

WEEK FOUR

CARBOHYDRATES

The name carbohydrate is derived from the French 'hydrate de carbone' and was applied to neutral chemical compounds containing the elements carbon, hydrogen and oxygen with which hydrogen and oxygen occurring in the same proportion as in water (CH₂O). Chemically, carbohydrates are therefore polyhydroxyl aldehyde or ketones or substances that yield these on hydrolysis. CHO consists of the greatest proportion of food consumed by animals except the carnivores.

FUNCTIONS OF CARBOHYDRATE

1. The primary function of carbohydrate in animal nutrition is to serve as a source of energy for normal life processes.
2. The relatively insoluble fractions (cellulose, hemicellulose) are most important in providing structural support for living plants.
3. Carbohydrates and lipids are the two major sources of energy for animal body in normal conditions.

DIGESTION AND ABSORPTION OF CARBOHYDRATES

NON-RUMINANTS

Starch is the only polysaccharide which is highly utilized by monogastric animals and dietary disaccharides have to be broken down by digestion into mono-sugars whose molecules are suitable for passage through the intestinal tract. For absorption to occur, poly, tri and disaccharides must be hydrolysed by digestive enzyme produced by the host or the microflora inhabiting the GIT of the host. The following schemes illustrate the mode of action of carbohydrates.

1. Starch $\xrightarrow{\alpha\text{-amylase}}$ Maltose $\xrightarrow{\alpha\text{-glucosidase}}$ Glucose
2. Saccharose $\xrightarrow{\alpha\text{-glucosidase}}$ Glucose + fructose
3. Lactose $\xrightarrow{\beta\text{-Glucosidase}}$ Glucose + Galactose

The major carbohydrate digesting enzyme is α -amylase secreted in the pancreatic juice which splits the α -1,4- linkages. α -amylase cannot hydrolyse α -1,6-branches or linkages. Intra-cellular amylases complete the hydrolysis of starch started by pancreatic amylase in

the intestinal lumen. The mechanism of /or intestinal absorption of sugar involves active transport. The rate of absorption of sugar decreases in the following order.

Galactose > Glucose > Fructose > Pentose

The absorbed sugars are carried by the portal blood to the liver.

Note: Cellulose and hemi-cellulose escaping the small intestine of poultry or pigs are substrats of fermentation which occur in the caecum. This microbial action resemble the ruminal fermentation of polysaccharide. The capacity of non-degraded CHO to absorb water increases in bulkiness of the chime passing through the tract. This encourages a peristaltic action by which food residues/digesta are drawn forward through the intestine and mechanical digestion is enhanced.

RUMINANTS

There are fundamental differences between ruminant and monogastric animals concerning the mode of digestion and metabolic pathways and the type of the end products formed by the 2 groups of animals. The major bulk of carbohydrate in ruminants feed are polymers; cellulose, hemicellulose, starch, fructose and pectin. Fodder plants contain on dry matter bases 20 – 30% of cellulose, 14 – 20% hemicelluloses, up to 10% of pectin and 2- 12% of lignin. The breakdown of carbohydrate in the rumen may be divided into 2 stages;

- a. First, is the digestion of complex carbohydrate to simple sugars. This is brought about by extra-cellular microbial enzymes and it is thus analogous to the digestion of carbohydrate in non-ruminants. Cellulose is decomposed by one or more β -1,3 glucosidase to cellobiose which is then converted either to glucose or through the action of a phosphorylase to glucose 1- phosphate. Starch and dextrin are first converted to maltose, by maltose phosphorylase or 1-6-glucosidase to glucose 1- phosphate.
- b. Fructans are hydrolysed by enzymes attacking 2,1 and 2,6 linkages to give fructose which may also be produced together with glucose by the digestion of sucrose. Pentoses are the major products of hemicellulose breakdown which is brought about by enzymes attacking β -1,4 linkages to give xylose and uronic acids.

Note: The cellulose in roughages are practically unutilisable by human beings and most species of monogastric animals. This may however be well utilized by ruminants due to ability of microorganisms that break it down.

Fermentation in the rumen is by far the most important means whereby ruminant animals digest and utilize carbohydrates.

METABOLISM OF CARBOHYDRATE IN NON-RUMINANTS

Metabolism of carbohydrate is important to farm animals since carbohydrates in the body are essential sources of energy in the body and the starting materials for biosynthesis of fats and non essential amino acids. The major product of carbohydrate digestion in non-ruminant is GLUCOSE and it is the starting materials for biosynthetic processes. The central transporting medium for glucose is the blood. The blood glucose concentration is determined by two opposing processes;

1. Entry of glucose into the blood from the intestine, (originating from food) liver and other organs.
2. Withdrawal of glucose from blood into various tissues (liver, muscles, kidney, adipose tissues and brain) and its utilization in the tissues for oxidation and biosynthetic purposes.

The blood sugar is maintained by conversion of circulating blood glucose into glycogen (glycogenesis) and re-conversion of glycogen to glucose (glycogenolysis). *Hypoglycemia is the condition of low level of glucose in the blood.*

Hyperglycemia is the condition of high level of glucose in the blood.

SOURCES OF BLOOD GLUCOSE

1. Absorption of glucose resulting from digestion of oligosaccharides and polysaccharides.
2. Biosynthetic formation in the body tissues particularly in the liver from non-carbohydrate metabolites, the such as amino acid, lactic acid, propionic acid and glycerol (gluconeogenesis).

Note: that glucose is the second important energy source for ruminants after volatile fatty acid (VFA) and it is formed mainly from biosynthetic processes in these animals.

