

Digestive enzymes, feed
digestibility, factors affecting
digestibility

Digestion

- Digestion is the process by which the ingested food material is broken down into simple, small, absorbable molecules
- Digestion is a progressive process, beginning in the stomach and possibly not ending until food leaves the rectum as faeces.
- The task of digestion is performed primarily by the digestive enzymes, which are secreted into the lumen of the alimentary canal from the oesophageal, gastric, pyloric caeca and intestinal mucosa and from the pancreas.

Digestive fluids and enzymes

- Digestive fluids and enzymes are part of the gastric secretions, pancreatic secretions, bile and intestinal secretions.
- Acid gastric fluid production probably occurs in most fish except in those without a stomach when neither HCl nor pepsin is formed in the gut.
- The digestive enzymes are termed as hydrolases (water soluble proteins) which are capable of catalyzing hydrolytic reactions. Based on the physiological functions they are divided into proteases, lipases/esterases and carbohydrases that breakdown proteins, lipids/ fats and carbohydrates respectively.

Site/type	Fluid/enzyme	function
Stomach Gastric secretions	HCl	Reduces gut pH and allows pepsinogens to act
Gastric glands	Zymogen Pepsinogen HCl Pepsin	Proteolytic enzymes; cleave peptide linkages at the NH ₂ groups of aromatic and acidic amino acids. Attack most proteins
	Amylase	Act on carbohydrates
	Lipase	Act on lipids
	Esterases	Acts on esters(class of lipids)
	Chitinase	Act on chitin

Site/type	Fluid/enzyme	function
Pancreas	Enzymes	Enzymes are stored as zymogens. Pepsin produced by the intestine convert trypsinogen into trypsin
	HCO ₃ ⁻	Neutralizes HCl entering intestine and prepare intestine for alkali digestion
	Proteases(trypsin,chymotrypsin, carboxypeptidases and elastase)	Optimal action of enzymes at pH 7.0
	Trypsin	Cleave peptide linkages at carboxy groups of lysine or arginine
	Chymotrypsin	Attacks peptide with carbonyls from aromatic side chains
	Elastase	Attacks peptide bonds on elastin

Site/type	Fluid/enzyme	function
Pancreas	Carboxy petidases	Hydrolyses the terminal peptide bond of their substrates
	Amylase	Carbohydrate digestion at non-acidic pH
	Chitinase	Splits chitin into dimers and trimers of N-acetyl-D-glucosamine, which is further broken down by NAGase
	Lipases	Hydrolyse triglycerides, fats, phospholipids and wax esters
Bile (secreted by the liver)	Bile salts, organic anions, cholesterol, phospholipids, inorganic ions	Make the intestinal medium alkaline, emulsify lipids; most bile salts are reabsorbed from the intestine and returned to liver in enterohepatic circulation

Site/type	Fluid/enzyme	function
Intestinal enzymes (secreted by the brush border of the epithelium)	Aminopeptidases (alkaline and acid)	Split nucleosides
	Polynucleotidase Lecithinase	Splits nucleic acids Splits phospholipids into glycerol, fatty acids

Protein digestion

- Proteolytic enzymes arise from inactive precursors known as zymogens.
- Zymogens are processed in the lumen of the gut either by acid hydrolysis or proteolytic action.
- Proteases break down peptide link of proteins.
- Different enzymes are capable of acting on peptide bonds either at the end of protein (exopeptidases) or at a point within the protein (endopeptidases). Endopeptidases are very specific in their action and exert their effect only at a particular point within the protein molecule.
- For example pepsin hydrolyses the bond on the amino side of the aromatic radical, while chymotrypsin hydrolyses the bond on the carboxyl side. Trypsin on the other hand acts on peptide bonds between arginine and lysine, These three enzymes are probably the most important in the digestion of protein.

Fat digestion

- The liver plays an important role in fat digestion.
- The bile that is produced in the liver and stored in gall bladder is released when food arrives in the intestine.
- It contains gallic acid of high surface activity and these emulsify the fats, breaking large fat drop lets in to very small droplets there by increasing the surface area and making them more accessible to fat splitting enzymes, which are termed as lipolytic enzymes or lipases.
- Lipase activity has been found in extracts of the pancreas, pyloric caeca and upper intestine, but necessarily in all these sites in all the species.
- Unlike in protein or carbohydrate digestion, lipases show relatively little substrate specificity and many will catalyse hydrolysis of almost any organic ester. Thus the progressive breakdown of a fat through various intermediate stages is often catalysed by a single lipase

Carbohydrate Digestion

- The carbohydrate digestion is performed by a large number of carbohydrate digesting enzymes called carbohydrases.
- Each one of the carbohydrases is very specific in its actions.
- Carbohydrases have been demonstrated to be present in pancreatic juice in the stomach, in the intestine and in the bile, but not necessarily at all sites in all the fishes.
- In most species however, the pancreas is the main producer of carbohydrases.
- α - amylase is known to hydrolyze starch or glycogen to oligosacchrides or maltose.
- Thus depending on the structure of the substrate, they are broken down by glucosidases, galactosidases or fructosidases.

Digestibility

- Digestibility is the quantification of the digestive processes.
- It gives a relative measure of the extent to which ingested food and its nutrient components have been digested and absorbed by the animal.
- The total and/or dry matter digestibility refers to the degree of digestibility of the complete diet and/or the ingredients
- Nutrient digestibility refers to a specified nutrient such as protein, lipid, aminoacid or carbohydrates of the diet and/or the ingredient.

Determination of digestibility

- Digestibility of a diet/feed can be determined directly or indirectly.
- **Direct Method:** the quantity ingested (total or nutrient) and faecal matter voided are determined and the ratio gives the percentage digestibility of the feed and/or the nutrients
- However, it is difficult to determine the quantity ingested and/or the total amount of faeces voided accurately as such determinations are subject to many errors.
- There are fine faecal particles in suspension which are almost impossible to collect by normal siphoning.
- The latter can be resolved to some degree by using automatic, continuous faecal collection devices incorporated into an experimental system.

- **Indirect Method:** first used by the Swedish scientist Edin in 1918, when he used markers in experimental on cattle.
- A marker is a material, thought to be indigestible, which is introduced in small quantities and distributed evenly in the test diet, or an indigestible component of the diet itself. These are known as external marker and internal markers
- The marker will concentrate relative to the digestive material in the faeces, and the relative quantities provide a measure of the extent of digestibility of the diet and/or its nutrient components.

- External markers are substances that are added to the feed, while endogenous or internal markers are naturally occurring dietary constituents.
- Commonly used external markers, i.e. those introduced into the diet, are Cr_2O_3 , Feo, SiO_2 , polypropylene etc. The most commonly used external marker is Cr_2O_3 in fish and terrestrial animals
- Internal marker commonly utilized for digestibility estimations are crude fibre, hydrolysis-resistant organic matter and hydrolysis-resistant ash.

Factors affecting digestibility

- Both biological and environmental factors affect the digestibility. The water temperature, salinity, fish size and feeding level are known to affect the digestibility.
- Decrease in digestion rate with increase in the meal size has been reported in some fishes.
- Type of food also influences gastric evacuation. For example presence of fat in the food delays gastric emptying.

- Increase in temperature increases the metabolic rate and subsequently enhance the transit of ingesta through digestive tract. Water temperature affects more the feed intake and results in poor digestibility in fishes.
- Presence of fat in the food may delay gastric emptying, possibly by a release of a hormone, similar to enterogastrone in mammals from the intestinal wall.