# DIGESTION in the PIG

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*We feed our horses hay and oats,*
*With grass for cows and sheep and goats.*
*Chickens look for grain to eat,*
*While ducks find worms, and dogs get meat.*
*Cats have meat and milk and fish;*
*To each, its own peculiar dish.*
*Some are fussy, others not,*
*But pigs, of course, will eat the lot.*

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We wish to apologise for any errors and misrepresentations, but are confident that these will be brought speedily to our attention so that they can be corrected in any subsequent edition.

## PREFACE

The digestive system of the pig is noteworthy in that it contains almost all the features found in the digestive system of any mammal. Even carbohydrate fermentation in an oesophageal portion of the stomach, a feature fully developed in the ruminants, is present in a limited form in the pig. A study of digestion in the pig is thus a sound basis for its understanding in any other mammal. It is this comprehensive and flexible digestive system which gives the pig its capacity to cope with an extremely wide range of feeding stuffs and has thus formed the traditional basis of the usefulness of the pig to man.

Digestion in the pig has been studied by agricultural scientists interested in food utilization, by physiologists who have found the pig to be a useful experimental model for particular studies, and by biochemists and pharmacologists who have found pig slaughterhouse material to be a valuable source of digestive enzymes and gastrointestinal hormones. The results obtained have consequently been scattered among journals in very different fields, and written in a variety of languages. The present book is an attempt to bring this work together. It gives detail on the different digestive processes and shows how the various facets contribute to the functioning of the system as a whole. By showing the present state of knowledge, it should help research workers to concentrate on those aspects where little or no work has been done, and where our admitted ignorance, or our misconceptions based on a few doubtful studies, hinder correct interpretation of work on related topics.

From such a collection of information, two points emerge very clearly. One is the progressive changes with age of almost every aspect of the digestive system, and the other is the relationship between the findings of the physiologist on organ function and those of the nutritionist on growth performance. We have tried to present our material in a way which brings out these points.

While the book is designed primarily for research workers studying the digestive physiology of the pig, it will be of interest to those studying nutrition of the pig or the digestive systems of other species.

CONTENTS

# CHAPTER 1
# DIMENSIONS OF THE TRACT

## INTRODUCTION

The structural anatomy of the digestive system of the pig is described and illustrated in textbooks of veterinary anatomy (e.g. Ellenberger & Baum, 1943; Nickel, Schummer, Seiferle, 1973; Sisson & Grossman, 1975) and will not be dealt with in this book. The organs are illustrated diagrammatically in Fig. 1.1. In the live animal, the stomach, the duodenum and the large intestines have fairly constant positions. The small intestine from the attachment of the pancreas, to the terminal ileum at the junction of the caecum and colon, is very mobile, being only held by its very flexible mesentery. While the small intestine will occupy a specific region of the abdominal cavity, any individual part of it may move quite considerably.

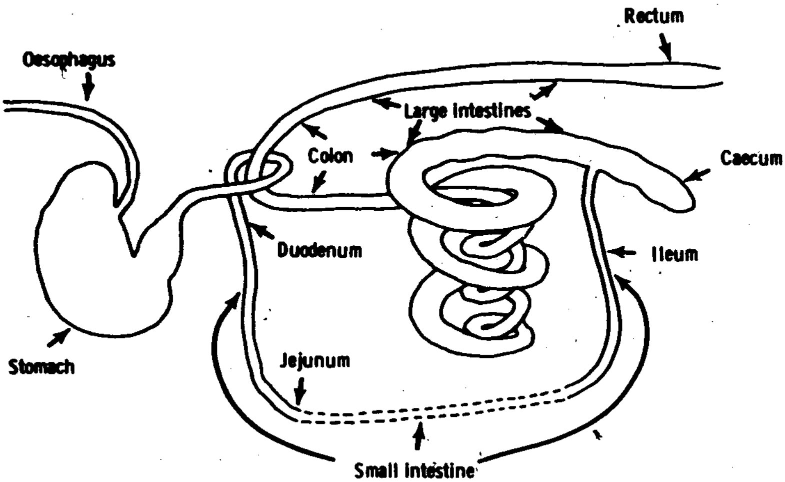


*Fig. 1.1 Diagrammatic representation of the alimentary tract of the pig*

Work on the dimensions of the tract is less adequately covered in anatomy textbooks and will be reported in more detail here.

