Changes in intragastric meal distribution are better predictors of gastric emptying rate in conscious pigs than are meal viscosity or dietary fibre concentration

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The effect of dietary fibre on the gastric emptying rate of solids is controversial. Similarly, the mechanisms by which it modulates food intake are partially unknown. Gastric emptying and proximal v. distal stomach filling were evaluated in triplicate on four conscious pigs using scintigraphic imaging. Each animal received in an isoenergetic manner a concentrate low-fibre diet enriched in starch (S) and two high-fibre diets based on sugar beet pulp (BP) or wheat bran (WB). All meals had the same viscosity before ingestion (100·0–100·5 Pa·s). Viscosity of the gastric contents was measured in four additional animals fitted with a gastric cannula. The gastric emptying rate of BP diet was significantly slower than S and WB diets ($t_{1/2}$ 78·4 (SEM 5·68), 62·8 (SEM 10·01) and 111·6 (SEM 10·82) min for S, WB and BP diets respectively, $P < 0·05$). For BP diet only, rate of distal stomach filling was steady during the first 120 min after the meal whereas that of S and WB diets decreased in an exponential manner. Numerous backflow episodes from the distal into the proximal stomach were observed for BP diet that generated the larger intragastric viscosity (0·26 (SEM 0·03), 0·3 (SEM 0·02) and 0·52 (SEM 0·002) Pa·s for S, WB and BP respectively). In conclusion, viscosity of the meal or the percentage total fibre, unlike viscosity of the gastric contents, are poor predictors for emptying. The reduced emptying rate observed with BP is associated with major changes in intragastric distribution of the meal absent with WB and S diets.

Gastric emptying: Dietary fibre: Viscosity

Dietary fibre is used increasingly in human and animal nutrition (Salminen et al. 1998). In man, it represents an alternative means for treating pathological conditions such as obesity, hypercholesterolaemia and diabetes (Miranda & Horwitz, 1978) since it reduces plasma glucose response to meal (Morgan et al. 1990) and slows down the return of hunger (Haber et al. 1977). In pregnant sows, dietary fibre minimises the stereotyped behaviour (Lawrence & Terrace, 1993) associated with feed restriction used to limit excessive weight gain and fat deposition. These effects are supposed to be entirely or partially related to a decreased gastric emptying rate (McIntyre et al. 1997) that in turn increases gastric distension and satiety (Phillips & Powley, 1996; Lepionka et al. 1997). Whereas the inhibitory effect of dietary fibre on liquids emptying is clearly demonstrated, its effect on the emptying of the solid phase of the meal is more controversial. Delayed (Brown et al. 1988; Di Lorenzo et al. 1988), normal (Rainbird & Low, 1986a,b) or accelerated gastric emptying (Meyer et al. 1986; Potkins & Lawrence, 1988) have all been reported.

The absence of consensus on the role of dietary fibre on gastric emptying of solids relates first to the difficulty of evaluating solid emptying of fibre-containing meals (Schade et al. 1991), and second to the inaccessible yet suspected difference between meal v. gastric chyme viscosity (Cherbut et al. 1990). The latter is supposed ultimately to be the main physical factor controlling emptying as hypothesised in the so-called ‘hydrodynamic’ theory (Meyer et al. 1986). Numerous methods have been evaluated to label fibrous contents of the meals but none can be claimed as ideal. Either they label unusual dietary components (Malagelada et al. 1980; Madsen & Jensen, 1989; Schade et al. 1991) or have some degree of inaccuracy due to a significant dissociation of the solid radioactive label into the liquid phase (Sagar et al. 1983; Houghton et al. 1989).

Abbreviations: BP, sugar beet pulp; S, starch; WB, wheat bran.

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One expected effect of dietary fibre is reduced hunger sensation produced by early satiety. Since activation of vagal mechanoreceptors present in the proximal stomach is likely at the origin of this effect (Mei, 1986; Moran et al. 1999), it might be more interesting to evaluate the effect of satiety-inducing fibre on proximal gastric filling rather than total gastric emptying. Indeed, dissociation between these two variables has been demonstrated especially with meals containing ingredients of different physical properties (Collins et al. 1988; Edelbroek et al. 1994). Unfortunately, in animals none of the presently available methods was proved to differentiate proximal v. distal stomach filling. In human subjects, however, scintigraphic imaging of the stomach has such capabilities.

