CARBOHYDRATES

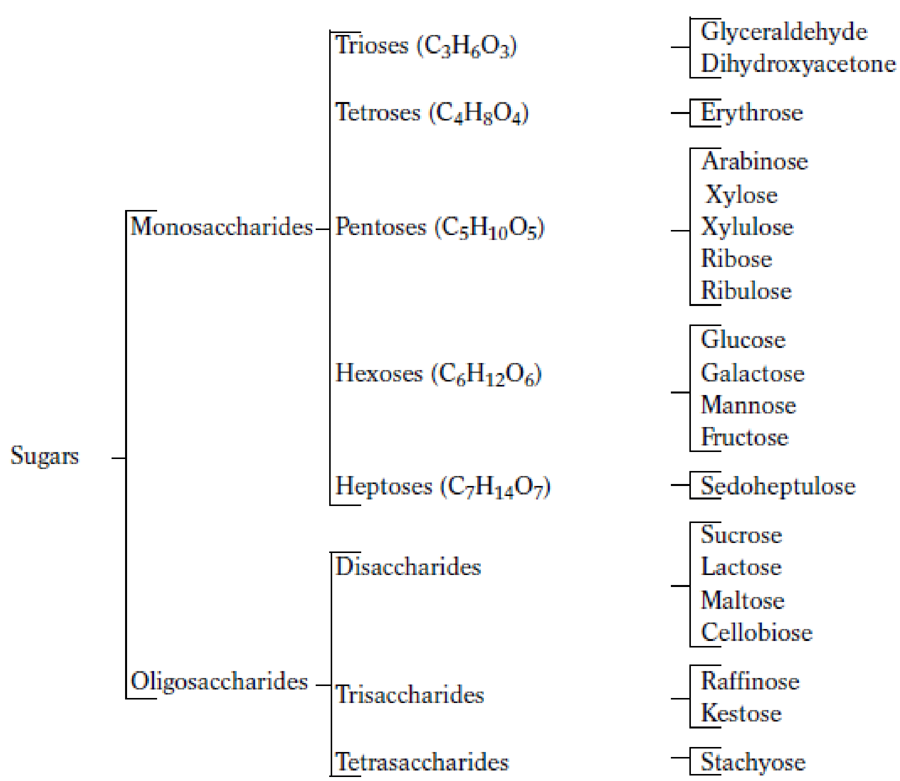
carbohydrates are neutral chemical compounds containing the elements carbon, hydrogen and oxygen.

Classification of carbohydrates:

The term ***sugar*** is generally restricted to those carbohydrates containing fewer than **ten monosaccharide** residues, while the name *oligosaccharides* is frequently used to include all sugars other than the monosaccharides.

Polysaccharides, also called glycans, are polymers of monosaccharide units. They are classified into two groups, the **homoglycans**, which contain only a single type of monosaccharide unit, and **the heteroglycans**, a mixture of monosaccharides.

In plants, water-insoluble carbohydrates, cellulose and hemicellulose are responsible for their structural stability and mechanical firmness, whereas the water-soluble carbohydrates (e.g., glucose and starch) serve as energy reserves.



- Non-sugars
  - Polysaccharides
    - Homoglycans
      - Arabinans
      - Xylans
      - Glucans
        - Starch
        - Dextrins
        - Glycogen
        - Cellulose
        - Callose
      - Fructans
        - Inulin
        - Levan
      - Galactans
      - Mannans
      - Glucosamines
    - Heteroglycans
      - Pectic substances
      - Hemicelluloses
      - Exudate gums
      - Acidic mucilages
      - Hyaluronic acid
      - Chondroitin
  - Complex carbohydrates
    - Glycolipids
    - Glycoproteins

Hemicelluloses

Hemicelluloses are defined as alkali-soluble cell wall polysaccharides that are closely associated with cellulose. Hemicelluloses are present on the cell walls of forage plants and are less resistant to chemical degradation than celluloses. For example, hemicelluloses can be hydrolyzed by a relatively mild acid, whereas cellulose hydrolysis requires a concentrated acid. Bacteria in the large intestine of nonruminants are able to ferment hemicelluloses more extensively than cellulose. In ruminants, most hemicelluloses are digested in the rumen just like cellulose, and some escape the rumen to be further degraded in the lower intestinal tract.

Lignin

Lignin, which is not a carbohydrate but is closely associated with this group of compounds, confers chemical and biological resistance to the cell wall, and mechanical strength to the plant. Lignin is of particular interest in animal nutrition because of its high resistance to chemical degradation. Physical layer of plant fibres by lignin reduces the inaccessibility to enzymes that would normally digest them. Wood products, mature hays and straws are rich in lignin and consequently are poorly digested unless treated chemically to break the bonds between lignin and other carbohydrates.

