and within individual people (WYMAN et al., 1978) and our results suggest that the same is true in pigs. In addition, we noted that sampling of digesta was more difficult in those pigs which defecated relatively rarely; this may have been related to the overall degree of activity of the pigs as those which provided samples fastest tended to be the most active. Such factors may be as important or more important than NSP in determining transit time.

Summary

The effects of various sources of dietary fibre (defined as non-starch polysaccharides (NSP)) on the transit time (TT) of digesta through sections of digestive tract were measured in pigs of 30–85 kg. The pigs were fitted with simple cannulas in the terminal ileum, caecum and mid-colon. Diets in experiments 1–3 were based on barley, wheat, soya bean meal and fish meal with NSP added in the form of wood cellulose (experiment 1), guar gum (experiment 2), wheat bran, pectin (experiment 3). Lactulose was also included in experiment 3 because of its NSP-like effects. Diets in experiments 4 and 5 were based on starch and casein and contained *Phaseoluos vulgaris* or *Pisum sativum* (experiment 4) and sugar beet pulp or wheat bran (experiment 5). Transit time (TT) was measured using ^{103} Ruthenium phenanthroline to label solids and ^{51} Chromium complexed to EDTA for liquids. Samples were taken every 3 h after marker administration for 51 h from all cannulas and the faecal output was collected every 3 h. The

values obtained were very variable. The range of TT (h) defined as first arrival of markers and peak marker level was 3–12.2 and 3–12.2 to the ileum, 3–22.3 and 4.5–22.3 to the caecum, 4.5–50.3 and 16.5–48.8 to the colon and 24–<51 and 30–<51 to the rectum respectively.

Zusammenfassung

E. A. Latymer, A. G. Low, Kathleen Fadden, I. E. Sambrook, Susan C. Woodley und H. D. Keal

Messung der Durchgangszeit der Digesta durch Abschnitte des Magen-Darm-Kanals von Schweinen gefüttert mit Rationen, die unterschiedliche Quellen von Fasern (Nicht-stärke-Polysacchariden) in den Futtermitteln enthielten

Die Wirkung unterschiedlicher Quellen von Fasern in Futtermitteln (definiert als Nicht-Stärke-Polysaccharide (NSP)) auf die Durchgangszeit (DZ) der Digesta durch Abschnitte des Verdauungstrakts wurde an Schweinen von 30–85 kg gemessen. Die Schweine waren mit einfachen Fisteln am Ende des Ileums, dem Blinddarm und in der Mitte des Dickdarms ausgestattet. Die Rationen in den Experimenten 1–3 basierten auf Gerste, Weizen, Sojamehl und Fischmehl mit Zusätzen von NSP in Form von Holzzellulose (Experiment 1), (Guarharz, guar gum Experiment 2), Weizenkleie und Pektin(Experiment 3). Laktulose wurde wegen ihrer NSP-ähnlichen Wirkung ebenfalls in Experiment 3 eingesetzt. Die Rationen in den Experimenten 4 und 5 basierten auf Stärke und Kasein und enthielten Phaseolus vulgaris oder Pisum sativum (Experiment 4) sowie Trockenschnitzel und Weizenkleie (Experiment 5). Die Durchgangszeit (DZ) wurde mit Hilfe von ^{103}Rutheniumphenantrolin zur Markierung der festen Phase und ^{51}Chrom im EDTA-Komplex zur Markierung der flüssigen Phase gemessen. Über 51 Stunden nach der Markierung wurden alle 3 Stunden Proben aus allen Fisteln genommen; der Kot wurde alle 3 Stunden gesammelt. Die gewonnenen Werte waren sehr unterschiedlich. Der Bereich der DZ (h) definiert als erster Durchgang bei der Marker und deren Peak betrug 3–12,2 und 3–12,2 am Ileum; 3–22,3 und 4,5–22,3 am Blinddarm; 4,5–50,3 und 16,5–48,8 am Dickdarm sowie 24–<51 und 30–<51 am Rektum.

