# Size of particles of bread and pasta emptied from the stomach of pigs, used as human models

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## Summary

The aim of this work was to evaluate gastric emptying rate of digestible solid food and the distribution of food particle size leaving the stomach after meals of different physical structures (bread versus pasta). Bread and pasta were of similar chemical composition but differed by their physical structure. The collection of digesta was performed on cannulated pigs with Roux-en-Y derivation of pancreatic secretions into the jejunum. Pasta left the stomach slower than bread ($t_{1/2}$ : 156±89 minutes vs $t_{1/2}$: 39±12 minutes) and were uncompletely emptied 4 hours after the meal (46±14% dry matter). The fractions leaving stomach or residual were composed of large particles (mean size:15 mm). In conclusion, the physical structure of food governs primarily gastric emptying rate and digestion

*Keywords: pig, model, gastric emptying, bread, pasta, solid food*

## Résumé

**Taille des particules de pain et de pâtes alimentaires vidangées de l'estomac du porc, utilisé comme modèle de l'homme**. L'objectif de cette étude était d'évaluer la vidange gastrique et la répartition particulaire d'aliments protéo-glucidiques de structure physique différente (pain, pâtes alimentaires), après leur passage dans l'estomac du porc pris comme modèle de l'homme. Au cours d'une période postprandiale de 4 heures, les pâtes alimentaires, plus lentement vidangées de l'estomac que le pain ($t_{1/2}$: 156±89 minutes vs $t_{1/2}$: 39±12 min) et de façon incomplète (46±14% de la matière sèche des pâtes), restaient sous forme de grosses particules (1,5 cm de long). Ainsi, les caractéristiques physiques peuvent persister au delà de la digestion gastrique et conditionner leur cinétique d'arrivée au lieu de digestion et d'absorption.

*Mots clés: porc, modèle, vidange gastrique, pain, pâte, aliment solide*

## Introduction

Gastric emptying rate depends on physical and chemical characteristics of the meal (Meyer et al., 1985). Among these parameters, the size of food particles is critical for their gastric retention time since, after a liver or indigestible meal, no particules greater than 2 mm could be found distal to the pylorus (Hinder & Kelly, 1977; Meyer et al., 1988). However, for food of different geometry, the occurrence of this sieving process is still controversial. The aim of this study is to determine the size of particles of bread and two different kinds of pasta (spaghetti, tortiglioni) emptied from the stomach of the pig used as a human model.

## Materials and methods

### Animals and diet

Four female pigs (Large White: 45-50 Kg) were fitted, under anaesthesia, with two cannulas, one inserted in the gastric corpus and the other in the proximal jejunum. Pancreatic secretions were diverted by a Roux-en-Y limb into the distal jejunum; so gastric contents were collected from the duodeno-jejunal cannula prior to their contact with pancreatic enzymes. The animals were allowed 1 week recovery before the experiments were started. During this recovery, the pigs were accustomed to the experimental diets.

During the experimental period, pigs were fed twice daily. Standard commercial diet (Axior Energic Farine, CANA, Ancenis, France: 500 g with 1,5 l of water) was given the evening , whereas morning meals (test-meals) were constituted in either 200 g of bread or pasta (in dry matter), added with water (290 ml or 100 ml respectively) and viandox (10 ml). Pasta were cooked according to the AFNOR 7304 procedure (june 1989). Two kinds of cylindrical pasta were used: spaghetti (length: 40 mm, diameter: 1,7 mm, thickness: 1,7 mm), tortiglioni (length: 4 mm, diameter: 11 mm, thickness: 1,8 mm). Bread and pasta (Barilla, Parma, Italy) were similarly composed of 72% of starch and 13-15% of proteins. Each pig tested, at random, the three test-meals.

### Gastric and jejunal contents collection

Prior to collection of the jejunal contents, a Foley catheter was introduced into the jejunal cannula and its balloon inflated with 5 ml of water to force digesta through the jejunal cannula. Digesta emptied from the jejunal cannula were collected on ice over 30 minutes periods for 4 hours after the ingestion of the test-meals. During collection, a nutrient containing solution (Sondalis, ISO, Clintec, Sopharga, Paris, France) was infused distal to the jejunal cannula to maintain a small intestinal brake on gastric emptying despite the diversion. After 4 hours of experiment, the residual gastric contents were recovered by the gastric cannula. Collected digesta were weighed and immediately processed as follows: digesta from pasta meals were filtered through a 600 µm screen; then centrifuged for 10 minutes at 3000 g. The three fractions (particles retained by the screen, supernatant and pellets) were weighed and analysed for dry matter and particle size. Digesta obtained from bread meals were processed similarly but not filtered.

