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Gastric Lipase in the Newborn Rat

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Summary

A substantial portion of rat milk triglycerides was hydrolyzed in the ligated stomach of suckling rats with excised lingual gland and pancreas, due to the action of gastric lipase. Free fatty acids were the main lipolytic products. There were some diglycerides and traces of monoglycerides. Medium chain length (C_8-C_{12}) fatty acids were predominantly recovered in the free fatty acid fraction, whereas the remaining tri- and diglycerides became richer in long chain ($\geq C_{14}$) fatty acids suggesting a preferential lipolysis of medium chain fatty acid ester bonds. The lipase activity in extracts of stomach wall and sublingual gland tissue was more stable at acid pH and more resistant to the action of pepsin than the activity of pancreatic lipase. Trypsin strongly affected lingual lipase activity but only moderately reduced gastric and pancreatic lipase activity. Presence of sodium taurocholate made the lingual and gastric lipases less sensitive to proteolytic attack.

It was also found that the activity of gastric lipase, related to the tissue protein content, decreased with the age of rats, whereas that of lingual lipase increased. The joint capacity of the stomach and lingual gland lipases amounted to about 50% of the total digestive lipolytic capacity 6 days after rat birth but decreased to about 20% at 60 days of life. This was due mainly to the considerable increase in the pancreatic gland size.

Speculation

Lingual and gastric lipases are distinct enzymes with a mildly acidic pH optimum. They are stable in acid medium, resistant to peptic proteolysis and able to split all three ester bonds on the glycerol molecule. These properties enable them to efficiently digest milk triglycerides in the stomach of the newborn. There is a carry-over of digestive activity by lingual and gastric lipases into the upper intestine where they supplement the action of pancreatic lipase and complement it with respect to lipid emulsification. Gastric lipase seems important in intestinal lipolysis because since it is activated by bile salts, the presence of which protects the enzyme against tryptic proteolysis. Although the relative contribution of gastric and lingual lipases to the overall lipolytic capacity falls short of that of pancreatic lipase, it is likely that the extrapancreatic lipases are compensatory in conditions of pancreatic lipase deficiency.

A lag in the development of exocrine pancreatic function and low concentration of bile salts were cited as possible reasons that account for the low capacity of intestinal lipid absorption during the postnatal period (7, 8, 24, 31, 32, 33, 34). In this situation, lipid hydrolysis in the stomach could compensate, at least in part, for the low duodenal digestion. Evidence of lipolytic activity in the stomach in man and in experimental animals is available from several recent studies (5, 11, 16, 19), as well as from earlier work cited in these reports. Intragastric lipolysis was observed in premature and term infants (16) and in infants with pyloric stenosis (12). Lipase activity was also found in gastric aspirates of infants with congenital esophagal atresia (29).

Efforts were made to determine the origin and to characterize the lipolytic activity in the stomach. Lipase, which is derived from sublingual serous and pharyngeal glands, flows into the stomach. It was recently investigated extensively (3, 12, 13, 14, 15, 17, 18). Evidence of the existence of a genuine gastric lipase is also available (1, 4, 5, 6, 11, 19, 28). Recently, we provided additional data on the properties of a gastric lipase, distinct from those of lingual and pancreatic lipases, and pointed to the stomach wall as the source of this enzyme in the rat (21). In particular, the gastric enzyme, released *in vitro* from stomach wall slices upon stimulation with histamine or pentagastrin, has shown optimal activity at pH 6.8. It was susceptible to considerable activation by bile salts and cleaved all three ester bonds on the glycerol backbone without marked preferences (21).

Presently, we wished to explore the physiologic circumstances in which the gastric lipase might play a role in overall fat digestion, especially in newborn rats. It is of interest to detect the conditions both favorable and inhibitory to its function in the stomach, as well as after the passage into the duodenum. The activities of lingual and pancreatic lipases are studied under similar conditions for comparison.