References

Bardon, T. and J. Fioramonti: Br. J. Nutr., 50, 685 (1983)

Canguilhem, R. and C. Labie: Révue de Méd. Vét. 128, 1669 (1977)

Chapman, R. W., J. K. Sillery, M. M. Graham and D. R. Saunders: Am. J. Clin. Nutr. 41, 1244 (1985)

Close, W. H., R. P. Heavens, D. B. Stephens and I. E. Sambrook: Proc. Nutr. Soc. 43, 66A (1984)

Cummings, J. H.: Dietary Fibre. John Libbey, London, 83 (1978)

Ehle, F. R., J. L. Jeraci, J. B. Robertson and P. J. van Soest: Jour. Anim. Sci. 55, 1071 (1982)

Englyst, H. N. and J. H. Cummings: Analyst 109, 937 (1984)

Fadden, K., R. W. Owen, M. J. Hill, E. A. Latymer, A. G. Low and A. N. Mason: Biochem. Soc. Trans. 12, 1105 (1984)

FAICHNEY, G. J.: Digestion and Metabolism in the Ruminant. University of New England Press, Armidale, Australia, 277 (1975)
FIORAMONTI, J. and L. BUENO: Br. J. Nutr. 43, 155 (1980)
FLEMING, S. E. and B. LEE: J. Nutr. 113, 592 (1983)
FLEMING, S. E. and M. M. WASILEWSKI: Nutr. Rep. Intern. 30, 825 (1984)
KASS, M., P. J. VAN SOEST, W. G. POND, B. LEWIS and R. E. MCDOWELL: J. Anim. Sci. 50, 175 (1980)
KOTB, A. R. and T. D. LUCKEY: Nutr. Abstr. Rev. 42, 813 (1972)
KUAN, K. K., G. STANOGIAS and A. C. DUNKIN: Anim. Prod. 36, 201 (1983)
LONGLAND, A. C. and A. G. LOW: Proc. Nutr. Soc. 47, 104A (1988)
LOW, A. G.: Proc. Nutr. Soc. 43, 153 (1988)
LOW, A. G., T. ZEBROWSKA, L. M. J. HEPPELL and H. A. SMITH: Proc. Nutr. Soc. 45, 153 (1986)
PARTRIDGE, I. G., H. D. KEAL and K. G. MITCHELL: Anim. Prod. 35, 209 (1982)
RAINBIRD, A. L.: Brit. J. Nutr. 55, 99 (1986)
RAINBIRD, A. L. and A. G. LOW: Brit. J. Nutr. 55, 87 (1986)
RAINBIRD, A. L. and A. G. LOW: Brit. J. Nutr. 55, 111 (1986a)
READ, N. W.: Dietary Fiber. Plenum Press, New York, 81 (1986)
SHUTLER, S. M., A. G. LOW and A. F. WALKER: Proc. Nutr. Soc. 47, 124A (1988)
TAN, T. N., R. H. WESTON and J. P. HOGAN: Internat. J. Appl. Rad. Isotop. 22, 301 (1971)
UDÉN, P., P. E. COLUCCI and P. J. VAN SOEST: J. Sci. Food Agri. 31, 625 (1980)
WYMAN, J. B., K. W. HEATON, A. P. MANNING and A. C. B. WICKS: Gut, 19, 146 (1978)
WRICK, K. L., J. B. ROBERTSON, P. J. VAN SOEST, B. A. LEWIS, J. M. RIVERS, D. A. ROE and L. R. HACKLER: J. Nutr. 113, 1464 (1983)

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Address of authors:

Dr. EVA A. LATYMER, Dr. A. G. LOW and Mr. H. D. KEAL
AFRC Institute for Grassland and Environmental Research
Pig Department,
Shinfield Reading
Berkshire
RG2 9AT
United Kingdom
Dr. KATHLEEN FADDEN
PHLS, Centre for Applied Microbiology and Research
Bacterial Metabolism Research Laboratory
Porton Down, Salisbury, Wiltshire
SP4 OJG
United Kingdom
Dr. I. E. SAMBROOCK and Miss SUSAN WOODLEY
AFRC Institute of Food Research, Reading Laboratory
Shinfield, Reading, Berkshire
RG2 9AT
United Kingdom