There cannot be a precise value for the capacity or length of any part of the alimentary tract, as in life the tract is almost continually in motion, with the dimensions of each part altering considerably, sometimes from one second to the next. Almost all the measurements of the dimensions of the alimentary tract have necessarily been made post-mortem and will not correspond with those in life. It was shown by Hirsch, Ahrens & Blankenhorn (1956) in man, and by Leigh-Browne & Harpur (1975) in the pig, that the post-mortem length of the intestine, as measured, is appreciably greater than that during life. Laplace (1970) showed that the method of slaughter affected the post-mortem measurement of intestinal length. Measurements of capacity are also materially affected by the degree of muscle relaxation, so post-mortem values cannot be regarded as a measure of the capacity in the live animal. Nevertheless, post-mortem measurements can be of value in comparing the dimensions of the organs of different animals, provided they are made under comparable conditions.

The limitations of post-mortem measurements do not, of course, apply to weight, but, in all the dimensions (capacity, length and weight), the results of different teams of workers have been remarkably similar. A feature of all of them is a relatively rapid growth between five and eight weeks of age. This is more marked in the large intestines than in the other sections of the gut, and more in the weight than in the other dimensions.

## CAPACITY

The most satisfactory way of measuring the capacity of any section of the gastro-intestinal tract is to immerse the organ in water or saline with one end closed, and then to find the amount of water or saline required to fill the organ. Kvasnitskii (1951) showed that, with this method, the hydrostatic pressure used had a marked effect on the results, particularly with the stomach, and gave results for the capacity of the stomach of six pigs measured at hydrostatic pressure differences between the inside and outside of 10 and 40 cm of water (Table 1.1). He also showed that there was variation in apparent stomach capacity obtained by slaughtering at different times after feeding (Table 1.2).

Using a standard hydrostatic pressure of 10 cm of water and a standardised feeding regime, Kvasnitskii measured the post-mortem capacity of the stomach, small and large intestines of pigs of ages from 1 day to 4 years (Table 1.3). Using the same hydrostatic technique, Jezková (1962) made a study on sow-reared piglets, covering the age-range of 1–26 days in more detail (Table 1.4). Vodovar, Flanzy & Francois (1964) compared the hydrostatic method of measuring capacity of the small intestine with results calculated from the length and diameter, and found the two methods to agree to within 8%. Using length and diameter measurements on pigs from birth to 3 years of age, they calculated the small intestine capacities (Table 1.5).

If we compare the mean values for capacity of the various organs obtained by Kvasnitskii, by Jezková and by Vodovar, Flanzy & Francois (Figs. 1.2, 1.3 and 1.4) we find that in spite of the factors which can cause considerable variation in this type of measurement, the various authors obtained quite similar results.

*Table 1.1 The apparent capacity of the stomach of the pig when measured with different pressures of water (from Kvasnitskii, 1951)*

| Weight of animal (kg) | Capacity of stomach (litres) under pressure of water column | |
|---|---|---|
| | 10 cm | 40 cm |
| 97 | 3.8 | 8.0 |
| 100 | 4.6 | 7.2 |
| 99 | 4.0 | 7.4 |
| 158 | 4.6 | 9.0 |
| 154 | 5.8 | 11.8 |
| 154 | 7.0 | 12.4 |

*Table 1.2* *Effect of time between feeding and slaughter on capacity of the digestive organs (mean values on 10 pigs in each group) (from Kvasnitskii, 1951)*

| Wt. (kg) | Interval between feeding and slaughter (hours) | Capacity (litres) Stomach | Small intestine | Large intestine |
|---|---|---|---|---|
| 155 | 5 | 6.0 | 19.4 | 18.8 |
| 154.6 | 15 | 3.7 | 17.7 | 18.6 |

