Nature of the effects of bran on digestive transit time in pigs

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1. Transit time of digesta, faecal volatile fatty acids (VFA) excretion and faecal output were measured in four pigs (initially of 90 kg live weight) fitted with chronic catheters inserted into the caecum.

2. Each pig was given a basal milk diet (20 g/kg live weight per d) for 30 d and then received successively four further treatments: the basal diet with bran (100 g/d), the bran-supplemented diet with a daily administration of neomycin (100 mg/kg orally and 100 mg/kg intracaecally), the basal diet with continuous intracaecal infusion of either saline (9 g sodium chloride/l) or with VFA solution (100 mM/h) at the same rate.

3. The mean retention time of the polyvinyl chloride marker was reduced from 98·6 h on the milk diet to 64·3 h on the milk + bran diet. This transit time was not significantly modified by neomycin treatment.

4. Daily faecal excretion of VFA was significantly affected by the diet: the addition of bran induced a 167% increase from the milk diet; neomycin treatment reduced VFA excretion with the bran-supplemented diet from 11·3 mM/d to 6·3 mM/d whereas during VFA infusion, excretion levels were twice those of the basal diet.

5. Infusion of VFA solution on the milk diet induced an 11% increase in transit time, without any change in faecal output and dry matter.

6. In conclusion, it is suggested that the decrease in transit time associated with bran supplementation is mediated by direct mechanical factors rather than fermentation products, including VFA.

A slow rate of digesta transit through the gut associated with a refined diet can be accelerated by the addition of bran (Payler *et al.* 1975; Canguilhem & Labie, 1977). In pigs on a low residue diet, bran stimulates propulsive colonic motility (Fioramonti & Buéno, 1980), but the mechanism by which bran as well as other dietary fibre affects digesta transit regulation remains unclear.

Dietary fibre may act by increasing the faecal bulk, since an inverse relationship has been demonstrated in humans between the daily faecal weight and the digestive transit time (Spiller *et al.* 1977). Another hypothesis is that the fibre exerts its effects by means of colonic fermentation products (Hellendoorn, 1978) and more precisely by means of volatile fatty acids (VFA). The addition of cellulose to the diet in humans (Spiller *et al.* 1980) and dogs (Buéno *et al.* 1981) increases the small intestinal transit time and faecal VFA output while the total transit time is decreased. Nevertheless, contradictory information is available on the effects of VFA on colonic motility since they have been found to stimulate the colonic motility in vitro in rats (Yokokura *et al.* 1977) and to reduce the caecal motility in vivo in sheep (Svendsen, 1972). Moreover, VFA can no longer be considered a non-absorbable osmotic driving force for colonic fluid retention as previously postulated (Phillips, 1972) since they have been shown to augment sodium and water absorption in the colon of several animal species (Argenzio *et al.* 1975; Argenzio & Whipp, 1979) as well as in humans (Roediger & Moore, 1981).

The purpose of the present study was to determine, using pigs, whether colonic fermentation and VFA were responsible for the decrease in transit time induced by adding bran to a fibre-free diet such as milk. Since neomycin has been found to reduce VFA caecal production in pigs (Gargallo & Zimmerman, 1980), the effects on digestive transit time of neomycin treatment and those of intracaecal infusion of VFA were determined.
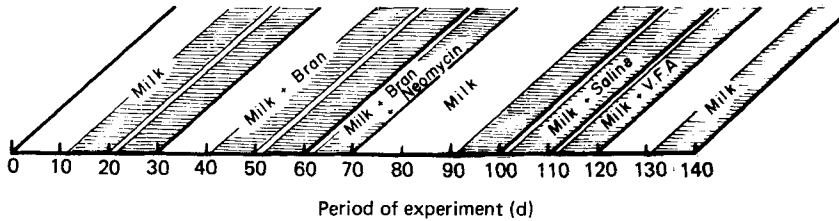
Fig. 1. Experimental plan for the different treatments, transit time measurements and faecal analysis. Hatched areas indicate periods of transit time measurement and faecal analysis. VFA, volatile fatty acids.

MATERIALS AND METHODS
Animals and diets

This study was carried out using four Large White pigs each weighing approximately 90 kg at the beginning of the experiments. Each pig was fitted with a chronic catheter (2 mm i.d.) inserted in the caecum midway between the apex and the ileo-caecal junction and exteriorized on the left flank. Pigs were housed in individual cages and allowed to recover for 10 d before the start of the experiment. The basal diet consisted of milk (20 g powdered milk substitute/kg body-weight per d, on a dry matter basis) given daily at 09.00 hours; water was available *ad lib*.

Experimental procedures

Each pig received five treatments (Fig. 1): (a) milk alone, (b) the addition of 100 g wheat bran/d to the diet, (c) daily administration of 200 mg neomycin sulphate/kg body-weight (100 mg in the food and 100 mg directly into the caecum via the catheter twice daily), (d) continuous infusion (1·7 ml/min) into the caecum of a VFA solution (0·1 M/h, pH 6·6, (mmol/mol) acetic 650, propionic 200, butyric 150), (e) caecal infusion (1·7 ml/min) of saline solution (9 g sodium chloride/l). A milk diet was given as a 'wash-out' treatment for 10 d after neomycin and VFA administrations.