MATERIALS AND METHODS

IN VIVO EXPERIMENTS

Albino rats of both sexes from the Hebrew University stock were used. To explore the extent of intragastric lipolysis of milk, 10-day-old rats were separated for 12–14 h from their mothers to allow stomach emptying and returned therafter for 2 h of suckling. The rats were then separated and at different times thereafter were killed by cervical dislocation, the stomach contents were removed and extracted for the analysis of lipolysis products (see below).

To measure specifically the lipolytic activity of gastric origin, rats without pancreas and lingual glands were prepared in several experiments. The animals were fasted overnight, the pylorus and esophagus were ligated under light pentobarbital anesthesia and thereafter the pancreas and the sublingual serous glands were excised. A polyethylene catheter was inserted into the stomach prior to the ligation, through which the stomach was rinsed with 0.9% NaCl solution. The washings were devoid of lipolytic activity. One ml of rat milk (obtained from nursing rat donors) was then introduced through the catheter. The stomach contents were recovered after 1 h of incubation and lipolysis was assessed as described below.

IN VITRO EXPERIMENTS

Homogenates of excised and well rinsed rat stomachs, sublingual serous glands and pancreas were prepared in 0.2 M sucrose solution (1: 3 w/v) at 4°C in an Ultra Turrax homogenizer. The hemogenates were centrifuged for 15 min at 1400 X *g* at 4°C. The supernatant fluid was used promptly as the enzyme source. In other experiments, acetone powders were prepared from the tissue homogenates at 4°C; rinsed with ether; dried in vacuum; stored not more than 1 wk at −20°C. For lipase assay, the dried powder was suspended in the buffer of choice and the clear supernatant fluid used after centrifugation at 2000 X *g* for 10 min.

LIPASE ASSAY USING LABELED TRIGLYCERIDE (TG)

The substrate was prepared by mixing 80 μCi of 1-[^{14}C] glycerol trioleate (Radiochemical Centre, Amersham, U.K.) with 212 mg of nonlabeled glycerol trioleate in heptane. The solvent was evaporated under N_2 and the lipid was emulsified by sonication for 1 min at 4 ml of 5% gum arabic solution. Six ml of neutralized 12% bovine albumin solution and 10 ml of 0.1 M borax buffer were added, the pH of which was 6.8 for gastric lipase, 5.8 for lingual lipase and 9.2 for pancreatic lipase assays. The assay mixture, consisting of 100 ml substrate (containing 1.2 μmoles of glycerol trioleate, 3.6 mg albumin) and 100 μl of the tissue homogenate or acetone powder extract, was incubated for 30 min at 37°C in a shaking bath. The reaction was stopped by the addition of 3.25 ml of a mixture of a methanol:chloroform:heptane (1.41:1.25:1.00, v/v/v) according to Belfrage and Vaughan (2) and the free fatty acids (FFA) were separated into the upper phase by the addition of 1.05 ml of potassium carbonate-borate buffer (pH 10.5) with agitation. A portion of the upper phase was transferred to vials containing 6 ml Instagel (Packard, USA) and counted in a liquid scintillation spectrometer. The results (mean of triplicates) were multiplied by a factor correcting for FFA extraction (72%) and the lipase activity was expressed as μmoles/h of FFA liberated per g of homogenate protein. The protein content in tissue homogenates and acetone powder extracts was determined by a modification of the method of Lowry, *et al.* (22).

LIPASE ASSAY USING NONLABELED TG SUBSTRATE AND GAS LIQUID CHROMATOGRAPHY

The assay of *in vivo* lipolysis of milk, as well as that of purified nonlabeled triglyceride (TG) substrates, was carried out on the reaction mixture as described for the labeled glycerol trioleate. With the purified TG of varying chain length (Sigma Chemical Co. Ltd., U.S.A.), double amounts of the substrate and enzyme were used. The reaction was stopped by the addition of methanol: chloroform (1:2, v/v) or of Dole's extraction mixture (9). The solvent containing the lipolytic products was evaporated and the FFA, diglyceride (DG) and monoglyceride (MG) were first separated on thin layer chromatographic plates with a solvent system containing hexane:diethylether:glacial acetic acid (80:20:3, v/v/v). The separated spots were visualized with 0.01% Rhodamine B in ethanol under UV light, scraped into small glass tubes and methylated for 16 h at 60°C by the addition of 1 ml dried methanol containing 2% concentrated sulfuric acid. The methyl esters were taken up in hexane together with methyl heptadecanoate (Supelco, Inc., U.S.A.) as an internal standard. Portions were injected into a glass column containing 10% SP 2330 on 100/120 chromosorb W-AW, in a Packard model, 824 gas chromatograph. Standard mixtures of fatty acid methyl esters of different chain length (Supelco, Inc., U.S.A.) were used for calculation of retention times and correction factors. The areas under the peaks were measured with the aid of Spectra Physics, System I computing Integrator (U.S.A.).

