The Review on Study of Digestive System

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Abstract:

It is crucial to replicate or mimic the human digestive system conditions closely in model systems to have the food digestion-related data as accurate as possible. Thus, the data obtained could contribute to studies like those on the relationship between health and nutrition. This review aims to express the human digestion system's role in food digestion and compare the capability of the models used in simulations, especially the dynamic in vitro models. Activities of the human digestive system governing food digestion and the food matrix's disintegration mechanism in the digestive system were discussed. Dynamic in vitro models and their relevance to the human digestive system were described. Advancements in the last 20 years, as well as limitations of those artificial systems, with prospects, were discussed. Extensive use and improvement on these models will extend our knowledge of the food matrix and digestive system's complex interaction. Thus, it will be possible to design next-generation foods with improved health benefits. Various formulations of enzyme supplementation are available commercially in the market, and are currently used in clinical practice for the management of several digestive diseases.

Keywords: In vitro, food digestion Dynamic model Food matrix.

Introduction:

Understanding the outcome of the ingested food components in the human digestive system is an area of interest for researchers because of its relation to nutrition and health. Foods contain components that can have either beneficial or adverse effects on human health. Consumed foods are combinations of diverse phases and structures depending on their sources, formulations, and processes used for their production. The digestive system must physically and chemically break down ingested food to release its components, which will be further metabolized to be used by the body. The foods' composition and structure have a significant role in their nutritional and functional performances during digestion. The food matrix affects the release of nutrients and their journey to the body's target sites during digestion. Therefore, it is essential to understand the underlying mechanisms affecting the release of the food components during digestion for health benefit. Digestion of food in the human digestive system is a complex combination of versatile and multiple-scale physicochemical processes that steer the food intake, disintegration to suitable forms, absorption of the basic units, transportation to related organs, and purging the remaining waste. The human digestive system consists of the digestive tract and the accessory organs controlled by the neural network and the hormones. The digestive tract can be described as an open-ended tube with a total length of about 8–9 m, extending from mouth to anus, consisting of the pharynx, easophagus, stomach, and small and large intestines. Accessory organs are the teeth, tongue, salivary glands, liver, gall bladder, and pancreas. Each part of the digestive tract has a specific function, where altogether, they perform the extraction of the digested products and the disposal of wastes. Increased interest in modifying the matrix and structural characteristics of foods to optimize their digestion and absorption behavior for health benefit requires implementing many food digestion studies in the digestive tract. However, studying human digestion's intricate process is complicated, costly, varies from person to person, and constrained by ethical considerations. The usage of animal models as an alternative should also be avoided as much as possible. Therefore, these limitations and considerations have led researchers to design and use in vitro models to simulate the human digestive system for research. The interaction between the food and human digestive systems controlling the disintegration of foods and releasing nutrients is quite complicated. This review describes the physiological processes of the human digestive system steering food digestion. The disintegration mechanism of the food matrix in the digestive system was discussed.[1,2,3]

The digestive system of the human body comprises a group of organs working together to convert food into energy for the body. Anatomically, the digestive system is made up of the gastrointestinal tract, along with accessory organs such as the liver, pancreas and gallbladder. The hollow organs that make up the gastrointestinal tract (GI tract) include the mouth, stomach, oesophagus, small intestine and large intestine that contains the rectum and anus.[4]

Human Digestive System and Nutrition involve the intake of food by an organism and its utilization for energy. This is a vital process which helps living beings to obtain their energy from various sources. The food which we eat undergoes much processing before the nutrients present in them are utilized to generate energy. This processing is known as digestion. Humans and other animals have specialized organs and systems for this process.

The digestion process involves the alimentary canal along with various accessory organs and organ systems. In humans, the process is quite simple due to our monogastric nature. This means that we have a one-chambered stomach, unlike other animals such as cows, which have four chambers.