The aim of the present study was to evaluate non-invasively total gastric emptying and proximal v. distal stomach filling in conscious pigs after a meal containing dietary fibre classically incorporated in pig diets such as wheat bran (WB) and sugar beet pulp (BP) (Bourns et al. 1995; Ramonet et al. 1999). Emptying from and filling of the stomach was measured by scintigraphic imaging of the abdomen, the solid phase of the meal being labelled with $^{99m}$Tc colloid. An additional aim was to correlate emptying rate and viscosity of the chyme present in the stomach by sampling the whole stomach contents from surgically prepared animals.

**Methods**

**Imaging protocol**

Imaging studies were carried out in four female Large White pigs (40 (SEM 3·2 kg)). All studies were performed in unsedated pigs trained to stand quietly in slings allowing approximately 40 cm movement in each direction. The slings were designed to allow the pig to stand for prolonged periods. Each animal was given three different test meals on separate days. For each meal the emptying experiments were performed in triplicate. The order of the studies was randomised with a minimum of 3 d between experiments. Meals were given after an overnight fast for solids only and were consumed spontaneously while the animal stood laterally to the head of a scintillation camera. Test meals were eaten spontaneously within 3 min after presentation. For 30 min before and during the imaging protocol, the animals had no access to drinking water.

The three test meals differed by the amount of total dietary fibre: 63·8, 207·1 and 340·5 g/kg DM for starch (S), WB and BP diets respectively (Table 1). To negate the influence of the energy density of meals on gastric emptying, the meals were given in isoenergetic quantities supplying 4·25 MJ to the animal. Between experiments, the animals were fed once daily using a standard animal diet containing 63·8 g total dietary fibre/kg DM and they had free access to drinking water. Feeds were analysed for DM, ash and crude fibre according to the methods of the Association of Official Analytical Chemists (1990). Cell wall fractions, neutral-detergent fibre, acid-detergent fibre and acid-detergent lignan were determined according to Van Soest et al. (1991) with previous amylolytic treatment. Total soluble and insoluble fibre was analysed in accordance with the Association of Official Analytical Chemists’ method described by Prosky et al. (1988).

**Preparation of the labelled test meals**

The dry components of the test meals were reduced into powder with a mean particle size of 1 mm necessary for uniform labelling with Tc and cancellation of the effect of particle size on gastric emptying rate. Afterwards, freshly-made $^{99m}$Tc colloid (15 MBq, TCK 1; CISBio International, Fontenay au Roses, France) was diluted with 600 ml hot water (75°C). Diet powder was gently incorporated into this preparation and allowed to incubate for 5 min. The labelled meal was washed twice with an equal volume of cold tap water to remove $^{99m}$Tc colloid in excess that was still in the liquid phase. Water in excess was removed by centrifugation (400 rpm, 5 min) of the mixture. The meal was allowed to cool to 20°C before consumption. At the time of eating, the consistency of the meals was identical to thick porridge. Immediately before ingestion the volumes of the meals were 598·4 (SEM 12·0), 638·4 (SEM 12·2) and 772·8 (SEM 13·7) ml for S, WB and BP diets respectively.

To evaluate the quality of the labelling and to confirm the adequate labelling of the solid phase only, 10 g labelled test meal were dissolved in 50 ml saline–HCl (2 M) and pepsin (three trials for each diet). The mixture was incubated for 60 min at 38°C. The assay tube was then centrifuged (4000 rpm, 5 min) and placed under the γ-camera for a static acquisition lasting 5 min. The amount of radioactivity was measured in two regions of interest delimiting the supernatant fraction and the sediment. The ratio between the counts obtained in the two regions was calculated afterwards. All values ranged from 92 to 95 % irrespective of the diet indicating that 8 to 5 % of the radioactivity was present in the liquid phase.

**Physical characterisation of the meals**

Four female Large White pigs (40 (SEM 3·6 kg)) were surgically fitted with a gastric silicon cannula inserted in the mid corpus region according to a previously described protocol.
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isotope

Emptying curves (expressed as percentage retention of

corresponding to the fundus and proximal corpus and the

proximal and distal regions with the proximal region

movement and radionuclide decay.