### Particle size determination

Particle of bread smaller than 1 mm were dispersed in isopropanol and analysed by laser granulometry using a Mastersizer IP Malvern (Malvern Instruments Limited, Malvern, UK), fitted with a 1000 mm lens. This apparatus records the intensity of light diffracted by the particle. The histogram of particle sizes was obtained by computerized analysis of the light intensity signal. The histograms were expressed in volumetric frequency of particles or percentage of total volume occupied by the particles.

The size of particles of pasta, unable to pass through the 600 µm screen, was evaluated by image analysis. Particles were individualized on a glass plate, put on black surface and lighted in determined conditions (4x100W lamps). The monochrome images were

digitalized and processed according to the method described by Devaux et al. (1992). The area of each particle was calculated and presented as a histogram, giving the percentage of the total surface occupied by the different classes of particles.

## Results

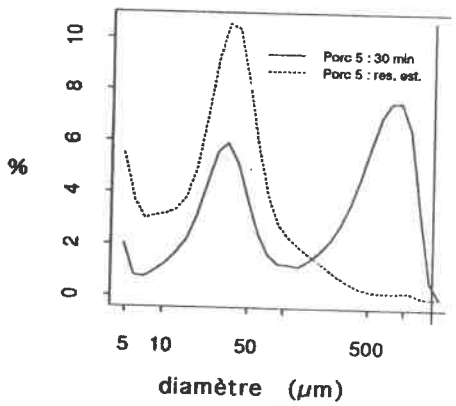
### Gastric emptying

Gastric emptying of food (in dry basis) was different according to the physical structure of the test meals (bread or pasta). Bread emptied from the stomach faster than pasta ($t_{1/2}$: 39±12 minutes vs 156±89 minutes). Four hours after the meal, no bread particles remained in the stomach whereas 20 to 40% of pasta dry matter was still unemptied. The size and shape of the two kinds of pasta (spaghetti, tortiglioni) did not significantly influence their gastric emptying rate.

### Size of food particles leaving the stomach

The size of food particles leaving the stomach changed over time and depended on the physical structure of the test meal. At the beginning of gastric digestion of bread (30 minutes) particle fraction was greater (70% of the total dry matter) than the liquid one but later decreased (45% of the total dry matter) because of solubilisation of bread digestion products. During the first hour of gastric digestion, the particle size was distributed in two peaks (mean dieameter : 30 µm and 600 µm) whereas one peak only was observed after 4 hours of gastric digestion (figure 1).

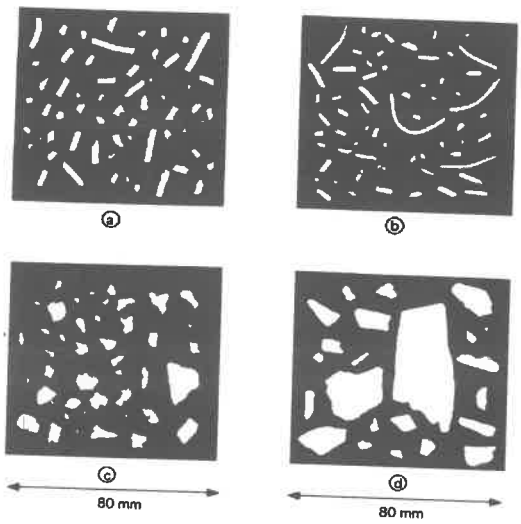
*Figure 1. Distribution of particle size of bread recovered in pig digesta 30 minutes after meal ingestion (——) or remaining in the stomach 240 minutes (·····)*




The dry matter emptied from stomach after pasta meal was equally distributed between large particles (>1mm), intermediate particles (<1mm) and soluble fraction irrespective of the kind of pasta (spaghetti, tortiglioni). During the first 30 minutes of gastric digestion, 36±19% of the dry matter were emptied from the stomach as large particles. The mean area of these particles was respectively 18-29 $mm^2$ for spaghetti and 30 $mm^2$ for tortiglioni (figure 2). This fraction was progressively transformed into smaller particles (<1mm) as gastric digestion went on. After 4 hours of gastric digestion, 22±6% of the ingested pasta

ry matter) emptied as large particles, whereas 26+14% of dry matter were retained by stomach. The later consisted in (i) heterogenous particles with area similar to that of spaghetti particles emptied (20-21 mm2); (ii) very large particles of tortiglioni (90-100mm2, figure 2).

*Figure 2. Particles of spaghetti (SP) and tortiglioni (TO) recovered 30 minutes (30 min) or remaining in stomach (St res.) 240 minutes after meal ingestion (a): SP, 30 min; (b) SP, St res.; (c) TO, 30 min; (d) TO, St res.*




## Conclusions

Our results show that digestible solid particles, larger than 2 mm were able to transit through the pylorus into the duodenum of pigs. The gastric emptying of these large particles will take longer than for smaller ones. The physical structure of food is likely a key parameter governing the particle size entering the duodenum hence their rate of gastric emptying and digestion.

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