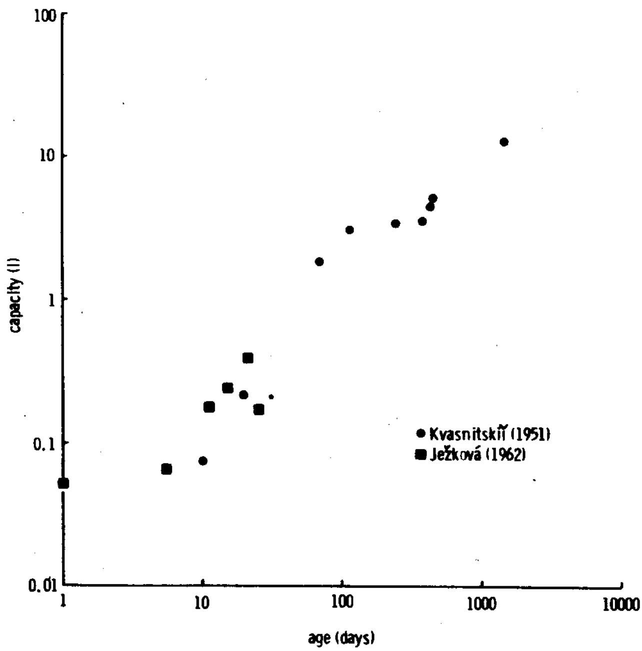


*Fig. 1.2* *The mean capacities of stomachs of pigs of different ages as found by different workers. Both age and capacity are on logarithmic scales*

*Table 1.3* ***Mean weights and capacities of the stomach and weights, capacities and lengths of the intestines of pigs of different age groups (from Kvasnitskii, 1951)***

| Mean weight (kg) | Age (days) | Stomach Weight (g) | Stomach Vol. (litres) | Small Intestine Weight (g) | Small Intestine Vol. (litres) | Small Intestine Length (m) | Large Intestine Weight (g) | Large Intestine Vol. (litres) | Large Intestine Length (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 4.5 | 0.025 | 40 | 0.1 | 3.8 | 10 | 0.04 | 0.8 |
| 2 | 10 | 15 | 0.073 | 95 | 0.2 | 5.6 | 22 | 0.09 | 1.2 |
| 3 | 20 | 24 | 0.213 | 115 | 0.7 | 7.3 | 36 | 0.1 | 1.2 |
| 18 | 70 | 232 | 1.815 | 996 | 6.0 | 16.5 | 458 | 2.1 | 3.1 |
| 32 | 115 | 360 | 2.50 | 1180 | 10.7 | 18.0 | 714 | 6.6 | 4.3 |
| 69 | 208 | 685 | 3.17 | 1670 | 13.3 | 18.8 | 1380 | 11.7 | 5.4 |
| 103 | 255 | 754 | 3.40 | 1530 | 14.1 | 18.8 | 1280 | 10.1 | 5.0 |
| 152 | 380 | 980 | 3.55 | 2510 | 20.6 | 23.7 | 2010 | 15.7 | 6.8 |
| 156 | 428 | 844 | 4.56 | 2323 | 19.1 | 22.4 | 2184 | 18.1 | 6.1 |
| 154 | 449 | 980 | 5.16 | 2310 | 17.4 | 21.2 | 1970 | 17.2 | 6.3 |
| 270 | 4 years | 1430 | 12.68 | 1998 | 22.6 | 22.9 | 2790 | 25.6 | 7.5 |

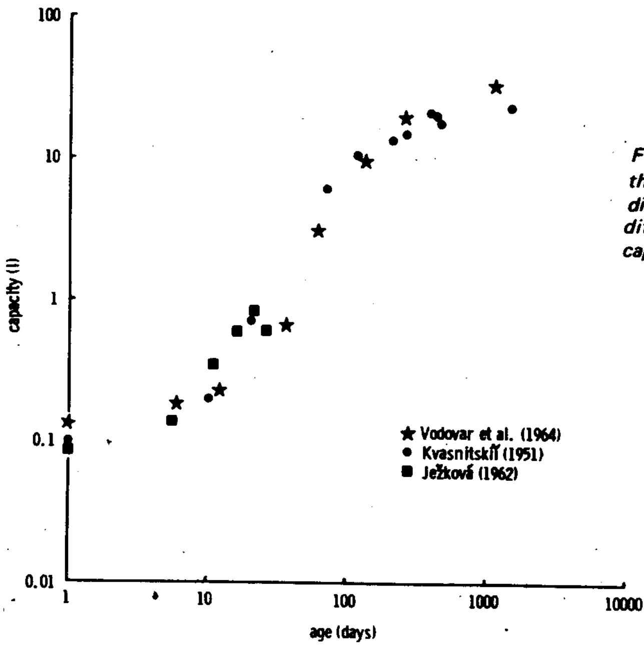


*Fig. 1.3 Mean capacities of the small intestines of pigs of different ages as found by different workers. Both age and capacity are on logarithmic scales*