RESULTS

INTRAGASTRIC LIPOLYSIS OF MILK TG

Considerable lipolysis of rat milk TG occurred in the stomach of suckling rats. As shown in Figure 1, >50% of the TG were hydrolyzed at 2 h after the cessation of suckling. The main product was FFA, accounting for most of the cleaved ester bonds. DG also increased appreciably, whereas the increase in MG during lipolysis was negligible. It should be noted that the rate of intragastric lipolysis during the first 30 min was faster than that observed during the following 90 min as apparent from the recovery of the lipolysis products.

To appraise the specific contribution of gastric lipase to the intragastric TG lipolysis, rat milk was introduced into the stomach of rats with ligated pylorus and esophagus and excised lingual serous glands and pancreas. Of the 170 μmoles of TG ester bonds

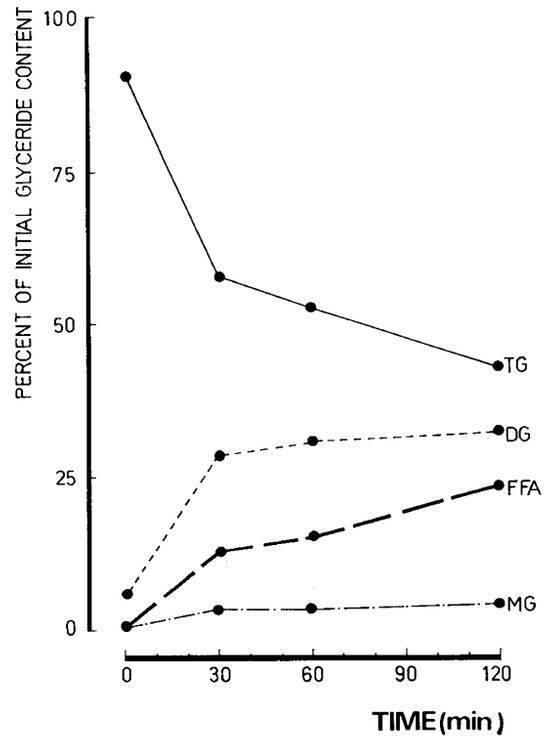

Fig. 1. Time course of intragastric lipolysis of rat milk TG in newborn rats. Values are means of three experiments.

intubated into the stomach, 48 μmoles (or about 28%) were split on the average during 1 h of intragastric incubation, of which about 58% was recovered as FFA (Table 1). The increment in DG and MG among the lipolytic products was small; 8 out of 48 μmoles of fatty acids (20%) cleaved from the original TG were found in the DG fraction and only 1.1 μmoles (or 2.2%) in the MG fraction.

Table 1 also shows the results of gas liquid chromatographic analysis of the intragastric lipolytic products. The FFA fraction comprised 50% medium chain fatty acids, whereas the proportion of long chain fatty acids in the TG and DG was higher. This is well demonstrated by a >3-fold increase in the ratio of medium chain/long chain fatty acids in the FFA fraction and a >2-fold decrease in the same ratio in the remaining TG substrate.