(1983). Radionuclide data were also corrected for subject

et al. achieved with the algorithm validated by Collins

dorso-ventral image for calculation of the correction

for tissue attenuation was performed off-line using this

image of the stomach was digitised over 60 s. Correction

tional) was given orally to the pig and a dorso-ventral static

diethylene triamine pentaacetate (TCK 6; Cis Bio Interna-

commencing immediately before the ingestion of the meal.

In each study, data were acquired for at least 120 min,

commencing immediately before the ingestion of the meal.

Data were collected in 120 s frames for the entire duration

of the study using a computerised scintillation camera

(Apex 900; Elscint, Israel) fitted with a high resolution–

low energy collimator. The position of the camera head was

right lateral relative to the animal. Since the long axis of the

pig stomach was slightly tilted to the left, attenuation

correction for tissue depth was necessary while acquiring a

lateral image. Therefore, at the completion of the study, 1

litre glucose (100 g/l) labelled with 10 MBq 99mTc-

diethylene triamine pentaacetate (TCK 6; Cis Bio Interna-
tional) was given orally to the pig and a dorso-ventral static

image of the stomach was digitised over 60 s. Correction

for tissue attenuation was performed off-line using this
dorso-ventral image for calculation of the correction

factors. Calculation of the total stomach counts was then

achieved with the algorithm validated by Collins et al.

(1983). Radionuclide data were also corrected for subject

movement and radionuclide decay.

The total stomach region of interest was divided into

proximal and distal regions with the proximal region

corresponding to the fundus and proximal corpus and the

distal region representing the distal corpus and antrum. Emptying curves (expressed as percentage retention of

isotope v. time) were derived from total stomach, proximal

stomach and distal stomach regions of interest. Emptying curves were fitted to a power exponential function (Elash-

off et al. 1982) to calculate \( t_{1/2} \) emptying time and the curve

shape variable (\( \beta \)). Emptying curves with a loose fitting to

the power exponential model indicated by a mean square

error >0.005 were not taken into account in the final

analyses.

Statistical analysis

Statistical significance between diets was tested using

repeated measures fixed effect ANOVA (Prism, GraphPad

Software; GraphPad Inc., San Diego, CA, USA). Matching

test was prior to ANOVA calculation and was found to

be effective for all comparisons described. Bonferroni post

hoc multiple comparison test was used to compare diets

effect (Motulsky, 1999). Data are expressed as mean values

with standard errors of the means. A \( P \) value <0.05 was

considered significant in all analyses.

Results

Viscosity of the test meal

Before ingestion, the viscosity of the three test meals was

not significantly different (Table 2). The viscosity of the

gastric contents, however, was significantly greater for BP

diet compared with S and WB diets.

Total stomach emptying

One emptying curve over a total of thirty-six experiments
cannot be fitted adequately to a power exponential and this

experiment was removed from subsequent analyses. Gastric

emptying of WB diet was significantly faster than that of S

and BP diets (Fig. 1). Similarly, BP diet was emptied

significantly slower than S and WB diets. The same

hierarchy was also observed for half-emptying times

(Table 3). A lag phase cannot be identified and radio-

activity can be found distal to the stomach immediately

after the end of the meal ingestion. Surprisingly, the overall

shape of the emptying curve, indicated by \( \beta \) value, was not

significantly different for the three test meals. A clear mid-

gastric band, e.g. a transverse band of reduced isotopic

activity separating proximal and distal stomach, was

observed for BP diet only (Fig. 2). This mid-gastric band

was clearly shown during the first 60 min after meal

ingestion.

Proximal stomach emptying

Proximal stomach retention of the test meals followed the

same pattern as that found in the whole stomach, i.e. WB

Table 2. Viscosity of the test meals and of the gastric contents 30 min after the ingestion of the different test meals*

<table>
<thead>
<tr>
<th></th>
<th>S diet</th>
<th></th>
<th>WB diet</th>
<th></th>
<th>BP diet</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SEM</td>
<td>Mean</td>
<td>SEM</td>
<td>Mean</td>
<td>SEM</td>
</tr>
<tr>
<td>Meal viscosity</td>
<td>105.0</td>
<td>6.1\textsuperscript{a}</td>
<td>104.0</td>
<td>2.2\textsuperscript{a}</td>
<td>100.0</td>
<td>3.7\textsuperscript{a}</td>
</tr>
<tr>
<td>(Pa·s)</td>
<td>0.26</td>
<td>0.03\textsuperscript{b}</td>
<td>0.30</td>
<td>0.02\textsuperscript{b}</td>
<td>0.52</td>
<td>0.02\textsuperscript{c}</td>
</tr>
<tr>
<td>Gastric contents viscosity (Pa·s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

S, starch-enriched; WB, wheat bran-enriched; BP, sugar beet pulp-enriched.