Some parts of nervous and circulatory systems also play a significant role in the digestion process. A combination of nerves, bacteria, hormones, blood and other organs of the digestive system completes the task of digestion.[5,6]

Digestion:

It is the breakdown of large insoluble food molecules into small water-soluble food molecules so that they can be absorbed into the watery blood plasma. In certain organisms, these smaller substances are absorbed through the small intestine into the bloodstream. Digestion is a form of catabolism that is often divided into two processes based on how food is broken down: mechanical and chemical digestion. The term mechanical digestion refers to the physical breakdown of large pieces of food into smaller pieces which can subsequently be accessed by digestive enzymes. Mechanical digestion takes place in the mouth through mastication and in the small intestine through segmentation contractions. In chemical digestion, enzymes break down food into small molecules the body can use.[7]

In the human digestive system, food enters the mouth and mechanical digestion of the food starts with the action of mastication (chewing), a form of mechanical digestion, and the wetting contact of saliva. Saliva, a liquid secreted by the salivary glands, contains salivary amylase, an enzyme that starts the digestion of starch in the food; the saliva also contains mucus, which lubricates the food, and hydrogen carbonate, which provides the ideal conditions of pH (alkaline) for amylase to work, and electrolytes (Na^+, K^+, Cl^-, HCO_3^-). About 30% of starch is hydrolyzed into disaccharides in the oral cavity(mouth). After undergoing mastication and starch digestion, the food will be in the form of a small, round slurry mass called a bolus. It will then travel down the esophagus and into the stomach by the action of peristalsis. Gastric juice in the stomach starts protein digestion. Gastric juice mainly contains hydrochloric acid and pepsin. In infants and toddlers, gastric juice also contains renin to digest milk proteins.[8]

As the first two chemicals may damage the stomach wall, mucus and bicarbonates are secreted by the stomach, providing a slimy layer that acts as a shield against the damaging effects of chemicals like concentrated hydrochloric acid and mucus also helps in lubrication. Hydrochloric acid provides acidic pH for pepsin. At the same time, protein digestion is occurring, mechanical mixing occurs by peristalsis, which is waves of muscular contractions that move along the stomach wall. This allows the mass of food to further mix with the digestive enzymes. Pepsin breaks down proteins into peptides or proteoses, which are further broken down into dipeptides and amino acids by enzymes in the small intestine. Studies suggest that increasing the number of chews per bite increases relevant gut hormones and may decrease self-reported hunger and food intake.[9]

Effect of food matrix on digestion:

The disintegration mechanism differs among foods and is related to the original food structure and how it changes during digestion. Although most of the breakdown process for solid foods happens in the mouth, the rest of the disintegration occurs while transiting the digestive system, especially in the stomach. The forces that food particles experience in the stomach are less than those applied by the teeth in the mouth. The maximum force that the human jaw can apply is about 400 N, while the force that the walls of the stomach (antrum) can apply is about 0.2–2 N depending on the subjects. Fragmentation, abrasion, and dissolution behaviors of the food in the digestive system determine their effect on human health. Fragmentation (cleavage into smaller pieces) and abrasion (erosion of the surface by shear stress) are the two primary disintegration mechanisms of the food. When the forces received by the food due to contractions and peristaltic movements in the stomach are higher than the critical value for the internal forces holding the food matrix together, fragmentation will be the dominant mechanism, and the food will be broken down into relatively larger pieces. When the applied stresses are smaller, surface abrasion will be dominant, and the smaller fragments leave the surface. The acidic environment and the digestive system’s enzymes also contribute to the leaching of solids to the digestion medium.[10,11]

The kinetic of food disintegration is affected by the physiological conditions in the digestive system like mechanical forces, pH, temperature, and enzymes, as well as by the meal properties such as composition, amount, texture, structure, and viscosity. Some foods are more susceptible to fragmentation than other foods under similar mechanical forces. Water absorption, acid hydrolysis, and enzymatic reactions may cause softening of the ingested foods. Cohesive forces holding the food matrix together may attenuate, leading to a shift in the disintegration mode from erosion to fragmentation. For example, cereal products like bread and snacks become very soft after mixing and absorption of saliva in the mouth, and then they fragment easily. On the other hand, for foods with a rigid and hard texture like carrots and nuts, erosion is the dominant disintegration mechanism. Moreover, diffusion processes inside the chyme are affected by physiological conditions such as pH, temperature, viscosity, and degree of mixing as well as by the structure and content of the food. One of the studies attempting to explain and quantify the disintegration mechanisms suggested a classification system for food breakdown similar to the one used by the pharmaceutical industry as a tool to be used for product development. Therefore, all modes of transport phenomena, mass, heat, and momentum, should be considered together in analyzing and simulating the digestive system.[12,13]

Food digestion in the human digestive system:

