DIGESTION AND METABOLISM OF CARBOHYDRATES

The digestion of at carbohydrates starts from the mouth cavity and ends in the small intestine.

- Digestion in the mouth cavity: Saliva is secreted from the salivary gland. Saliva has two digestive enzymes. One is *ptyalin* or *salivary amylase* and another is *maltase*. *Ptyalin* acts on boiled starch only and maltase enzyme on maltose. *Ptyalin* does not act on uncooked starch; it acts only on boiled starch. *Ptyalin* converts boiled starch to maltose.
- Digestion in the stomach: No carbohydrate splitting enzyme is available in the gastric juice. However, HCl of gastric juice has some ability to hydrolyze some sucrose to glucose and fructose.
- Digestion in the intestine: Bile has no carbohydrate digestive enzymes. Pancreatic juice has two CHO digestive enzyme viz. *pancreatic amylase* and *maltase*. *Pancreatic amylase* acts on both boiled and unboiled starch. So, boiled or unboiled starch and dextrins are digested to maltose by pancreatic amylase enzyme. Maltose is digested to glucose by maltase enzyme. Digestive juices of succus entericus for CHO digestion are *sucrase, lactase, maltase, isomaltase, α-limited dextrinase and intestinal amylase. Sucrase* converts sucrose to glucose and fructose. *Lactase* converts lactose to glucose and galactose, *maltase* converts maltose to glucose, *isomaltase* converts isomaltose to glucose. *, α-limited dextrinase* converts alpha limited dextrins to glucose and *intestinal amylase* which is present in minute amount digests boiled or unboiled starch to maltose.

Absorption:

Absorption of monosaccharide may result by either passive diffusion or active transport. Fructose, mannose and other pentoses are absorbed passively. Glucose and galactose are absorbed by active transport which requires energy and Na+. Rate of absorption of hexoses: galactose has the highest followed by glucose and fructose. The rate of absorption of carbohydrates by bird is rapid. Feed passes rapidly through the digestive tract.

Metabolism of carbohydrates:

The most important function of CHO is to provide energy to the animal body. It is provided when they are burnt to carbon dioxide and water. One gram molecular weight (180g) of hexose yields 686 Kcal of heat when burnt to carbon dioxide and water. The same amount of energy is released in the cell also but most of the energy released by oxidation in the cell is stored in the form of high energy bonds particularly those found in ATP. There are 3 pathways of CHO metabolism viz. Glycolysis, Citric acid cycle and pentose phosphate pathways.

Glycolysis:

In this process glycogen, glucose or other monosaccharides are broken down to pyruvic acid (in presence of oxygen) and lactic acid in the absence of molecular oxygen. **In aerobic glycolysis**, 10 moles of ATP are produced from 1 mole of glucose. Since 2 moles of ATP are used, the net production of ATP from ADP is 8 moles. **In anaerobic glycolysis,** 2 moles of ATP are used in phosphorylation of glucose and fructose-6-phosphate. 4 moles of ATP are produced in remainder of sequence. The net yield is 2 moles of glucose.

Citric acid cycle:

Pyruvic acid then undergoes oxidative decarboxylation by reaction with Coenzyme A to give acetyl-CoA. The initial reaction of citric acid cycle involves oxaloacetate with acetyl CoA where by citric acid is formed. Pyruvate and lactate are caboxylated directly in the liver to form oxaloacetate. All the reactions are reversible except the formation of succinyl CoA, this prevents the cycle from running in reverse direction. 2 moles of pyruvic acid to carbon dioxide and water (aerobic), yielding 30 ATP from 1 mole of glucose. Actually, when 1 mole of glucose is oxidized to carbon dioxide and water, 38 moles of ATP are formed (8 ATP from glycolysis and 30 ATP from cycle). 1 mole of ATP stores about 7 Kcal of energy. Therefore 1 mole of glucose oxidized yields about 7×38 = 266 Kcal/ mole. So, the efficiency of free energy captured by the body is 266/686×100 = 40%. This means, about 60% energy is lost in the form of heat.