\textsuperscript{a,b,c} Mean values within a row with unlike superscript letters were significantly different (\( P < 0.05 \)).

* For details of the composition of the diets see Table 1.
diet emptied the fastest and BP diet emptied the slowest. Nevertheless, proximal stomach retention at half-emptying time was less for WB diet than for BP diet (63% v. 73%). This is in accordance with a significantly lower steepness of the emptying curve for BP compared with S and WB diets (Fig. 1). For S and WB diets, the emptying curve for the proximal stomach was approximately parallel to that of the proximal stomach.

**Distal stomach emptying**

The amount of the meal in the distal stomach followed a bi-exponential function for all diets. The amount of the meal in the distal stomach at 40 min was greater for WB diet compared with S and BP diets while the percentage remaining at 150 min was greater for BP and less for S diets. For BP diet only, the percentage radioactivity present in the distal stomach was almost constant from 58 (SEM 12.3) to 189 (SEM 15.0) min after the meal. Afterwards, the amount of radioactivity decreased rapidly so that half-emptying time of the distal stomach was 380 (SEM 25.4) min (compared with 144 (SEM 5.6) and 191 (SEM 6.0) min for WB and S diets respectively). In all studies involving BP diet, there was evidence of retrograde movement of radioactivity from the distal to the proximal stomach with a rise in proximal stomach counts associated with a fall in the distal stomach (Fig. 3). These events were observed between 40 and 90 min after the ingestion of the meal. Their number varied between animals but not within the same subject ranging from one to four backflow episodes for the duration of the imaging period.

**Discussion**

Using \( \gamma \)-scintigraphy imaging, the recognised gold standard for gastric emptying measurement, we have demonstrated that the amount of total dietary fibre in the diet, unlike the nature of the fibre, was not critical for emptying rate of the solids. S diet containing 63.8 g total dietary fibre/kg emptied slower than WB diet that contained 207.1 g total dietary fibre/kg. Furthermore, solid emptying rate was not related to meal viscosity since the medium-viscous meal (WB diet) emptied faster than low-viscous meal (S diet).

### Table 3. Half-emptying time of S, WB and BP diets in the total and proximal stomach*

<table>
<thead>
<tr>
<th></th>
<th>S diet</th>
<th>WB diet</th>
<th>BP diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean t(_{1/2}) (min)</td>
<td>78.4 5.68(^a)</td>
<td>62.8 10.01(^b)</td>
<td>111.6 10.82(^c)</td>
</tr>
<tr>
<td>SEM</td>
<td>0.93 0.053</td>
<td>0.93 0.047</td>
<td>0.92 0.064</td>
</tr>
<tr>
<td>Proximal stomach</td>
<td>53.6 5.55(^a)</td>
<td>39.6 7.03(^b)</td>
<td>81.6 5.23(^c)</td>
</tr>
<tr>
<td>Mean t(_{1/2}) (min)</td>
<td>0.78 0.049</td>
<td>0.77 0.039</td>
<td>0.86 0.049</td>
</tr>
<tr>
<td>SEM</td>
<td>0.78 0.049</td>
<td>0.77 0.039</td>
<td>0.86 0.049</td>
</tr>
</tbody>
</table>

\(^a,b,c\) Mean values within a row with unlike superscript letters were significantly different (\(P < 0.05\)).