Samples of rat milk were also tested for any intrinsic lipolytic activity that might have contributed to the results presented in Figure 1 and Table 1. Rat milk, when incubated *in vitro* at 37°C for 1 h (either alone or in the presence of labeled substrate, with or without 4% albumin) showed no appreciable increase in FFA, at pH 6.4–7.0 or at pH 8.5 adjusted by the addition of 0.1 M borax buffer. Addition of 6 mM sodium taurocholate did not activate lipolysis in rat milk in contrast to the presence of a bile salt–activated lipase in human milk (20). It was assumed, therefore, that rat milk was devoid of intrinsic lipolytic activity under the circumstances of intragastric lipolysis.

EFFECT OF EXPOSURE TO ACID pH AND TO PROTEASES

The pH of stomach contents in suckling rats was found to range from 4.2–5.8 and that in the 2 month-old rats from 3.2–5.2. These values are somewhat lower than the optimal pH 6.8 for gastric lipase, or pH 5.8 for lingual lipase, as determined under our conditions of *in vitro* lipolysis (21). To investigate the stability of the lipases at the low pH prevalent to the stomach, *in vitro* incubations were performed showing that gastric, as well as lingual lipases in homogenates of their respective tissues or origin, were definitely more resistant to pH 4 or pH 3 than pancreatic lipase (Fig. 2).

The gastric and lingual lipases also retained most of their

Table 1. *Lipolysis of rat milk TG and distribution of fatty acids among lipolytic products in stomach of newborn rats excluded from contact with lingual and pancreatic lipases*[1]

Fraction	TG		DG		MG		FFA	
Time of lypolysis	0	1h	0	1h	0	1h	0	1h
Fatty acid content (μmoles/ml)	170 ± 18	122 ± 13	0.9 ± 0.4	8.9 ± 1.9	0.0	1.1 ± 0.4	0.4 ± 0.5	28.4 ± 4.6
C_8 to C_{12} fatty acids (%)	33.3 ± 3.4	18.2 ± 3.5	23.8 ± 2.4	16.2 ± 1.9	0.0	16.8 ± 2.6	22.9 ± 4.6	48.2 ±6.1
C_{14} to C_{18} fatty acids (%)	66.7 ± 3.5	81.8 ± 4.0	76.2 ± 2.8	83.8 ± 2.8	0.0	83.2 ± 2.6	77.1 ± 4.6	51.8 ± 5.0
$\frac{C_8 \text{ to } C_{12}}{C_{14} \text{ to } C_{18}}$ ratio	0.50	0.22	0.31	0.19	0.0	0.20	0.30	0.93

[1] One ml of milk was introduced to the ligated stomach of 10-day-old rats with excised lingual glands and pancreas. One h later the gastric contents were collected, the stomach washed out with 0.9% NaCl solution and the combined fluids extracted and prepared for gas liquid chromatographic analyses. Values in the Table are means ± S.E. of six experiments.

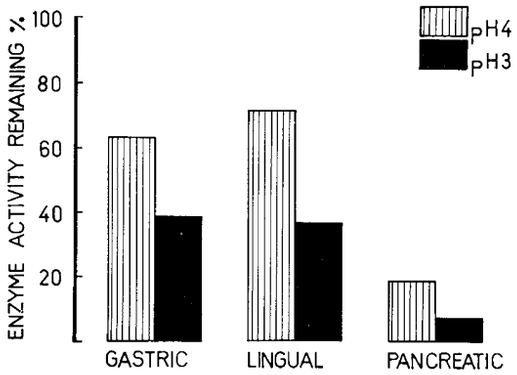

Fig. 2. Stability of gastric, lingual and pancreatic lipases at acute pH. The decrease in enzyme activity as a result of incubation at pH 4 or 3 is relative to that measured after incubation at pH 7. Acetone powders of gastric, lingual and pancreatic homogenates were dissolved (40–50 mg/ml) in 0.1 M citrate buffer (pH 3 or 4), the solutions incubated for 1 h at 37°C, then diluted 50-fold with 0.1 M borax buffer of pH appropriate for each lipase. The lipolytic activity was assayed using the labeled TG substrate (see Methods). Results shown are representative of three similar experiments.

