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DIGESTIVE SYSTEM AND DIGESTION OF FOOD IN CULTIVABLE FINFISH AND CRUSTACEANS

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The digestive system in fish and shellfish shows much variation in structure and function and is specialised and adapted to suit specific diets. Variation in crustacean digestive system is mainly in the foregut which may be a simple passage way or highly complex chambered structure provided with triturating, straining and filtering mechanisms. In fish the length of the intestine is highly variable depending on the diet and the intestine-body length ratio is low in carnivores and very high in herbivores and detritivores. In cyprinids a true stomach is completely absent.

DIGESTIVE SYSTEM OF FISH

The alimentary tract of a fish consists of the mouth, oesophagus, stomach - if it is present -, intestine, rectum and associated glands like liver and pancreas.

There is no chewing or predigestion of food in fish mouth which serves for selection, seisure and orientation of food towards stomach. Dentition is developed to suit the feeding habits of particular fish and is highly variable. The buccal cavity has stratified mucoid epithelium which produce mucus to lubricate the food.

Oesophagus in fish is usually a short straight muscular tube leading from mouth to the cardiac stomach. The epithelium of oesophagus is folded and can distant to swallow large prey. Oesophageal sacs or oesophageal teeth are present in some fishes.

Usually the stomach is a sigmoid, highly distensible sac with numerous folds in its lining. Size of the stomach varies considerably and is related to the nature of food. Numerous blind diverticulae - the pyloric caecae - are present at the junction of pyloric stomachand anterior intestine in teleosts and these structures aids in digestion and absorption. The stomach is highly muscular and its wall is modified to deal with a particular diet in teleosts. The gastric mucosa is very mucoid with numerous glands at the bases of the folds. Detritivores like mullet and chanos stomach have a gizzard like that of a fowl and in cyprinids no true stomach is present, probably for quick passage of indigestible matter consumed in large quantity by these fishes.

The intestine is a very simple tube which is usually long and coiled in herbivores. The gut length-body length ratio is 0.6-0.8 in carnivores and 1.3-4 in herbivores, with silver carp and <u>Labio</u> sp. (Africa) having a ratio of 13 and 15-17 respectively. The intestine has a simple mucoid columnar epithelium overlying a submucosa with oesinophilic granule cells and limited by dense muscularis mucosa and fibroelastic layer.

Rectum in fish has a thicker muscle wall than that of the intestine and its lining is highly mucigenic and capable of considerable distension.

Liver is the most important digestive gland in fishes and its colour is reddish brown in carnivores and light brown in herbivores. In some fishes liver forms a compound organ with pancreas and is termed hepatopancreas. Hepatocytes are polygonal with distinctive central nucleus and a nucleolus and are usually swollen with glycogen and neutral fats in normally fed fishes. Under starvation the cells may shrink and the liver will be loaded with yellow ceroid pigments. Gall bladder is associated with liver and contains greenish yellow bile which is transported to the intestine via the common bile duct.

Pancreas is more variable in location even with in a single species, most common cites of which are among the fat cells in the mesentary of pyloric caeca and around spleen and hepatic portal vein. Pancreatic juice contain protease and the endocrine component of pancrease - the "Islets of Langerhans" - produces insulin.

Digestive tract of Malacostraca

The digestive system of malacostracans consists of the gut divisible into three distinct regions, its accompanying glands, caecae and diverticulae. The fore and hind guts are derived from the embryonic ectogerm and lined with chitin while midgut is endodermal in origin and has the midgut gland, caecae and diverticulae.

The fore gut or proventriculus has an anterior distensible part, the posterior end of which constricts towards a gastric mill. There is a complex system of muscular attachments, especially around the gastric mill. The gastric mill has a median dorsal and two lateral ossicles with many subsidiary ossicles. Gastric mill leads to the posterior part of the proventriculus which possess a filter press on its ventral chamber. Mixing of food with digestive fluids and triturition occurs in the anterior part and the fluids then pass into the ventral grooves of the anterior chamber which carries it to the filter press which excludes particles above 1 µm and leads the contents to the entrance of the digestive gland. Further digestion and absorption of nutrients are carried out inside the tubules of the digestive gland. The anterior diverticula could also be contributing essential components of digestive enzymes.

There is a difference of opinion about the naming of the midgut gland which is variously described as hepato-pancreas, digestive gland and midgut gland. The digestive gland is a pair of bilobed glands lying on either side of the gut and opens at or near the foregut. In penaeids only a median sac like bilobed caecum is present in the midgut. The digestive gland secretes digestive enzymes and is the major site of absorption of nutrients. The epithelium of digestive gland has two cell types the 'R' cells which stire nutrients and the 'B' cells which is generally believed to contain digestive enzymes. The digestive gland also serves as an organ for accumulation and metabolism of calcium and copper and inactivation of other potentially toxic metals.

Midgut is lined by a dense columnar epithelium with light and dark cells that have absorptive and secretory functions. A cylindrical peritrophic membrane is secreted by a ring of cells behind the digestive gland opening. Faeces are enclosed in this membrane to form dry pellets and it protects the gut from abrasive particles and aids in defecation.