Transit time

To measure the retention time of digesta in the digestive tract, a marker was incorporated in one meal (Fig. 1). The marker consisted of fifty small, flexible disks of coloured polyvinyl chloride, approximately 3 mm in diameter and 0·3–0·5 mm thick. Faeces were collected continuously for 8 d on a conveyer belt (200 mm/h) under the animal's cage. Thus the time of defaecations was given with a precision of ±15 min. The excretion of the marker v. time was recorded and the mean retention time (MRT) was calculated according to Castle & Castle (1956).

Samples of faeces for VFA and dry matter determination were collected directly from the rectum each day at 09.00 hours during the periods of transit time measurement.

Analytical methods

Samples for VFA analysis were immediately weighed (8–10 g) and mixed with distilled water (10 ml) for 3 min; fermentation was stopped by the addition of two drops of 12 M-sulphuric acid. Each suspension was then centrifuged (1900 g, 20 min, 0°), the supernatant fraction was frozen and stored at −25° until analysed for VFA.

Portions (1·0 ml) of the supernatant fraction were treated with 0·2 ml metaphosphoric acid (250 g/l). VFA (acetic, propionic, butyric acids) assays were performed by gas–liquid

Table 1. *Digestive transit time and faecal measurements for the different treatments*

(Mean values with their standard errors)

Treatment*...	Milk		Milk + bran		Milk + bran + neomycin		Milk + VFA infusion		Milk + saline infusion	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Mean retention time (h)	$98 \cdot 6^a$	5·8	$64 \cdot 3^b$	3·8	$66 \cdot 4^b$	4	$111 \cdot 2^{bc}$	3·9	$94 \cdot 2^a$	2·5
Faecal VFA excretion (mmol/24 h)	$4 \cdot 3^a$	0·2	$11 \cdot 5^b$	0·9	$6 \cdot 3^{bc}$	1·2	$8 \cdot 6^{bcd}$	0·2	$4 \cdot 4^a$	0·5
Faecal output (g/24 h)	$182 \cdot 5^a$	11·3	$291 \cdot 0^b$	14·6	$287 \cdot 6^b$	16·0	$190 \cdot 6^a$	9·1	$193 \cdot 6^a$	9·6
Faecal dry matter (g/kg)	463^a	15	417^b	9	408^b	17	451^a	25	459^a	19

VFA, volatile fatty acids.

* For details of treatment, see p. 686.

[a, b, c, d] Means in the same row not sharing a common superscript letter differ significantly ($P < 0 \cdot 01$).

chromatography (IGC 120 DFL, Intersmat, France) equipped with a flame-ionization detector using a column packed with 20% NPGA, 2% H_3PO_4 on 80% Chromosorb WAN of 80/100 mesh.

Statistical methods

The statistical significance of the changes in retention time and faecal measurements, compared with the control diet, was calculated using Student's paired *t* test. Results are expressed as mean values, with their standard errors in parentheses.

RESULTS
MRT

MRT of the marker during the control period on the milk diet before treatment was 98·6 (5·8) h. When the milk diet was given after neomycin or VFA treatment, MRT were respectively 101·7 (6·4) h and 102·8 (6·5) h and did not significantly ($P > 0 \cdot 2$) differ from the values obtained previously on the control diet.

The MRT was significantly ($P < 0 \cdot 001$) decreased to 64·3 (3·8) h when 100 g bran/d was added to the milk diet (Table 1).

The administration of 200 mg of neomycin sulphate/kg body-weight per d to the bran-supplemented milk diet did not significantly ($P > 0 \cdot 2$) modify MRT observed with the milk + bran diet alone (66·4 (4) h *v.* 64·3 (3·8) h).

When VFA were continuously infused into the caecum the MRT for the milk diet was increased ($P < 0 \cdot 01$) to 111·2 (3·9) h when compared with the values obtained on the milk diet alone. Continuous infusion of saline at the same rate had no significant effect ($P > 0 \cdot 1$) on the MRT observed on the milk diet.

Faecal output and dry matter

On the milk diet the daily faeces weight was 182·5 (11·3) g. Addition of bran (100 g) to the diet caused a 60% increase in faecal output (Table 1). Administration of neomycin did not modify ($P > 0 \cdot 3$) the faecal output increase induced by the addition of bran.

Caecal infusion of VFA on the milk diet did not significantly modify the daily faecal output, compared with that observed with milk alone (190·6 (9·1) g *v.* 182·5 (11·3) g).

The faecal dry matter was 46·3 (1·5) g/kg moist faeces. The dry matter content was significantly decreased ($P < 0 \cdot 001$) by bran (10%) and bran plus neomycin (12%). In contrast, caecal infusion of VFA had no significant effect on faecal moisture.

