Postprandial absorption of α-aminonitrogen and sugars in pigs. Quantitative measurement using discontinuous pancreatic derivation

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The role of the pancreas in protein digestion was investigated in the past either by digestibility or absorption studies. Partial pancreatectomy in the dog (Cohen and Annegers, 1953) or ligature of the pancreatic duct in the pig (Pekas, Hays and Thompson, 1964 ; Anderson and Ash, 1971 ; Corring and Bourdon, 1977) resulted in poor utilization of dietary protein, decrease in apparent digestibility ranging between 13 and 70 p. 100. After total pancreatectomy in dog, nitrogen absorption decreased by 30 p. 100 one hour after a meal containing ^{131}I-labelled serum albumin (Shingleton et al,, 1955 ; Douglas et al., 1953). Measurement of the α-aminonitrogen level in the systemic plasma was used to define total pancreatic enzyme deficiencies in children (West, Wilson and Eyles, 1946 ; Anfanger and Heavenrich, 1949). However, the limits of the methods used for these studies must be examined. Only the disappeai ance of dietary constituents is measured with digestibility techniques so that the kinetics of the occurrence of nutrients in the organism or the nature of these nutrients is not specified. Furthermore, α-aminonitrogen titer in the systemic plasma hardly indicates the process of absorption because absorbed nutrients may be metabolized in the liver.

For these reasons, it seemed necessary to use more accurate criteria for estimating the role of the pancreas in the digestive processes. Thus, the absorption of a given nutrient can be quantitatively determined at any moment after the meal by simultaneously measuring the nutrient enrichment of the digestive tract efferent blood and the flow rate of the blood irrigating this organ. In other words, the amounts absorbed (q) after a determined meal and for a given time (dt) can be estimated by continuously measuring postprandial differences in porto-arterial titer $(Cp - Ca)$ of the nutrient studied and portal flow rate (F_r), using the formula, $q = (Cp - Ca) F_r dt$. It must be emphasized that this computation does not take into account the quantities of nutrients metabolized in the gut wall ; it concerns only apparent absorption. This method was used to study the effect of the presence or absence of pancreatic juice in the gut on the kinetics of absorption of α-aminonitrogen, reducing substances and aminoacids. The results of studies in progress on the latter will not be reported here.

Material and methods.

Nine pigs (30-50 kg liveweight) were fitted with permanent cannulae in the portal vein and the aorta (through the carotid). A flow probe connected with an electromagnetic flowmeter was placed around the portal vein (Rérat, 1971). These same animals were also fitted with pancreatic and duodenal permanent cannulae (Corring, Aumaitre and Rérat, 1972). About ten days after these had been placed, several series of assays were done on the animals (reintroduction vs no reintroduction of pancreatic juice into the gut) after intake of a given meal (table 1) varying in

TABLE 1

Cereal mixture (composition per 100)

Barley	35
Wheat	15
Maize	15
Wheat bran	10
Soyabean meal	18
Sodium chloride	0.5
Ground chalk	1.2
Calcium carbonate	1.2
Trace elements	0.1
Vitamin mixture	4

$N \times 6.25 = 16.3$

amount between 250 g and 700 g. In experiments with no reintroduction, return of pancreatic juice to the gut was stopped 14 hrs before the meal to be sure that no pancreatic enzymes were left in the gut ; this was confirmed by enzymatic determination of gut contents (Palmers and Peters, 1965). Blood levels of α-aminonitrogen and reducing substances (Vaissade, Aumaitre and Rérat, 1973) were continuously recorded during an 8-hour postprandial period.

Results.

For studying the gross effect of exocrine pancreas on absorption, all data on the occurrence of α-aminonitrogen and reducing substances in the portal blood during an 8-hr post-prandial period were related to protein and carbohydrate intake, levels, respectively (table 2).