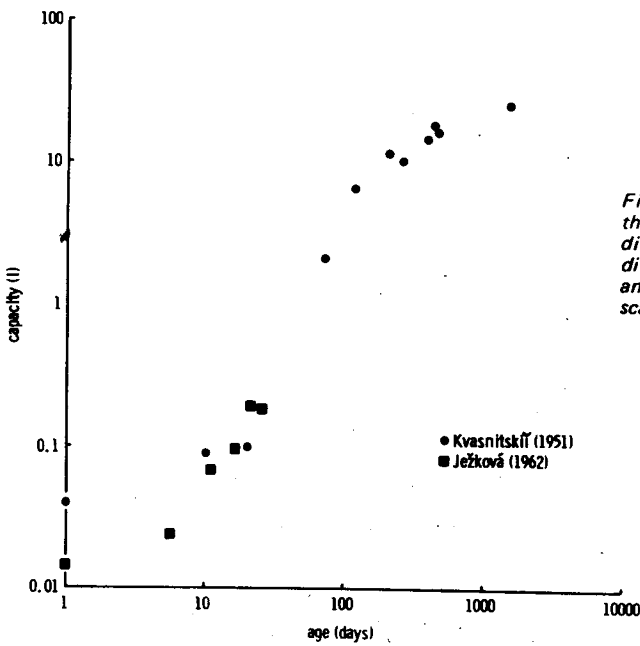


*Fig. 1.4 Mean capacities of the large intestines of pigs of different ages as found by different workers. Both age and capacity are on logarithmic scales*

*Table 1.4 Capacities of the stomach and intestines of sow-reared piglets up to 26 days of age (from Jezková, 1962)*

| Age (days) | No. of animals | Stomach | Volume (cm²) Small Intestine | Large Intestine |
|---|---|---|---|---|
| 1 | 5 | 52 ± 14 | 88 ± 14 | 14 ± 6.0 |
| 5–6 | 5 | 65 ± 10 | 138.6 ± 35 | 23 ± 1.1 |
| 11 | 6 | 179 ± 33 | 350 ± 25 | 66 ± 10 |
| 16 | 5 | 240 ± 34 | 587 ± 42 | 94 ± 14 |
| 21 | 4 | 390 ± 128 | 824 ± 142 | 190 ± 107 |
| 25–26 | 5 | 172 ± 95 | 585 ± 324 | 184 ± 117 |

### Effect of Diet on Capacity

There have been a number of reports demonstrating that the bulk of the food material ingested affects the subsequent capacity of the gastrointestinal tract.

Kvasnitskii (1951) compared pigs reared from 3 months of age (18 kg live weight) on either bulky or concentrated diets, and at slaughter, found the mean total capacities of the digestive organs to be greater on the bulky diets. Starovoitov (1956) compared the capacities of the digestive organs at slaughter of 4 groups of pigs which had had different supplements during the suckling period and found that the capacities of the stomach, small and large intestines were greater where more supplement was given, and still greater when this contained bulky foods.

Shearer & Dunkin (1968) found that pigs fed to 120 lb weight on high-lactose diets had a much larger caecum than those on a low-lactose diet or one without lactose. As described in Chapter 6, lactose, when fed at high levels, is incompletely absorbed in the small intestine of adult pigs, so that there is osmotic retention of water and a consequent increase in the volume of the contents entering the caecum.

## LENGTH

Leigh-Browne & Harpur (1975), using a plastic tube inserted through a cannula to measure the in vivo length on a conscious pig, found this to be about half the post-mortem length. This is about the same ratio of in vivo to post-mortem length as was found in man by Hirsch, Ahrens & Blankenhorn (1956). While Nickel (1933) found that a wide tube passed in vivo caused rucking up and shortening of the intestine, Hirsch et al. and Leigh-Browne & Harpur established that this was not the case in their studies. Laplace (1970), comparing lengths of intestinal loops in fasted, anaesthetized pigs with measurement made post-mortem on the same animals, found the in vivo measurements to be longer, but this might be related to fasting and anaesthesia. He also found that the method of slaughter made a difference to the post-mortem length. The shrinkage after removal of the intestine from the pig can be readily observed especially in empty sections of the small intestine. Results of measurements must therefore be regarded only as approximate and as comparisons rather than absolute values.