3. Glycogen stored in the liver serves as a reservoir for glucose when the latter is needed in metabolic processes. The glucose is released from glycogen by enzymatic breakdown of glycogenolysis. The glycogen stored are derived from absorbed glucose or from glucose formed by gluconeogenesis.

The fate of glucose removed from the blood - the glucose removed from the blood into cells and organs may be utilized in the following ways:

1. For the biosynthesis of glycogen.
2. For conversion into fat.
3. Conversion into amino acids.
4. It can also be used as a source of energy.

EMBEDDED EMMEYERHOFFS GLYCOLYTIC PATHWAY

The major pathway whereby glucose from feed is metabolized to give energy has two stages. The 1st stage is known as GLYCOLYSIS. This can occur under anaerobic condition and result in the production of pyruvate/pyruvic acid. The metabolism of CHO is effected with the aid of their phosphate derivatives.

Glycolysis involves the breaking down of a unit or 1 mole of glucose to yield pyruvic acid. Enzymes are released during the process. It is a process involving **PHOSPHORYLATION REACTIONS** and by the end of the pathway, a six carbon molecule would have been successfully broken down into 2 moles of 3-carbon units. All the steps of glycolysis are enzymatically catalysed.

Glycogen is stored in the liver and situation may arise that the glucose that is circulating in the blood is depleted; for example in athletes or actively running animal, the glycogen can be mobilized to release glucose through the process of **GLYCOLYSIS**.

The glucose can also be from the breakdown of starch in the diet. When glycogen is broken down, it releases glucose unit as GLUCOSE-1-PHOSPHATE. Anytime a carbohydrate is been phosphorylated, it requires a high energy constituent called ATP, the glucose-1-phosphate is converted to glucose-6-phosphate by enzyme called phosphoglucomutase. Most of the reactions are irreversible but the interconversion of

glucose to glucose-6-phosphate and that of mannose to mannose-6-phosphate are reversible.

Glucose-6-phosphate is converted by a reversible step to fructose-6-phosphate. The enzyme responsible is phosphohexoisomerase. If fructose is present in the blood, glucose-6-phosphate is produced directly from fructose and the enzyme responsible is fructokinase.

Fructose-1,6 Biphosphate enzyme is phosphofructose kinase, this then breaks down to form a 3 carbon unit called Triphosphate. This reaction is catalysed by Triosphosphate-isomerase.

At this stage, there is a link between carbohydrate and fat metabolism because the dihydroxyl acetone phosphate produced can be channeled to produce glycerol which is important in fat metabolism.

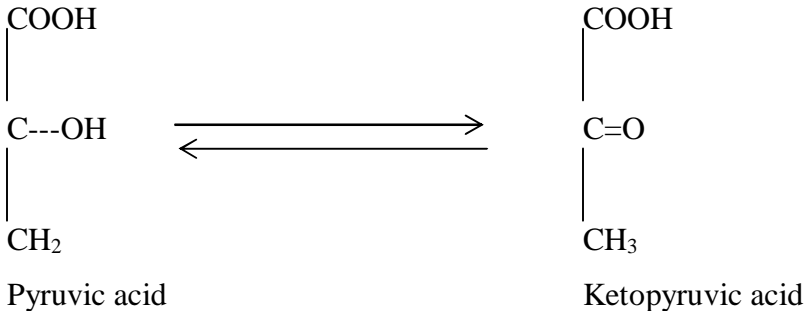
3-phosphoglyceraldehyde is converted to 1,3 biphosphoglycerate, this need an energy compound called NAD (nicotinic adenine dinucleotide).

The 1,3 biphosphoglyceric acids (PGA) formed is catalysed by phosphoglycerate mutase because the phosphate group changes position from carbon 3 to carbon 2. After this, a water molecule is removed to form phosphopyruvic acid (enol). The double bond so formed here, is as a result of removal of water molecule, ADP and enzyme.

The next step is a spontaneous reversible reaction which form pyruvic acid or (ketone form) which now goes on to form acetaldehyde. The enol form of pyruvic acid is not stable because of the double-bond position because of its instability, it spontaneously form keto-pyruvic acid.

Note:

1. The 2 forms of pyruvic acid are (a) Enol form (production of an enol pyruvate)
(b) Ketone
2. The end product of glycolysis is usually pyruvate.



Acetaldehyde goes on to form an ethyl-alcohol by enzyme called Alcoholdehydrogenase because the same enzyme facilitates forward and backward reactions. Pyruvic acid can go into lactic acid in the presence of lactic acid dehydrogenases, this reaction occurs in anaerobic condition where there is no oxygen. Under aerobic condition, pyruvic is oxidized to CO₂ and without producing energy.

Note: PPP i.e (Pentose Phosphate Pathway) is an alternative pathway to glycolysis and it takes place in small animals (anaerobic condition).

FUNCTIONS OF METABOLIC PATHWAY

1. Production of fuel and energy
2. Conversion of glycogen
3. Providing/Reducing ion e.g hydrogen ion for synthesis of fat.
4. PPP –Pentose Phosphate Pathway (5 carbon sugar operate in PPP environment) provides ribose sugar for synthesis of RNA and DNA.
5. Triosphosphate is used for the synthesis of glycerol.
6. production of pyruvate/pyruvic acid.
7. All the intermediate substances in the TCA are used for protein synthesis.
8. A-coA (Acetic-co-enzyme A) is used for the synthesis of fat and also synthesis of cholesterol for steroids.