Table 2. *Concentrations (mmol/mol) of volatile fatty acids (VFA) in the faeces of pigs during the different treatments*

(Mean values with their standard errors)

Treatment*...	Milk diet		Milk + bran		Milk + bran + neomycin		Milk + saline infusion		Milk + VFA infusion	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acetic	714	47	626	42	675	55	719	54	632	40
Propionic	75	13	137	25	152	31	69	21	144	18
Butyric	162	18	187	29	132	34	159	24	192	36
Other VFA†	49	6	50	4	41	9	53	4	32	9

* For details of treatments, see p. 686.
† Isobutyric, valeric and isovaleric acids.

VFA excretion

The daily faecal excretion of VFA was 4·3 (0·2) mmol on the milk diet. The addition of 100 g bran to the milk diet caused a 167% increase in the VFA excretion (Table 1) which was reduced to a 47% increase during administration of neomycin. During VFA infusion the faecal VFA excretion was doubled by comparison with the basal milk diet.

The proportions of individual VFA are given in Table 2. The major VFA was acetic acid for the control milk diet and for all treatments. Valeric and isovaleric acids were present in small amounts and traces of isobutyric acid were found only occasionally. The addition of bran to the milk diet caused a significant decrease in the percentage of acetic acid (62·6% v. 71·4%) with a concomitant increase of propionic acid (13·7% v. 7·5%). No significant changes in the proportions of butyric acid were observed. With both neomycin treatment and caecal VFA infusion on the milk diet the proportions of VFA observed were the same as those with the milk + bran diet. Caecal infusion of saline did not induce any significant change ($P > 0.5$) in VFA when compared with the control milk diet.

DISCUSSION

The results reported in the present study showed that VFA were not involved in the acceleration of digestive transit time induced by the addition of bran to a low-residue diet in pigs. These findings are similar to those of previous studies. For example, in humans coarse bran produced a shorter mean transit time than did finely-ground bran (Heller *et al.* 1980), while VFA concentrations in faeces were not significantly different for coarse and fine bran (Ehle *et al.* 1982).

In the present study VFA production was increased by bran, but the level of the daily flow of VFA in the milk + bran diet was low when compared with the values obtained with standard diets (Sambrook, 1979) for which VFA output averaged 35 mmol/24 h v. 11·5 mmol/24 h in the milk + bran diet. Although a substantial fraction of lactose in the milk diet has been demonstrated to be available for microbial fermentation (Kim *et al.* 1978), it seems from our results that milk alone was a highly digested diet in pigs, comparable with the 'high starch–low fibre' diet used by Sambrook (1979); it is notable that our basal milk diet is (absolutely) fibre-free. A small amount of bran was sufficient to cause an appreciable increase of fermentation products; however, the results obtained in the present study with bran cannot be directly extended to other fibres. On the other hand, the quantities

of VFA present in the faeces mean very little in terms of quantities produced by bran digestion since VFA are absorbed from the large intestine (Barcroft *et al.* 1944). However, the decrease in VFA output observed with the milk + bran + neomycin diet compared with the milk + bran diet reflects variations in VFA production since neomycin is able to arrest completely the digestion of cellulose in pigs (Gargallo & Zimmerman, 1980).

The lack of effect of VFA on the decrease in transit time caused by bran is indicated by the caecal infusion of VFA which did not decrease but significantly increased transit time. The rate of VFA infusion for the milk diet was probably in a physiological range, since the corresponding VFA faecal elimination was slightly lower than that observed when bran was added to the milk diet. Moreover, as far as we are aware, only one report, in which in vitro conditions were used, indicates that VFA stimulate colonic motility (Yokokura *et al.* 1977) whereas in conscious sheep VFA decrease caecal motility (Svendsen, 1972). In conscious horses, intracaecal infusion of VFA not only decreases the frequency of propagated propulsive contractions but also increases the rate of localized tonic contractions (Candau & Vigroux, 1974) which were found to act like a brake against the transit of digesta (Fioramonti *et al.* 1980). In pigs the addition of bran to a milk diet had an opposite effect since propulsive contractions were increased and tonic contractions decreased (Fioramonti & Buéno, 1980).

On the other hand, it is widely felt that the capacity of dietary fibres to take up and hold water is important in their action (Eastwood, 1973). However, a study performed with several fibres (Stephen & Cummings, 1979) had shown an inverse relationship between water-holding and faecal bulking; bran having the lowest water-holding capacity produces the largest increase in faecal weight. Since an inverse relationship has also been demonstrated between faecal weight and transit time (Spiller *et al.* 1980) the water uptake of bran does not seem to be involved in the accelerating effect on transit time.

Finally, bran added to a low-residue diet decreased the transit time through an unknown mechanism. Since neither products of fermentation nor water holding are involved, the hypothesis of a direct physical action which would stimulate colonic motility can be postulated.

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