Pentose phosphate pathways:

This pathway is of considerable importance in the liver cells, adipose tissue and the lactating mammary glands. The initial phosphorylation of glucose used 1 mole of ATP and the oxidation of hydrogen via NADP+ yields 36 ATP, thereby leaving a net production of 35 ATPs per mole of glucose and in this case energy captured is 245/686×100 = 35%.

Glycogenesis:

Glycogen synthesis from simple sugars in the body tissues is known as glycogenesis. Glucose, galactose, fructose and mannose are readily converted to glycogen by various stages in which various enzyme systems are involved. Glycogen reserve is short lived. A 24 hours fast will reduce the levels nearly 0. Glycogen stores have to be constantly replenished.

Glycogenolysis:

The process of degradation of glycogen to glucose-1-phosphate in the cells is known as glycogenolysis. This process is controlled by the influence of epinephrine in the muscles or under the influence of glucagons in the liver.

Glycogen------*phosphorylase(-1ATP)*-----→Glucose-1-phosphate←-------→Glucose-6-phosphate----------→Enters glycolytic pathway.

Blood glucose level poultry:

Birds have higher blood sugar values than do mammals.

DIGESTION AND METABOLISM OF PROTEINS IN POULTRY

Digestion of protein starts at stomach and ends at small intestine.

Digestion in the stomach:

- There are three proteolytic enzymes present in the stomach viz. ***pepsin, gelatinase and chymosine.***
- Proteins like albumins, globulins, etc. digested to peptone by the enzyme pepsin (proteins—acid metaprotein---primary protiose—secondary proteose----peptone). Pepsinogen is the precursor of pepsin.
- Nucleoprotein is digested to nuclein by the enzyme *pepsin.*
- Mucin is digested to glucosamine and peptone by the enzyme *pepsin.*
- Gelatin is converted to gelatin peptone by the enzyme *gelatinase.*
- Milk protein, caseinogens is converted to casein by the enzyme *chymosin.*

Digestion in the small intestine: Bile has no proteolytic enzyme.

Digestion in pancreatic juice: The proteolytic enzymes of the pancreas are ***trypsin, chymotrypsin, aminopeptidase, tripeptidase, dipeptidase, carboxypeptidase, ribonuclease, elastage, collaginase***, etc**.**

- *Trypsin* is the precursor of trypsinogen which converts proteins or peptone to lower peptides or amino acids.

- *Chymotrypsin* is the precursor of chymotrypsinogen which converts milk protein caseinogen to casein and casein to polypeptides.
- *Aminopeptidase* converts polypeptides to amino acids.
- *Tripeptidase* converts tripeptides to amino acids.
- *Dipeptidase* converts dipeptides to amino acids.
- *Carboxypeptidases* convert polypeptides to amino acids.
- *Ribonuclease* converts nucleic acid to nucleotide.
- *Elastase* converts elastin proteins to peptone.
- *Collaginase* converts collagen protein to peptone.

Digestion in intestinal juices: The proteolytic enzymes of intestinal juices are **erepsin, polynucleotidase, nucleosidase, nucleotidase, etc.**

- *Erepsin* converts polypeptides or lower peptides to amino acids.
- *Polynucleotidase* converts nucleic acid to nucleotides.
- *Nucleosidase* converts nucleosides to purines, pyrimidines base and pentose, phosphate.
- *Nucleotidase* converts nucleotides to purines, pyrimidines base and nucleosides.

Digestion of milk proteins: Caseinogens is one of the main components of milk protein, a phosphoprotein.

Renin, an enzyme present in the stomach of young one of ruminants which with the help of Ca ion, produces casein from caseinogens. The same enzyme is present in the monogastrics named ***chymosin*****.** Casein is converted to paracaseionate by the stomach proteases. This paracasonate is converted to phosphopeptone by the enzyme *trypsin* and *chymotrypsin.* Then phosphopeptone is converted to polypeptide by trypsin. Polypeptides are converted to amino acids by *erepsin* enzyme.

Metabolism of proteins:

Amino acids undergo transamination, oxidative and non-oxidative deamination and decarboxylation.