The digestive tract that begins at the mouth continues as the throat (pharynx), the esophagus, the stomach, the small intestine (duodenum, jejunum, and ileum), the large intestine (cecum, ascending colon, transverse colon, descending colon, and sigmoid colon) and rectum, ending at the anus where the wastes are excreted. Digestive juices are secreted by the salivary glands, gastric glands, pancreas, and liver with its adjuncts (the gallbladder and bile ducts). Secretions from the digestive organs alter the physical properties of the digested meal by dilution. On average, humans can produce 1.5 L of saliva, 2 L of stomach secretions, and 0.5 L of bile solution.[14]

Mouth:

Food enters the digestion system through the mouth and is broken down into small pieces while mixed with saliva to speed its progression through the digestive system. Textural and rheological properties of foods as well as age, gender, and eating ability of individuals affect the oral processing behavior. The mechanical digestion of foods starts by chewing. The teeth in the human mouth are responsible for different tasks like cutting, tearing, grinding, and shearing. Biting force can range approximately from 100 to 400 N depending on the individual. Solid foods are more difficult to manipulate. Therefore, the amount of food taken in by the mouth decreases from liquid foods to solids. Moreover, the bolus' mean particle size depends on the physical properties of the food, smaller for hard and larger for softer foods. Bolus formation in the mouth includes deformation, deterioration, and disintegration processes, which are accomplished by the coordinated effort of the teeth, tongue, and saliva secretion mechanism. [15]

Saliva, which is about 99% water, contains sodium, potassium, calcium, bicarbonate, mucin, and enzymes (amylase, lingual lipase). The saliva secreted by the salivary glands moistens and starts to dissolve the food with the amylase enzyme action that splits starch into disaccharide molecules of maltose. The bolus is propelled from the mouth to the esophagus by the pharynx during the swallowing process. A pressure of 10 kPa can be generated on the tongue's surface during swallowing. Peristaltic contractions of the esophagus transfer the bolus to the stomach. Transport of material through the esophagus (length: ̃25 cm and diameter: 1.5–2 cm takes approximately 8–10 s. When the bolus arrives at the stomach junction, the bolus can enter the stomach through the relaxed esophageal sphincter (a muscular cuff). Even though the transport of liquids through the esophagus may be faster than solids due to gravity.[16]

Stomach:

In the stomach, which is a J-shaped muscular pouch, the digested food goes through mechanical and chemical disintegration. The stomach where the digested food is diluted with the gastric juice works like a container, mixer, and sieve. The stomach is the main digestion region. Even though digestion of starch and triglycerides can start in the mouth due to amylase and lingual lipase in the saliva, protein digestion starts in the stomach. The concave border of the human stomach on the right is named as the lesser curvature, and the convex border to the left is named as the greater curvature. The section where the stomach is connected to the esophagus is called the cardia. The fundus, body (corpus), and antrumare the main sections of the stomach. The stomach's proximal region regulates the pressure for food storage, and the distal stomach functions as a gastric pump. After a meal, the fundus, which sticks out like a dome, usually stores swallowed air. The largest section of the stomach, the body, serves as a reservoir for the ingested meal. The antrum has a conical shape and is between the lower section of the body and the pyloric canal. The pylorus is the stomach's slimmest portion and has enclosed by thick, smooth muscle layers.[17]

Small intestine:

Most of the processes that convert the food into suitable forms that the body can use happen in the small intestine, where the nutrients are absorbed. The small intestine is the longest (6–7 m) part of the gastrointestinal tract and is folded to fit in the abdominal cavity. It is joined to the stomach by the pylorus and to the colon by the ileocecal valve. The duodenum, jejunum, and ileum are the small intestine’s main segments, respectively. The duodenum (23–28 cm long) is where the canals secrete pancreatic juice and bile opens up. The jejunum (~2 m) is the first 40% of the small intestine beyond the duodenum. The remaining 60% is the ileum (~3 m), which joins the large intestine through the ileocecal valve. Most of the secretions controlled by nerves and hormones occur in the duodenum; the secretions are minimal in the other parts of the small intestine.[18]