\(^*\) For details of the composition of the diets see Table 1. Data for the distal stomach are not represented because the emptying curve cannot be fitted to a power exponential function for all diets.
Soluble sources of dietary fibre have been shown to delay absorption of glucose, an effect thought to be mediated through a reduced gastric emptying rate of liquids and a diminished intestinal glucose absorption. However, the effect of soluble dietary fibre on solid emptying was ambiguous (Rainbird & Low, 1986b; Cherbut et al. 1990; Johansen et al. 1996) mainly because of the difficulties in evaluating non-invasively gastric emptying of the solid phase in conscious animals (Malbert et al. 1997). Our present work demonstrates that a significant increase in gastric contents viscosity (BP diet) resulted in a marked decrease in overall gastric emptying of solids. As a first approximation, transpyloric flow relates to the Poiseuille law describing the relationship between pressure gradient across the pylorus, pyloric diameter and the flow of viscous contents (Meyer et al. 1986; Malbert & Ruckebusch, 1991). Assuming that the pressure gradient and the pyloric diameter remained unchanged, the doubling in viscosity between S and BP diets (0.52 v. 0.26 Pa-s) will theoretically result in a doubling in half-emptying time, a feature confirmed by experimental data (111 v. 78 min). Nevertheless, as already suggested (Johansen et al. 1996), the viscosity relevant to gastric emptying was that of the gastric contents and not that of the meal itself. Indeed, the viscosity of BP, WB and S diets before ingestion do not differ significantly, a situation that was modified within the stomach probably in relation to salivary and gastric secretions.

Meal volume is known as a major factor controlling gastric emptying (Hunt & Stubbs, 1975; Moran et al. 1999). However, the differences in gastric half-emptying time between S, WB and BP meals were unlikely to be related to different meals volumes. Indeed, the largest volume meal (BP) had the slowest emptying rate. In addition, S meal, which has the smallest volume, exhibited an intermediate half-emptying time compared with BP and WB. Whereas meal volume was probably not involved in the differences in emptying, lipid concentration might be important. Indeed, S, WB and BP meals differed in their lipids concentration and this variable is critical for gastric emptying time (Heddle et al. 1989; Latge et al. 1994; Maes et al. 1996). Nevertheless, the difference in lipid concentrations is unlikely to be involved in the differences between the rates of S, WB and BP diets emptying since WB diet, which supplied the largest amount of lipid, was also the fastest to empty.

Fig. 2. Scintiphotographs showing the distribution of (a) wheat bran-, (b) sugar beet pulp- and (c) starch-enriched meals in one subject at 10, 60 and 120 min after meal ingestion. For details of the diets and procedures see Table 1 and p. 344. At 10 and 60 min, there was evidence of a mid-gastric band for sugar beet pulp-enriched diet only (——). Note that the whole stomach is outlined for an extended period of time (up to 60 min) for sugar beet pulp-enriched diet.
This is, to our knowledge, the first study evaluating gastric emptying rate and gastric distribution of a solid energy-containing meal in conscious pigs using \(\gamma\)-scintigraphic imaging. The anatomical location of the porcine stomach, lying from left to right flank, makes depth correction an absolute requirement while using lateral imaging of the stomach. Alternatively, lateral imaging of the stomach is superior compared to dorso-ventral projection since minute motion of the partially restrained pig relative to the \(\gamma\)-camera head is far less. Nevertheless, attenuation errors are likely to occur with a single-head camera imaging. It is impossible to evaluate the magnitude of the error induced by our method since all available methods capable of monitoring emptying of a solid meal in conscious pigs have not, by far, the temporal resolution of \(\gamma\)-scintigraphy. Nevertheless, based on studies of human subjects (Collins et al. 1983), the correction method applied, while not affecting the temporal resolution of the imaging, suppressed day-to-day variations in gastric emptying within individual subjects while preserving inter-individual and inter-treatments variations. Furthermore, the overall gastric emptying can be adequately fitted to a power exponential function, unlike other studies performed in pigs (Gregory et al. 1990; Johansen et al. 1996) but in accordance with most of the studies performed earlier in almost all mammals (Heading et al. 1976; Hinder & Kelly, 1977; Theodorakis, 1980; Dubois, 1982; Elashoff et al. 1982; Hornof et al. 1989). The possibility of an incorrect binding between \(^{99m}\text{Tc}\) and the meal was an important issue since previous studies have reported dissociation up to 50 % of the radioactive label into the liquid phase of the gastric contents using \(^{99m}\text{Tc}\) alone (Sagar et al. 1983; Houghton et al. 1989). This poor result has made the 'Mayo clinic method' using \(^{131}\text{I}\) an interesting but complex labelling method for cellulose fibres (Malagelade et al. 1980). Labelling fibrous test meals using \(^{99m}\text{Tc}\) colloid was proven to be a fast and efficient method. Indeed, \textit{in vitro} \(^{99m}\text{Tc}\) release from the meal into the liquid phase was only 5 %. Nevertheless, it is probable that the labelling performed with our present method is not limited to the fibre component of the meal but involved also the other components of the meal, mainly the protein fraction.