Transamination: The process where by amino groups are transferred from an amino acid to a keto acid without the intermediate formation of ammonia. It requires an enzyme called *transaminases* or *aminotransferases*. *Transaminases* are involved directly in the biosynthesis of a number of dispensable amino acids (amino group of one amino acid is transferred to the alpha-carbon atom of keto acid). Liver contain *transaminases* that are spes that are specific forformation of each amino acid. Example:

Alanine + alpha-ketoglutarate ----------→Glutamic acid + pyruvic acid.

Deamination: Deamination is the removal of amino group from an amino acid which may be oxidative or non-oxidative. In case of oxidative the enzyme *amino acid oxidase* is involved. Example,

α-amino acid – NH2---------- α-keto acid + NH3

Alanine----------Pyruvic acid + NH3

In case of non-oxidative reaction the enzyme *amino acid dehydrase* is involved. Example,

Serine----------Pyruvic acid + NH3.

Decarboxylation of amino acids:

Enzymes are found in liver, kidney and brain those decarboxylate amino acids. Examples are histidine to histamine; tyrosine to tyramine; DOPA to dopamine; tryptophan to tryptamine.

Transmethylation:

Example: Methionine to cystine.

Symptoms of protein deficiency:

Marginal deficiency in chicken causes increase in appetite and increased feed intake. In layer chicken **Marginal deficiency** of protein will not cause reduction in egg production but causes the reduction in egg size. But a **severe deficiency** of protein in the diet of growing chicken causes slow growth, poor feathering, lack of appetite, feather picking and cannibalism.

A severe deficiency of protein in layers will cause reduced feed consumption and a marked decrease in egg production.

Symptoms of excess protein intake:

A diet having more than 30% protein results in a higher concentration of uric acid in the blood. There is deposition of crystals of calcium urate salts in and on the soft tissues of visceral organs and degeneration of kidneys. Also there is deposit of crystals in various joints.

CALORIE-PROTEIN RATIO:

A constant relationship between the dietary metabolizable energy and protein level needs to be maintained in the diet of non-ruminants/birds. The calorie protein ratio (C: P) is defined as metabolizable energy (Kcal) per kilogram divided by the percentage of crude protein in the ration.

$$\text{C: P} = \frac{\text{Metabolizable energy in Kcal/ kg diet.}}{\text{\% protein in the diet}}$$

This C: P ratio is very important in case of poultry feeding. This ratio varies with age of the bird. This ratio ensures adequate protein intake by the animal at all possible dietary ME levels. Diets having wider C: P ratios lead to higher fat deposition of the carcass and improve its finish. This concept is used in case of finisher rations like finisher broilers. When lean meat is required the animal/bird should be fed diets having narrower C: P ratios which will result in low fat and high protein deposition on the carcasses. C: P ratios for the diet of various classes of chickens are as under (as per BIS).

Type of feed	Broiler starter	Broiler finisher	Chick starter	Grower	Layer
Crude protein (%)	23	20	20	16	18
ME (Kcal/ kg diet)	2800	2900	2600	2500	2600

C: P	1:122	1: 145	1: 130	1: 156	1: 144

DIGESTION AND METABOLISM OF FAT IN POULTRY

Digestion of fat starts at stomach and ends at small intestine. In saliva there is no splitting enzyme. Neutral fats, phospholipids, cholesterides, etc. are digested in the GIT.

Digestion in the stomach:

Gastric lipase enzyme is secreted from the stomach which acts in acidic pH i.e. at 4-5. By this enzyme neutral fats are converted to fatty acids and glycerol. Steps in hydrolysis of neutral fats:

Fat-------→Fatty acid + diglycerides.

Diglycerides------→fatty acid + monoglycerides.

Monoglycerides-------→ fatty acid + glycerol.

So, in complete hydrolysis of 1 molecule of fat there is production of 3 moles of fatty acids and 1 mole of glycerol.

Digestion of fat in the small intestine:

In small intestine fatty foods are mixed up with bile, pancreatic juice and intestinal juice.

Functions of bile: Emulsification of fat is caused by bile salts (sodium glycocholate and sodium taurocholate) through which fat molecules become soluble in water. This emulsified fat is digested by the pancreatic and intestinal juices.