When the pancreatic juice was returned to the gut, there was a close linear relationship between absorbed α-aminonitrogen and protein intake ; the correlation coefficient, $r = 0.88$, was highly significant. The value of the ordinate at the origin (for zero protein intake) is of special interest ; this 20 g value, representing the absorbed α-aminonitrogen of endogenous origin, was very close to the data directly recorded with a protein-free diet (16.3 g for a postprandial period of 7 hrs : Rérat, Corring and Laplace, 1976). When no pancreatic juice was reintroduced, the relationship between absorption and ingestion level was not so close, and the 0.56 correlation coefficient

only significant at the 0.05 level. When comparing the two regressions, it was seen that derivation of pancreatic enzymes resulted in marked impairment of nitrogen absorption, i. e. about a 40 p. 100 reduction for a 100 g protein meal. When consider-

TABLE 2

Relationship between the amount absorbed (Y g) after 8 h and the amount ingested (X g)

	n	Regression	r	Significance
α-aminonitrogen				
With pancreatic juice	14	$Y = 0.64 X + 20$	0,887	**
Without pancreatic juice	11	$Y = 0.31 X + 21$	0.561	*
Reducing sugars				
With pancreatic juice	10	$Y = 0.42 X - 10$	0.774	*
Without pancreatic juice	9	$Y = 0.13 X + 80$	0.215	NS

ing the mean data of apparent absorption during an 8-hr postprandial period (table 3), this difference was not apparent for the lowest intake levels ($\sim$ 40 g), absorption percentage being almost the same in the two conditions (with vs without pancreatic juice). However, this difference was evident for the highest quantities ingested (41 p. 100 reduction for 80 g intake, 35 p. 100 reduction for 112 g intake). It must be noted at the highest levels of intake that, in the absence of pancreatic enzymes, the quantities

TABLE 3

Apparent absorption (during a postprandial period of 8 hrs) of sugars dan aminoacids ;
variations with level of ingestion

	Ingested quantity (g)	With pancreatic juice			Without pancreatic juice		
		n	Absorption		n	Absorption	
			Quantity (g)	p. 100		Quantity (g)	p. 100
Reducing	365	4	136 ± 8.1	37.2 ± 2.2	4	117 ± 21.6	$32,1 \pm 5.9$
Substances	511	4	202 ± 32.2	40.5 ± 5.0	4	155 ± 53.5	30.4 ± 10.5
Free amino	$\sim$ 40 *	3	42,7	100.5	2	37.0	99.2
	80	4	72.5 ± 3.1	90.6 ± 3.9	4	42.7 ± 7.8	53.3 ± 9.8
acids	112	5	90.3 ± 5.9	80.7 ± 5.3	4	58.3 ± 8.3	52.1 ± 7.4

* mean : with pancreatic juice : 42.6 g.
       without   —   —   : 37.6 g.

absorbed increased at the same rate as the intake level, the percentage of absorption (53 p. 100), however, being far below that observed in normal conditions (80 to 90 p. 100). All these data indicated that the impairment of nitrogen digestion due to absence of pancreatic enzymes was more marked for high intakes than for low quantities. The problem of absorption of very high quantities must therefore be studied in more detail.

The evolution of the process of absorption (expressed as hourly quantities during the course of digestion) (table 4) showed that reduction of absorption, only evident

TABLE 4

Evolution of the mean absorption of α-aminonitrogen per time unit (g/hour) during the post-prandial period

Time interval after the meal (h)			0-2	2-4	4-6	6-8	$\overline{m}$
Amount of protein ingested	Pancreatic juice	Number of data					
40 (∼)	+	(3)	7.5	5.9	3.8	4.2	5.4
	—	(2)	6.3	5.8	3.3	3.3	4.8
60	+	(2)	10.3	10.1	7.3	5.3	8.3
	—	(1)	5.0	6.5	4.4	2.3	4.6
80	+	(4)	9.5	10.1	8.7	7.9	9.1
	—	(4)	4.8	5.8	6.3	4.5	5.3
112	+	(5)	9.8	13.7	11.3	10.2	11.3
	—	(4)	6.0	9.7	7.4	6.0	7.3
$\overline{m} = 80,6$	+	(14)	9,3	10.5	8.4	7.6	8.95
$\overline{m} = 82,0$	—	(11)	5.5	7.3	6.0	4.6	5.86

