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Carbohydrates: Is defined as natural chemical compounds which is containing the element carbon, hydrogen and oxygen in formula CH_20, the last two element present in the same proportion as in water.

Carbohydrates classified into two group according to digestibility and solubility into:

1. Soluble CHO: which called nitrogen free extract (NFE) include simple sugar, starch and hemicelluloses which is easily digestible in body.
2. Non soluble CHO: which called crude fiber (hard fibrous substance) like celluloses and lignin. They are less digestible by non ruminant and easily digested in ruminant by rumen microflora.

structure of Carbohydrates:

Monosaccharide (simple sugar) can be classified according to the number of carbon atoms e.g. Triose (three carbon atoms C3H6O3), Pentose (five carbon atoms $C_5H_{10}O_5$) and Hexose (six carbon atoms $C_6H_{12}0_6$).

Disaccharides contain two monosaccharide, oligosaccharide contain from two to ten (2- 10) monosaccharide, but polysaccharides contain more than 10 monosaccharide units.

Function of carbohydrates:

1. A major source of energy in animal body.
2. They are essential component of milk lactose.
3. They are stored as glycogen , excess of CHO in the diets is converted into glycogen in liver and muscles.
4. they provide suitable environment for the growth of rumen bacteria and protozoa.
5. they help in peristalsis movement of food.
6. they maintain the glucose level of plasma.
7. they are also component of several important bio-chemical compounds such as nucleic acid, coenzymes.
8. they play role in metabolism of amino acids and fatty acids.

Classification of carbohydrates: Carbohydrates usually are classified into two major group:

1. Sugar: The term sugar which contain less than ten monosaccharide. Sugars are

divided into two groups:

l- Monosaccharide: The simplest sugars, they cannot be hydrolyzed into smaller,

they are divided into sub groups depending upon the number of carbon atoms present in the molecules for examples.

A-Triose ($C_3H_6O_3$): e.g. glyceraldehydes and dihydroxy acetone, are important intermediates in energy metabolism.

B- Pentoses ($C_5H_{10}O_5$): e.g. ribose, which found in number of compounds such as ATP, ADP, DNA, RNA and etc.

C- Hexoses ($C_6H_{12}O_6$): e.g. Glucose, Galactose, Fructose and Maltose

Glucose: which is found in free form in fresh fruits, etc., Act as one of the sugar units of sucrose and lactose. Which is considered as an end products of all type of carbohydrates digestion and act as source of energy.

Galactose: one of the sugar units in lactose, no free form in nature and converted into glucose in liver.

Fructose: one of the sugar units of sucrose and have relative sweetness.

Mannose: no free form in nature.

2-Oligosaccharides:

A- Disaccharides: e.g. maltose, sucrose, and lactose

- Maltose: Two glucose molecules joined together by a(l-4, 1-6) linkages. - , .
- Sucrose: Two molecules of glucose and fructose which is found in cane and beet sugar and fruits and etc.
- Lactose: Two molecules of Galactose and glucose joined together which synthesized by mammary gland.

B- Trisaccharides: The unions of three molecules of hexoses e.g. Raffinose and Kestose C- Tetrasaccharides:

The unions of four molecules of hexoses Stachyose D- Pentasaccharides

2. **Non sugar:** they are tasteless, insoluble, amorphous compounds with high molecular weight. They are divided into two groups polysaccharides and complex carbohydrates. Polysaccharides is

divided into two sub groups:

• Homopolysaccharides: **e.g.**

A- Glucans: polymers of glucose.

B- Fructans: polymers of fructose. Which hydrolysis into glucose. Inulin is the known polysaccharide belonged to this group.

C- Starch: most plants consist primarily of starch. Starch is hydrolyzed with acids or enzymes, it is changed into dextrin, maltose and finally into glucose.

Starch ___ ► Dextrin --------► maltose ------ ►glucose

In food, starch is exists as a straight chain of glucose units called amylase, mixed with a branched chain structure called amylopectin.

D- Glycogen: The small amount of carbohydrate reserve in the liver and muscles in the form of glycogen, which is called animal starch. Glycogen is the main CHO storage product in the animal body and play an essential role in energy metabolism.

E- **Dextrins:** these are intermediates products of the hydrolysis of starch and glycogen.

F- Cellulose: It is Glucans (polymers of glucose) and is the most abundant plant constituent. Cellulose molecule contains between 1600 to 2700 glucose units. Cellulose is more resistant to chemicals agents than the other glucosans and hydrolysis with strong acids to produce glucose. Fungi and bacteria attack cellulose and produce cellubiose and produce glucose by action of cellubiase enzyme. In rumen, cellulose fermented by microbial enzymes and produce volatile fatty acids like acetic acid, propionic acid and butyric acids.

G- **Pectin:** which is refer to a group of plant polysaccharide which is found in peel of citrus fruits.

H- chitin: It is major constituent of the exoskeleton of insects.

- Heteropolysaccharide:
- e.g. Hemicelluloses, Gum Arabic, Mucilages, Agar, Heparin, Lignin.