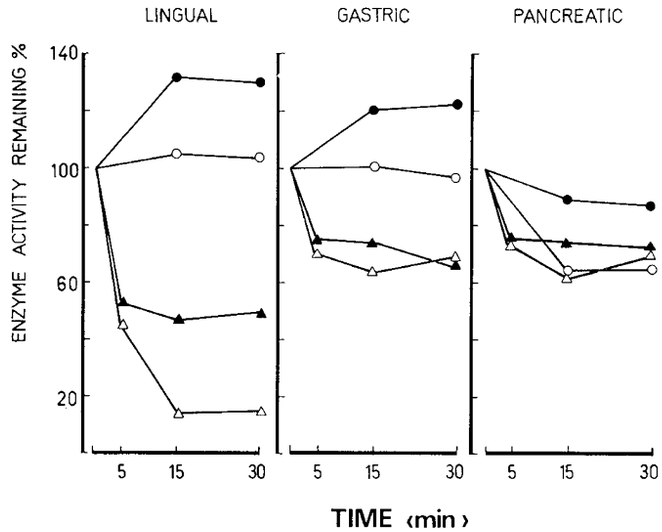

Fig. 3. Effect of pepsin and trypsin upon gastric, lingual and pancreatic lipases. The change in activity is relative to that measured at the same pH, without addition of proteases. Solutions of acetone powders (40–50 mg/ml), containing the lipases, were incubated (37°C) at pH 5.0 in the presence of pepsin (0.4 mg/ml) without O——O and with ●——● 6 mM sodium taurocholate, or at pH 6.5 in the presence of trypsin (10 mg/ml) without △——△ and with ▲——▲ 6 mM sodium taurocholate. Samples were removed at different time intervals, diluted 50-fold with 0.1 M borax buffer of pH optimal for each lipase and the lipolytic activity assayed using the labeled TG substrate (see Methods). Results shown are representative of three similar experiments.

activity in the presence of purified proteolytic enzymes in physiological concentration (20) (Fig. 3). In the presence of pepsin, pancreatic lipase activity was reduced by about 40% whereas gastric and lingual lipase activities remained unchanged. Since bile salts were shown to activate both gastric and lingual lipases (21), sodium taurocholate was added. An activation of these lipases was observed even in the presence of pepsin. In the case of pancreatic lipase, which is not activated by sodium taurocholate, the loss of activity was smaller.

Exposure to trypsin reduced the activity of gastric and pancreatic lipases by about 40%, but the addition of sodium taurocholate moderately enhanced their activity. Lingual lipase became strongly inactivated (90%) by trypsin; the presence of sodium taurocholate had a protective effect, since only 50% of activity was lost. It should be noted that the effect of proteases on lipase activity was prompt: the change observed after the first 5 min did not appreciably progress during the additional 25 min of incubation.

SUBSTRATE PREFERENCES

Figure 4 shows the activity of the three investigated lipases toward purified, homogenous TG of fatty acids of varying chain length in comparison to that of trioctanoin, which was taken as 100%. Gastric lipase showed a gradually lower preference for TG esters with rising chain length of fatty acids. Tripalmitin was cleaved by this lipase slightly faster than either trimyristin or triolein on repeated experiments, a phenomenon which requires further investigation. Lingual lipase showed a gradually decreasing preference for TG with fatty acids C_8 to C_{18}, whereas pancreatic lipase showed a bimodal preference: decreasing rate of cleavage from C_8 to C_{12}, then increasing from C_{12} to C_{18}.

LIPOLYTIC CAPACITY AS FUNCTION OF RAT AGE

Figure 5 presents a comparison of specific activities of the three lipases, expressed per g of protein in the respective tissue homogenates. Gastric lipase activity considerably decreased with age (90% between day 8 and 60 of life). In contrast, lingual lipase showed a 3-fold increase over this time span. The specific activity of pancreatic lipase was high quite early and showed a small but consistent increase with age.