Figures for the length of the small and large intestines from birth to 4 years of age were given by Kvasnitskii (1951) (Table 1.3) and by McCance (1974) and

*Table 1.5* *Lengths and capacities of the small intestines of pigs (from Vodovar, Flanzy & Francois, 1964)*

| Pigs | | | Small Intestine | | | |
|---|---|---|---|---|---|---|
| | | | | Diameter | | |
| Number | Age (days) | Weight (kg) | Length (m) | Duodenal end (cm) | Ileal end (cm) | Capacities (ml) |
| 22 | birth | 0.950–1.150 | 2.15 (2.07–2.24) | 0.65 (0.60–0.68) | 0.65 (0.59–0.68) | 72 |
| 12 | 1 | 1.100–1.250 | 3.05 (2.94–3.14) | 0.72 (0.67–0.76) | 0.72 (0.65–0.75) | 130 |
| 12 | 6 | 1.840–2.300 | 3.85 (3.69–3.97 | 0.78 (0.73–0.80) | 0.78 (0.71–0.80) | 183 |
| 8 | 12 | 2.500–2.800 | 4.50 (4.33–2.62) | 0.8 (0.77–0.85) | 0.8 (0.75–0.83) | 226 |
| 5 | 30–40 | 7–9 | 6.55 (6.31–6.73) | 1.62 (1.49–1.72) | 1.58 (1.48–1.69) | 662 |
| 3 | 55–65 | 15–17 | 9 (8.70–9.35) | 2.4 (2.1–2.7) | 2.2 (1.9–2.5) | 3110 |
| 15 | 120–140 | 45–55 | 13 (12.46–13.46) | 3.2 (2.75–3.55) | 3 (2.7–3.4) | 9744 |
| 35 | 200–230 | 95–105 | 16.50 (15.87–17.27) | 4.2 (3.6–4.7) | 3.6 (3.3–4.1) | 19182 |
| 2 | 3 years | 223 & 245 | 18.40 & 19.60 | 4.9 & 5.1 | 4.6 & 4.8 | 32945 |

for the small intestine by Vodovar, Flanzy & Francois (1964) (Table 1.5). More detailed figures over the age range of 1–26 days were given Jezková (1962) (Table 1.4). Values for newborn, 1 and 10 day old pigs have been given by Widdowson, Colombo & Artavanis (1976).

Fig. 1.5 shows the results of Kvasnitskii, Vodovar et al., Jezková, McCance, and Widdowson et al., for the small intestine, plotted with a logarithmic age scale. From 20 days onwards, the measurements given by Vodovar et al. are rather lower than those of the other three authors, which show remarkable agreement. Fig. 1.6 shows the results of Kvasnitskii, Jezková, McCance and Widdowson et al. for the large intestine. Again, in spite of all the possible causes of variation, the measurements are in good agreement.

## WEIGHT

The total tissue weights of various sections of the digestive tract in pigs of different ages have been reported by McMeekan (1940) and Kvasnitskii (1951) and for newborn, 1 day and 10 day old piglets by Widdowson, Colombo and Artavanis (1976). Figs. 1.7, 1.8 and 1.9 illustrate diagrammatically the results of these workers. The similarity of the results of the various workers is evident, as in the results on length and volume. The relatively rapid increase in weight of the large intestine between 5 and 8 weeks of age is noteworthy.

A significant difference has been demonstrated by Miniats & Valli (1973) between the weights of the intestines of germ-free and conventional young pigs, with specific-pathogen-free pigs being intermediate. The intestines of the germ-free pigs had thinner walls and were consequently lighter.