Digestion

Digestion involves a series of processes in the digestive tract by which the complex food particles are broken down into their simple forms that can be readily absorbed into the body. This is accomplished by a combination of mechanical and enzymatic processes.

In malacostraca mechanical trituritian is done in the proventriculus aided by gastric mill while in some fishes oesophagial teeth aids in this process. Oral teeth in many fishes are used only to seize and hold the prey. Chemical process of digestion is carried out by enzymes secreted by digestive glands and in fishes this process is aided by secretion of gastric fluids that contain hydrochloric acid and bile which emulsify the fats. Rates of enzymatic activity depends on variable amounts of enzymes, substrates, enzyme activators and inhibitors, and biproducts reacting under the modifying influence of pH and temperature.

Digestion in fish

Digestion is initiated in the stomach in fishes that possess a true stomach. Hydrochloric secreted by the gastric glands leads to activation of pepsin, whose pH optima is 2-2.2. In tilapia pH of the gastric fluid is reported to be as low as 1. Common carp which does not possess a true stomach maintain a digestive tract pH that is slightly alkaline.

Carbohydrates are digested in the first and second quarters of the intestine while protein digestion is completed in the first quarter. Amino acid absorption, however, continues the length of the intestine.

Di and polysaccharides are broken down to monosaccharides which are readily absorbed into the blood. Cellulose, hemicellulose and lignins are not digested at all by fish but microbial cellulase activity has been reported in tilapia and channel catfish. The carbohydrate digesting enzymes in fish are Amylase, maltase, chitinase, cellobiase, oligo-1,6 glucosidase lactase and sucrase.

Protein is the most important component of the fish diet and its requirement is 2-4 times more than that of terrestrial animals. Proteins are broken down to amino acids which are absorbed in the intestine. Dipeptides and tripeptides are also rarely absorbed. The peptade uptake theory states, however, that small peptides with 2-6 aminoacids are absorbed more readily by the intestinal mucosa than individual amino acids.

Proteins are acted on by proteinases like pepsin and trypsin which breaks them into small peptides which are then broken down to constituent amino acids by peptidases like carboxypeptidase, aminopeptidase, dipeptidase and there are various nucleases that digest the nucleic acids.

Fish can completely oxidise fats and release all energy. Fish lipases can act on all the three fatty acids in a triglyceride while mammalian lipases can act only on the first and the third fatty acids. Fats are absorbed as fatty acids, mainly in the hepatocytes of the liver. Marine fishes have enormous surface area and extensive pyloric caecae that permits longer time for emulsification of waxes and wax esters which are abundant in zooplankton especially copepods. Bile emulsifies fats which are then digested by lipase and other esterases in fish.

Digestion in Malacostraca

Storage, trituritíon and digestion of food takes place in the proventriculus and the digestion and absorption are completed in the midgut. Secretion of enzyme is limited to midgut in crustacea. Enzyme secretion increases immediately after feeding and digestion aided by gastric mill would then begin almost immediately.

There is a second peak in enzyme secretion after few hours which may represent final phase of digestion in the tubules of the digestive gland.

About 80-90% of nutrients are absorbed in the digestive gland and midgut while only a fraction is absorbed in the hingut. Lysine and glycine are actively transported in penaeids in the midgut and glucogen is also absorbed in a similar way. The digestive gland in crustacea is considered to be under endocrine control.

Digestive enzymes in crustacea

A large number of proteinases and peptidases are present in crustacea. Trypsin of penaeids is similar to the mammalian trypsin with pH optima of 7-9 but differ in that they attack undenatured proteins like collagen and synthetic substrates. Other proteinases with light molecular weights and specific activities are detected in several crustaceans. Among the peptidases, carboxypeptidase, arylamidase and a dipeptidase have been reported in cray fish *Astacus astacus*. No zymogens (inactive precursers) of crustacean proteolytic enzymes have been detected so far.

Lipid and esterase activity have been demonstrated in many crustaceans. Fats are probably absorbed as a mixture of free fatty acids, mono and diglycerides.

Amylase activity has been demonstrated in all the crustaceans investigated. Maltase and oligo 1,6, glucosidase is also suspected to be present in crustacea, since these are necessary for complete oxidation of starch and crustaceans are capable of digesting starch completely. Cellulolytic activity has been demonstrated in many crustacea, but whether it is synthesized or secreted by micro organisms is yet to be ascertained. 1,3 gluconase

(Laminarinase) is also believed to be present in all crustaceans. All crustaceans are capable of digesting chitin which demonstrates the presence of chitinase. Glucosidases that hydrolyse less well characterised polymers present in algae and micro-organisms are believed to be present in those crustaceans that feed on these items. These may degrade glycolipids and glycoproteins in addition to mucopolysaccharides and polysaccharides.

pH optima

Foregut fluid of most crustaceans is reported to be slightly acidic. Some enzymes such as those related to trypsin have alkaline optima.

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