A- **hemicellulose:** The hemicellulose are less resistant to chemical agents than cellulose B- **Gum Arabic:** It is useful plant gum and produced from the wound in the plant, and may arise as a natural exudates from bark and leaves.

C- **Lignin:** The woody part of plants contain a complex indigestible substance called lignin. Lignin is not carbohydrates but because of its association with carbohydrates its usually discussed along with carbohydrates. There is a strong chemical bonds existing between lignin and many plant polysaccharide like cellulose. Lignin is resistant to strong acids and microbial action in the rumen and

considered to be indigestible by the animal.

1 CHO digestion in ruminant: The major portion of the ruminant diet consist of cellulose, hemicelluloses and other carbohydrates which cannot be hydrolyzed

Carbohydrates digestion:

by the enzymes secreted by the animals in the digestive tract but broken down

by enzymes secreted by rumen microorganisms with the production of volatile fatty acids and gases. The bacteria and protozoa mainly responsible for fermentation in the digestive tract. The normal concentration of bacteria in rumen are 10^{11} bacteria per ml; and protozoa are 10^{6} per ml of rumen content. All CHO are converted in rumen into pyruvic acid then pyruvate produce volatile fatty acids like acetic, propionic, and butyric acids. Roughage diet produce high level of acetic acid, but concentrates diet produce high level of propionic and less of acetic.

Absorption of volatile fatty acid: Most volatile fatty acids are absorbed directly from rumen, reticulum, and omasum. Small amount may pass to abomasum and small intestine. Portion of these volatile fatty acids are used by bacteria and protozoa to synthesized their own polysaccharides.

CHO metabolism in rumin: In ruminants, considerable amounts of volatile fatty acids (Acetic, propionic, and butyric acids) are produce from carbohydrates breakdown in the rumen. The acids then pass across the rumen wall. The net gain of ATP per mole of acetic acid is 10 ATP, propionic is 17 ATP, and butyric acid 25 ATP.

CHO Digestion in non-ruminants: Digestion of CHO begin in the mouth, food mixed with saliva which contain the enzyme ptyalin (salivary gland a-amylase); this enzyme hydrolyzed starch into maltose and isomaltose. Food remain in the mouth for short time and about 3- 5% of starch hydrolyzed into

maltose. After that, the food enter the stomach and the action of a- amylase

enzyme of saliva continues for about 30- 50 minutes until the acid of gastric secretion blocks the activity of the salivary amylase. After ingested food reach small intestine gall bladder secreted bile juice (bile pigment and bile salt) which act neutralize acidity of chyme and stop action of pepsin and allow action of intestinal enzymes emulsify fat. Pancreatic secretion contain large quantities of intestinal a- amylase enzymes which converted starch into maltose and isomaltose. Theforth stage of CHO digestion occur by enzymes synthesized by the

intestinal mucosal cells which is lining of the upper jejunum which including the action of several enzymes e.g. (disaccharidase and oligosaccharidase) for example isomaltase which degraded polysaccharides into monosaccharide like glucose.

Absorption of CHO: The duodenum and upper jejunum absorbed the bulk of dietary sugars. Insulin is not requirement for the uptake of glucose by intestinal cells. Any defect in disaccharidase enzymes activity of the intestinal mucosa cause the passage of non digestible CHO into the large intestine which cause osmotic diarrhea because water is drawn from the mucosa into the large intestine causing osmotic diarrhea.

Metabolism of CHO:

Metabolism: The sum of all chemical changes (catabolism and anabolism) accruing in the cell, tissue, or the body.

Catabolism (degradation): Break down of complex molecules such as proteins, polysaccharides and lipids to a few simple molecules e.g. CO_2 and H_20.

Anabolism: Formation of complex end product from simple precursors e.g. synthesis of polysaccharides and glycogen from glucose.

Glucose is the energy source for all cells. Blood glucose can be obtained from three primary source which is the diet, degradation of glycogen and gluconeogenesis.

Glycogen is the major storage form of carbohydrate in animals and corresponds to starch in plants. The process of biosynthesis of glycogen from glucose is known as glycogenesis. This occurs in all the tissues of the body but the major sites are liver and muscles. A considerable amount is synthesized in kidney also. Glycogenesis is a very essential process since the excess of glucose is converted and stored up as glycogen which could be utilized at the time of requirement.

Liver glycogen, an essential postprandial source of glucose which can meet these needs for only 10-18 hours in the absence of dietary intake of CHO. During prolonged fasting hepatic glycogen is depleted and glucose is synthesized by a special pathway which called gluconeogenesis from precursors such as lactate, pyruvate, glycerol. Gluconeogenesis means The synthesis of glucose from non-carbohydrate precursors is known as. The major site of gluconeogenesis is liver.

In exercising, muscle glycogen is degraded to providing the tissue with an important energy source and after muscles glycogen is depleted, specific tissue synthesized glucose by gluconeogenesis.

The function of muscle glycogen is to serve as a fuel for synthesis of adenosine tri phosphate (ATP) during contraction; whereas; liver glycogen is to maintain the blood glucose concentration during the early stage of fasting.