The pancreas is a large gland that produces enzymes and hormones. The pancreatic juice and the bile flow through the duodenal papilla (rounded projection into the duodenum) to enter the duodenum. When the chyme enters the duodenum, gastric secretions within the chyme continue their digestive processes for a short time in the small intestine. Incoming chyme stimulates the pancreas to release a concentrated bicarbonate solution that neutralizes the highly acidic gastric juice. Other secretions from the pancreas, gallbladder, and glands in the intestinal wall increase the total volume of chyme. Pancreatic secretion includes many enzymes, proteases (trypsin and chymotrypsin), pancreatic lipase, and pancreatic amylase. Bile is an aqueous solution produced by the liver and stored in the gallbladder facilitates digestion and absorption of lipids, acting as an emulsifier. Bile consists of bile salts, phospholipids, cholesterol, bilirubin (a breakdown product of red blood cells), electrolytes, and water. Here, digestion enzymes break down proteins, carbohydrates, triglycerides, and nucleic acids to smaller sizes. Pancreatic amylase can split starch into disaccharides such as maltose, but, here, disaccharides such as sucrose (from sugar and fruits) and lactose (from milk) cannot be broken down into their monomers yet.[19]

Large intestine:

The large intestine has a large diameter (~6 cm), but it is shorter (~150 cm) than the small intestine. The ileocecal valve joining the small and large intestines shields the opening of the ileum into the cecum. The large intestine absorbs water into the body, and the remaining thick waste is ejected to complete the digestion. Each day about 1.5–2 L of chyme passes through the ileocecal valve . The chyme volume becomes about 150 ml after the water absorption in the colon . The large intestine has an anaerobic environment and is colonized by an involved community of microorganisms (~1011/g) formed mainly by obligate anaerobic bacteria. The microbiota produces a variety of enzymes that break down dietary fibers not digested in the small intestine. The bacteria also metabolize the bile salts and pancreatic enzymes that reach the colon. The colon also contains bacteria that synthesize some essential vitamins (niacin, vitamin B1, and vitamin K). The free fatty acids (by-products of fermentation) content increases from about 6 to 8 mM in the ileum to 32-29 mM in the cecum. Chyme content affects the composition of the microbiota and metabolites produced, which can impact health.[20]

The digestive enzyme in Human Body:

Digestive enzymes are produced and secreted by the gastrointestinal system to degrade fats, proteins, and carbohydrates, to accomplish digestion and, afterward, the absorption of nutrients. The following is a table showing the enzyme, source, and products of digestion.

Causes of digestive enzyme deficiency

Several factors cause enzyme inadequacy and deficiency, some of which are mentioned as follows:

1. Impaired secretion:

Dysfunction of digestive organs, mucosal disease, gastrointestinal surgery and nutritional deficiency can lead to impaired secretion.

2. Habits:

Poor eating habits [inadequate chewing food], eating late in the day.

3. Dietary choices:

Excessive alcohol, refined carbohydrates and fats, high meat consumption, and minimal enzyme-rich foods.

4. Age:

Aging alters the digestive enzyme secretion with a linear decrease after 40 years. Treatment of Functional Dyspepsia For the management of functional dyspepsia, medical treatment is recommended as a supportive measure. The duration of treatment is limited (e.g., a period of 8–12 weeks) in the absence of casual therapy and is always oriented on the principal symptoms, particularly since the placebo success rate can be very high, up to 60%.[21,22]

Digestive enzymes:

Studies have shown that pancreatic enzyme supplementation in functional dyspepsia is beneficial and significantly reduces the symptoms of flatulence, bloating, belching, fullness, and post-prandial distress. The rationale for digestive enzymes is that carbohydrates, proteins, and fats are initially converted to smaller units by various digestive enzymes and are then assimilated. By aiding the digestive process, the dyspeptic symptoms would be ameliorated. Hence, to assist the adequate digestion of every nutrient, a combination of different enzymes must be supplemented in an individual with enzyme deficiency leading to functional dyspepsia and GI disorder. The required digestive enzymes.[23]

Conclusion:

Clinical studies elucidate that digestive enzymes and probiotics are essential for normal digestive function. The addition of probiotics to enzymes helps in digestion and restoring the normal flora of the gut and promotes a healthy intestinal tract environment. Together, the combination would be useful in relieving GI discomfort as seen in dyspepsia, constipation, diarrhea, lactose intolerance, etc., and thereby may even prevent it. Carrier-mediated transport and passive diffusion through the small intestine epithelial cells were simulated as passive diffusion by using a filter medium or by exposing the digested samples to cell lines. The systems sometimes used a texture analyzer to measure and control the applied forces in the stomach. Even individual organs can be modeled to close perfection in anatomy and physiology.[24]

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