The faster emptying rate of WB compared with S diet is a surprising result since the viscosity of WB is slightly greater, yet not significantly so, than S gastric contents. It is impossible, based on our results, to understand the origin of such discrepancy since the intragastric distribution for both diets is almost identical. However, the possibility that the thermal processing of WB meal required for \(^{99m}\text{Tc}\) to bind with the diet may have modified the physical characteristics of the fibre cannot be excluded. Nevertheless, this was unlikely since the temperature required to break starch–H bonds is greater than 50°C, i.e. a temperature

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**Fig. 3.** Raw percentage retention of wheat bran-enriched diet in one subject. For details of the diets and procedures see Table 1 and p. 344. ○, Total stomach; ●, proximal stomach; +, distal stomach. Retrograde movements of the meal from distal to proximal stomach are demonstrated by the increase in proximal radioactivity, ↓, decrease in distal radioactivity.
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greater than that used during our labelling process (Champ & Colona, 1993).

Scintigraphic imaging of the stomach allows identification of the proximal and distal parts of the stomach and measurements of proximal v. distal stomach filling. Three differences relevant to intragastric distribution of the meal can be identified during the process of emptying of BP diet compared with S and WB diets. First, there was a well-defined mid-gastric band that has been suggested to contribute to retention of the meal in the proximal stomach (Moore et al. 1986; Edelbroek et al. 1992). Second, there were retrograde movements of BP diet from the distal into the proximal stomach. The time of occurrence of such intragastric reflux episodes is consistent with that already mentioned for slow-emptying meals such as those containing oil (Houghton et al. 1990; Horowitz et al. 1993). The increased pyloric resistance observed while the viscosity of the digesta was increased (Keinke et al. 1987) might be one of the causative factors for such backflow. Third, for BP diet only, the amount of radioactivity in the distal stomach remained almost constant during most of the emptying phase. This indicates that the amount of digesta leaving and entering the distal stomach is identical. Whereas the underlying viscoelastic mechanisms responsible for this constant antral filling were complex is beyond doubt, nonetheless a reduced antral motor activity already described with high viscous meals (Ehrlein et al. 1987; Keinke et al. 1987) might be one important factor. Furthermore, a similar accumulation of fibre meal in the distal part of the stomach has been already observed in human subjects (Mcintyre et al. 1997).

The greater retention in the proximal stomach of BP diet compared with S and WB diets must also be considered outside the scope of gastric emptying per se and also in relation to vagal mecanoreceptors activation controlling short-term food intake. Several lines of evidence have suggested, in various mammalian species, a short-term control of food intake related to the arrival and storage of the meal in the proximal part of the stomach (Wirth & McHugh, 1983; Phillips & Powley, 1996). Recently, our group has demonstrated a reduction in voluntary food intake in conscious pigs during mild isobaric distension of the proximal stomach while receptive relaxation was artificially suppressed (Lepionka et al. 1997). Since BP diet stayed longer in the proximal stomach, it is likely that the amount of nervous afferent information relevant to satiety was greater in this situation compared with WB or S diets. This is probably one of the mechanisms explaining the drastic reduction of food intake in adult sows fed with BP (Bourns et al. 1995).

In conclusion, meal viscosity alone is not the only factor controlling gastric emptying rate of solids. Furthermore, gastric emptying is not only directly related to gastric digesta viscosity but depends also on dietary fibre type. The unique capability of γ-sciitigraphy to evaluate non-invasively proximal gastric filling might be essential to estimate the satiety-related effects of dietary fibre.

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References


Rainbird AL & Low AG (1986b) Effect of various types of dietary fibre on gastric emptying in growing pigs. *British Journal of Nutrition* 55, 111–121.