Statistical significance [1]				Degree of freedom
Pancreatic juice (+ or —)	12.41 **	11.13 **	6.57 *	8.19 *	(1)
Amount of protein ingested	0.34 NS	7.82 **	6,39 **	3.93 **	(3)
Interaction	0.60 NS	0.88 NS	0.47 NS	0.39 NS	(3)

[1] Value of F.
* Significant at the 0.05 level.
** Significant at the 0.01 level.
NS Non Significant.

over and from 60 g of protein intake, occurred very early when the pancreatic juice was not returned ; the relative magnitude of the decrease caused by absence of pancreatic enzymes seemed fairly constant during the whole digestive process, whatever the protein intake. It is to be wondered what happens after the end of the study period ; it is most likely that digestive and absorptive processes continue during a longer period when pancreatic secretions are absent than when they are present. Despite the decreasing hourly quantities absorbed, the drop in nitrogen digestibility

was no more than 13 p. 100 when pancreatic juice was derived by cannulation (Corring and Bourdon, 1976). This decrease in digestibility was, however, about 35 p. 100 over a longer period when the pancreatic duct was ligated (Corring and Bourdon, 1977).

As regards apparent absorption of sugars, when the pancreatic juice was returned to the gut, there was a linear relationship between occurrence of reducing substances (expressed as cumulated amounts absorbed during an 8-hour postprandial period) and quantity of dietary carbohydrates (table 2) ; the correlation coefficient ($r = 0.77$) was significant at the 0.02 level. The slope of this line was close to that previously noted for animals without any pancreatic and duodenal cannulae and fed maize starch diets (Rérat and Aumaitre, 1975 ; Rérat et al., 1976). When the pancreatic juice was not returned, there was no relationship between absorption and intake level because of the great dispersion of data. However, means recorded at two intake levels (table 3) showed that absence of pancreatic enzymes resulted in about a 20 p. 100 depression of carbohydrate absorption rate for 8 hrs. Comparison of this result with digestibility data (Corring and Bourdon, 1976) shows there is a compensatory effect during late digestion, the differences in absorption between the two assays (with vs without pancreatic juice) disappearing when digestibility is examined.

These preliminary results show that absence of pancreatic enzymes results in early depression of the absorption of protein and carbohydrate digestive products. Decreased carbohydrate absorption, due to absence of amylolytic enzymes, is less than depressed nitrogen absorption because of absence of proteolytic enzymes. However, this early depression does not necessarily result in a drop in digestibility of the same magnitude, and must be considered in relation to its effects on the duration of digestion, pattern of absorption products (particularly aminoacids) and their metabolic utilization.

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Commission CNERNA Digestion-Absorption,
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Résumé. Le rôle du pancréas exocrine dans la digestion des protéines et des glucides a été examiné à l'aide d'une méthode directe permettant de rendre compte à la fois de la cinétique de l'absorption et de la nature des nutriments absorbés. Dans ce but on mesure simultanément, de façon continue, l'enrichissement postprandial en nutriments (azote α aminé et sucres réducteurs) du sang efférent du tube digestif, et le débit D du sang irriguant cet organe, les quantités (q) absorbées étant calculées grâce à la formule $q = (Cp — Ca) D dt$, où Cp et Ca représentent les concentrations instantanées des nutriments étudiés dans la veine porte et l'artère aorte, et dt le temps d'étude (8 h). Neuf porcs (30-50 kg de poids vif) munis de cathéters permanents de la veine porte et de l'artère aorte, d'une sonde débitmétrique autour de la veine porte ainsi que de canules permanentes du canal pancréatique et du duodénum sont soumis à plusieurs séries d'essais (réintroduction ou non réintroduction du suc pancréatique dans le tube digestif au cours de la digestion), réalisés après l'ingestion d'un repas défini. Dans ces conditions, l'absence de suc pancréatique se traduit très précocement par un ralentissement marqué de l'absorption d'azote α-aminé, les quantités apparues dans l'organisme pendant 8 h étant environ 40 p. 100 inférieures à celles trouvées en présence du suc pancréatique. Ce phénomène semble varier selon le niveau de consommation. L'absorption apparente des sucres est sensiblement moins affectée que celle des protéines, la dépression liée à l'absence de suc pancréatique étant environ de 20 p. 100.

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