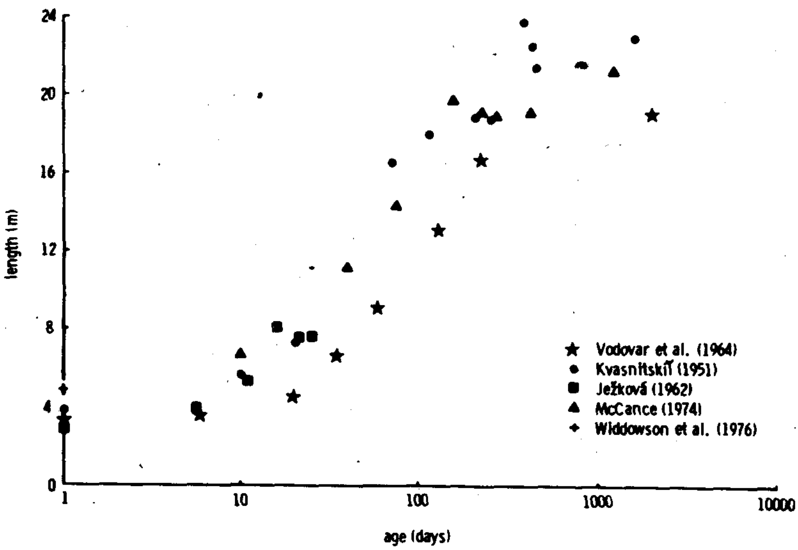


*Fig. 1.5 Mean lengths of the small intestines of pigs of different ages as found by different workers. Age is plotted on a logarithmic and length on a linear scale*

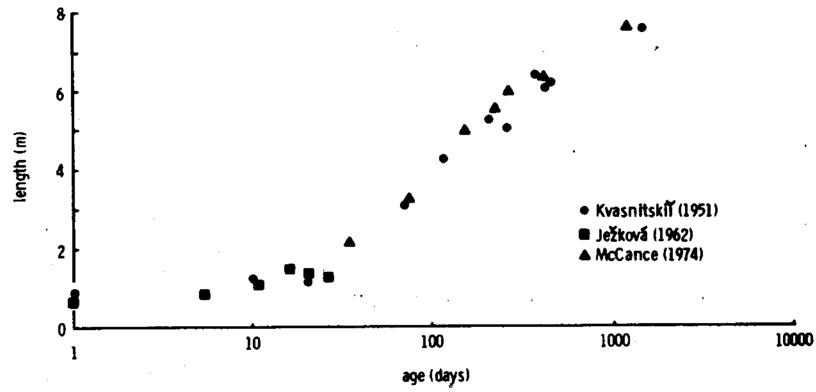


*Fig. 1.6* *Mean lengths of the large intestines of pigs of different ages as found by different workers. Age is plotted on a logarithmic and length on a linear scale*

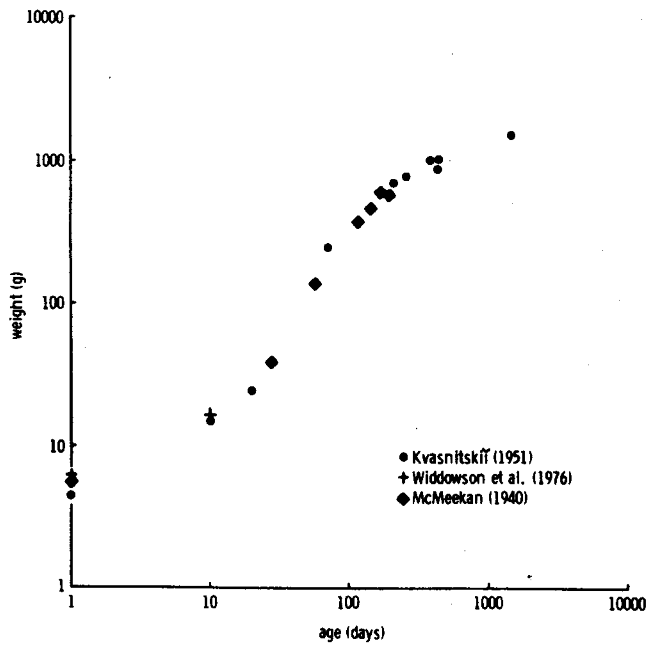


*Fig. 1.7* *Mean tissue weights of stomachs of pigs of different ages as found by different workers. Both age and weight are plotted on logarithmic scales*