The potential contribution of the three lipases to TG digestion in the growing rat was also assessed with respect to the changes in size of their tissues or origin. As seen in Table 2, the size of stomach increased about 11-fold during the period extending from 6 to 60 days of life. In the same time, the specific activity of lipase decreased. At 15 days of life there was a 3-fold increase in

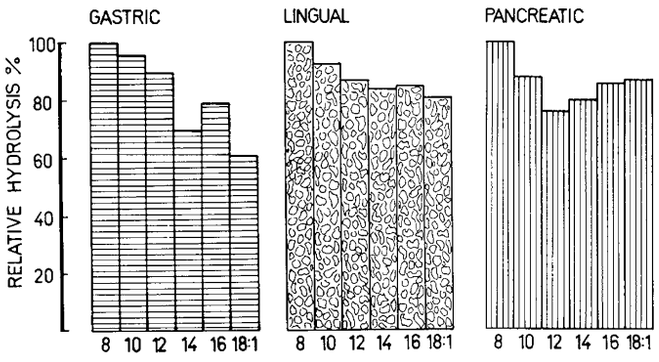

Fig. 4. Cleavage of purified TG with fatty acids of different chain length by gastric, lingual and pancreatic lipases. Lipase activity was measured in a reaction mixture which contained the tissue homogenate and 3 μmoles of each TG emulsified in gum arabic (see Methods) in the presence of albumin at final concentration of 4% and at pH optimal for each lipase. The reaction was stopped by extraction in the Dole's mixture and the results were corrected by the distribution coefficient between the solvents for each fatty acid as determined by Dole and Meinertz (9). The fatty acid content was determined by gasliquid chromatography, the lipolysis of tricaprylin being taken as 100% ($C_{8:0}$ = tricaprylin; $C_{10:0}$ = tricaprin: $C_{12:0}$ = trilaurin; $C_{14:0}$ = trimyristin; $C_{16:0}$ = tripalmitin; $C_{18:1}$ = triolein). Results shown are representative of three similar experiments.

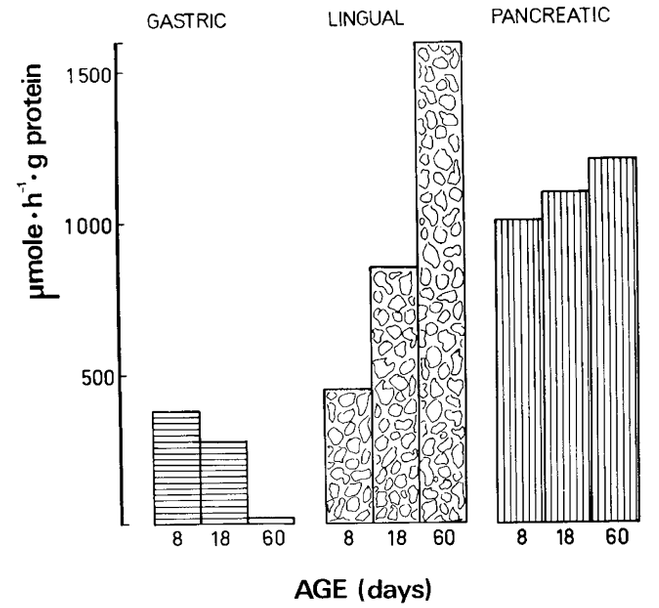

Fig. 5. Effect of age on lipolytic activity of gastric, lingual and pancreatic lipases measured with labeled TG as substrate. Results are expressed per g protein in the respective tissue homogenate and are means of three experiments.

stomach total lipolytic capacity which did not continue later. The lingual gland area did not increase in size as much as the stomach; however, the capacity of lingual lipase, which was comparable to that of gastric lipase on the sixth day of life, rose considerably due to the increase in specific activity. Thus, the total lipolytic capacity of the lingual gland exceeded that of the stomach by about 10–fold in the 2–month–old rat.

As calculated in the Table, the potential joint contribution of gastric and lingual lipases to the total digestive lipolytic capacity in the newborn rat was similar or slightly higher than that of pancreatic lipase at 6 days of life. This seemed to be related to the small size of the pancreatic gland at this time. When the specific activity of pancreatic lipase did not appreciably change, the size of pancreas markedly increased (>23 times between day 6 and 60). Thus, the potential availability of the pancreatic lipase exceeded several–fold that of both lingual and gastric lipases in the adult rat.

