In Vitro Studies of Intragastric Digestion

JAMES G. ARNOLD, BA, and ANDRE DUBOIS, MD, PhD

Following consumption of a meal, 99% of the large food particles are emptied only after intragastric fragmentation has reduced their diameter to less than 2 mm. An in vitro model was constructed to evaluate some of the factors which may play a role in the process of intragastric digestion. Gastric mixing of food was simulated in a silicone rubber tube (ID 19 mm) placed in a peristaltic pump. Peristaltic waves progressed upwards along the tube at a frequency of 0, 1, or 3/min, reducing the internal diameter of the tube to 5 mm. Cooked chicken liver particles (2-2.8 mm in diameter) were placed in the tube with one of the following: (1) 150 mM NaCl, (2) 150 mM HCl with or without pepsin, or (3) phosphate buffer at pH 7, 5.4, or 2.6 + pepsin. After 30 min, the extent of particle reduction and of solubilization of proteins were determined and expressed as percent of the initial liver weight. The diameter of liver particles was reduced to a greater extent in NaCl than in pH 7 buffer or acid solutions with or without pepsin. In contrast, the amount of proteins solubilized was enhanced two- to threefold by acid pepsin solutions compared to NaCl or pH 7 phosphate. The present in vitro studies suggest that changes in motor and/or secretory activity of the stomach significantly modify intragastric digestion.

Gastric emptying of liquids is faster than gastric emptying of solids, and it was known long ago that finely chopped food leaves the stomach faster than coarse chunks (1). These early studies were confirmed by Hinder and Kelly (2), who demonstrated, in addition, that large, nondigestible particles are emptied from the stomach only after a long delay and through forceful contractions of the gastric antrum. Furthermore, Meyer et al showed that 99% of solid food is emptied from the canine stomach only after the diameter of food particles has been reduced to less than 2 mm (3). From these observations, one can conclude that the difference between the emptying of solids and liquids probably reflects the time required by the intragastric grinding of the swallowed chunks of food to produce a "liquid-like" suspension.

The factors involved in this process in vivo probably include gastric motor activity and secretion of acid, ions, and enzymes. In addition, extragastric factors such as chewing of food and salivary secretion may also play a role. One of these factors, peptic digestion, has been evaluated in dogs (4); however, since the in vivo situation is very complex, we have developed an in vitro model in order to study the role of three of the variables involved in intragastric digestion, ie, mechanical agitation, composition of the fluids bathing food particles, and time. We selected chicken livers as the food substrate because they can be firmly tagged with radioactive markers and are widely used for studying emptying of solid meals.

MATERIALS AND METHODS

Principle of the Method. Figure 1 illustrates the factors that may be involved in the intragastric digestion and in
the sieving of food by the antropyloric pump. Figure 2 illustrates the in vitro system that was designed for the present studies in order to simulate the antropyloric pump. A 17-cm-long Tygon tube (ID, 19 mm; wall thickness, 3 mm) was plugged at one end with a silicone sealant and placed in a peristaltic pump (Harvard Apparatus, model 1203, Millis, Massachusetts). The width of the slot was adjusted so that the peristaltic wave would close only a portion of the lumen, leaving 5 mm of the tube unoccluded. The tubing was oriented as indicated on Figure 2, allowing the movements illustrated by the arrows. The frequency of peristalsis was adjusted to 0, 1, or 3 waves/min to approximate rates of stomach contractions.

Preparation of Particles. Approximately once a week, previously frozen chicken livers were cooked for 3.5–4.5 min in a microwave oven on medium-high setting, until they were firm and light brown. The cooked livers were ground and placed on a stack of two wire mesh sieves with mesh size of 2.8 and 1.4 mm, respectively. After forcing the ground liver through the larger sieve and shaking to allow small particles to pass through the second sieve, the 1.4- to 2.8-mm particles were collected and refrigerated for later use. Chicken liver is composed of 72% water, 20% protein, 4% fat, and 3% carbohydrate.

At the start of each study, 6 g of the prepared liver particles were placed in 20 ml 0.15 M NaCl to allow them to swell (3). After 20 min in saline, the liver was filtered with suction on a filter paper disk to remove excess fluid. At that time, the mass of liver particles had increased by 8.2 ± 0.5%. The swollen particles were transferred to a stack of two sieves with mesh size of 2.8 and 2.0 mm, respectively. These were sieves for use with a sonic sifter (model L3P, ATM Corporation, Milwaukee, Wisconsin),...