DISCUSSION

Gastric lipolytic activity was the subject of several studies. Helander and Olivecrona (19) and Hamosh and Scow (13) were among the first to report that milk TG are hydrolyzed to DG and FFA in the stomach of suckling rats. Cohen, *et al.* (6) presented data on lipolytic activity in human gastric aspirates free of duodenal reflux. Blum and Linscheer (4) found hydrolytic activity toward trioctanoin in canine gastric juice. Most of these studies supplied convincing evidence of the presence of a lipase in the stomach. That this activity may be due to a distinct enzyme originating in the gastric tissue was supported by the experiments of Clark, *et al.* (5) who observed the cleavage of short- and medium-chain TG by rat gastric mucosa and of Engstrom, *et al.* (11) using the fluid contents of the Heidenhein pouch in the dog. We have recently demonstrated a release of lipolytic activity from stomach slices when stimulated with histamine or pentagastrin (21). However, we felt that the possibilities of admixture of duodenal reflux containing pancreatic lipase or the participation of lingual lipase have not been hitherto completely excluded when demonstrating genuine gastric lipolysis *in vivo*. In fact, the lingual lipolytic activity has been shown to significantly contribute to fat digestion in the stomach (16, 18).

By using rats with ligated stomach, excised pancreas and sublingual glands, we have already shown a considerable hydrolysis of purified TG emulsions *in situ* (21). Using the same isolated stomach preparation we have demonstrated now the cleavage of the physiologic milk TG substrate in suckling rats without contamination by other lipases of the digestive tract. Additional evidence, based on positional specificity, activation and inhibition characteristics and pH optimum strongly supports the existence of a hormonally responsive lipase in the stomach wall, distinct from pancreatic and lingual lipase (21). However, under physiologic circumstances, it is most probable that intragastric hydrolysis of milk TG is carried out by the combined action of lingual and gastric lipases. Both enzymes withstand acidic pH and the presence of pepsin. The pH of the stomach of newborn rats is not too low for the expression of their activity.

Table 2. *Changes in lipolytic capacity of stomach, lingual glands and pancreas with rat age*[1]

	Rat age	6 days	15days	60 days
Stomach	Wet weight (mg)	56	106	627
	Homogenate protein (mg)	2.0 (3.6%)	7.3 (6.9%)	52 (8.3%)
	Lipase capacity (μmoles/h per total tissue)	0.88	2.45	2.60
Lingual glands	Wet weight (mg)	76	122	161
	Homogenate protein (mg)	2.3 (3.0%)	11.0 (9.0%)	18 (11.2%)
	Lipase capacity (μmoles/h per total tissue)	0.92	8.25	27.9
Pancreas	Wet weight (mg)	14	36	328
	Homogenate protein (mg)	0.6 (4.3%)	3.1 (8.6%)	32 (9.8%)
	Lipase capacity (μmoles/h per total tissue)	1.60	9.77	121.6

[1] A representative experiment in which the respective tissues were pooled from five rats of the same litter and the results averaged.

In our *in vivo* experiments, the lipolysis of milk TG in the nonligated stomach was not linear with time (Fig. 1). Several possibilities may account for the fall of lipolytic activity: (1) lack of protein acceptor for the FFA in the stomach which results in end product inhibition of lipolysis, (2) milk coagulation which decreases the contact and equilibration between the enzyme and substrate, (3) a drop in pH as a result of secretion of acid, and (4) the disappearance of lipolysis products. The first possibility was tested by submitting rat milk to lipolysis in the presence or absence of 4% albumin. Only a slight rise in FFA production was observed during intragastric lipolysis or on incubation of milk *in vitro* with gastric, lingual and pancreatic homogenates. We believe, therefore, that milk curdling, some pH lowering and possible loss of FFA into the duodenum or across the stomach wall, might have interfered with the long term linearity of lipolysis.

Follow-up of lipolysis in the ligated stomach preparation also showed some deficit in the recovery of the fatty acids among lipolysis products. In this case, the incomplete recovery (81%) cannot be ascribed to the escape of lipolysis products to the duodenum, but may be attributable to direct absorption of part of the FFA through the stomach wall (10).

The intragastric breakdown of milk TG yielded FFA rich in medium chain fatty acids. A high rate of lipolysis of medium chain TG was confirmed *in vitro* using purified TG substrates and tissue homogenates as the source of lipase. However, the differences in cleavage rates in relation to chain length seemed somewhat less impressive in the case of *in vitro* lipolysis of purified TG (Fig. 4) than intragastric lipolysis of milk TG (Table 1). The gradual decrease in lipolysis with the chain length stepwise longer by 2 carbon units was small but the difference between the cleavage of TG with C_{16} or $C_{18:1}$ fatty acids, as compared with that of TG with C_8 or C_{10} fatty acids, was certainly substantive, particularly in the case of gastric lipase.

The rates of *in vitro* TG lipolysis, as opposed to intragastric milk cleavage, may be influenced by factors such as pH, presence of albumin or the duration of effective lipolysis. It should be also noted that milk TG contain ester bonds with medium chain and long chain fatty acids at different *sn* positions in contrast to the *in vitro* experiment in which a homogenous TG species was offered to the enzymes. The structure of milk TG is asymmetric, the *sn* 3 position being especially rich in medium chain fatty acids (25) and probably creating a steric situation conducive to lingual and gastric lipase activities.

The fact that gastric and lingual lipases are activated and protected by bile salts suggests that these enzymes could play a role in fat digestion in the upper duodenum as well, since the pH there is not strongly alkaline in the newborn. The duodenal alkalinity increases from pH 7.2 at 6 days to PH 7.8 at 60 days of life (unpublished results). Our findings support the contention that gastric and lingual lipase play a role in intestinal fat digestion (26). We have demonstrated that gastric and lingual lipase withstand trypsin in the presence of bile salts, especially taurocholate which is the predominant bile salt in the rat. It is of interest that Hernell (20) found that human milk lipase is also protected from proteolysis by bile salts and may thus significantly contribute to milk TG hydrolysis in the intestine.

It should be noted that most of the loss of lipolytic activity in contact with proteases occurred during the first 5 min of incubation. It is then conceivable that the change in activity was not due to continuing proteolytic disintegration of the enzymes but to a rapid removal of a part of the enzyme needed for maximal lipolytic efficiency.

Another aspect of the activity of gastric and lingual lipases in the duodenum is that these lipases supplement the activity of pancreatic lipase by facilitating the total hydrolysis of TG molecules due to their greater affinity toward the *sn* 2 ester bond on the glycerol backbone and rapid hydrolysis of partial glycerides (21). Thus, the joint action of the three lipases ensures rapid degradation of TG without the accumulation of intermediary lipolytic products.

The role of different lipases in fat digestion during the time of development should be reassessed in light of previous information on the lag in pancreas development (7, 8, 24, 32, 34). The lingual and gastric lipases appear important during the first (2–3 wk of life since the combined lipolytic capacity of these two sources matches that of the pancreas (Table 2). However, in view of the extensive growth of the pancreas at 2 months of age (rather than increase in specific activity of pancreatic lipase), the contribution of pancreas becomes predominant in overall fat digestion in the adult rat. The changes in the specific and total lipase capacities were seen in the three tissues during the suckling period (22 days) and after weaning (Fig. 5 and Table 2). Therefore, it is unlikely that they were caused by a change in diet. However, the possibility of additional dietary influences on these lipases requires further exploration.

The presence of substantial lipolytic activity of gastric and sublingual derivation and its participation in intestinal lipolysis deserves the consideration that it may represent a potential mitigating factor in case of pancreatic insufficiency. The possibility of a compensatory mechanism operating in the absence or inaccessibility of pancreatic lipase is suggested from the fact that in congenital pancreatic lipase deficiency most of the dietary fat is hydrolyzed and absorbed (23, 30) and from the observation that an increase in gastric lipolytic activity occurs in cystic fibrosis patients, relative to matched control subjects (27).

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