Carbohydrate digestion

	Ruminants	Non-ruminants
Salivary amylase	Zero	Varies with species High in primates, Low in strict carnivores
Pre-gastric fermentation	Extensive	Zero
Gastric digestion	Very low	Very low
Pancreatic amylase	Low to moderate	Very high
Intestinal glucose absorption	Zero to negligible	High

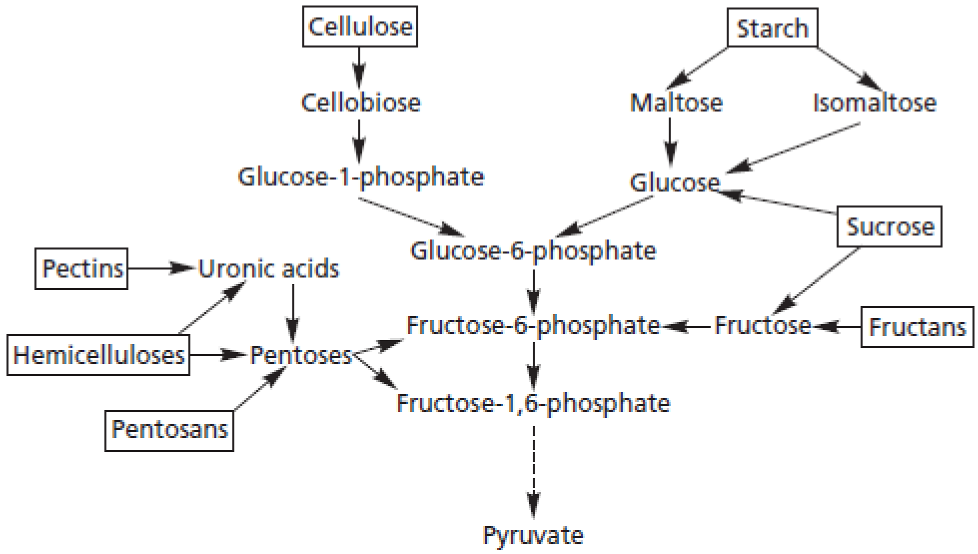
Fermentative Digestion of Carbohydrates in Ruminants

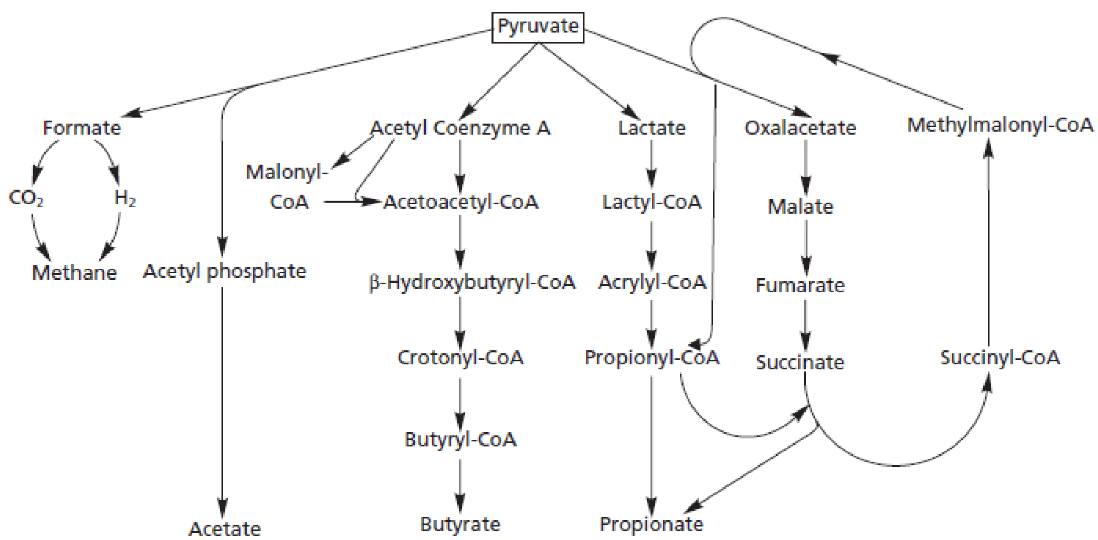
In forages, plant cell walls are composed of polysaccharides which are complexed with lignin. Plant-source carbohydrates can be broadly classified as structural and nonstructural. Structural carbohydrates (e.g., cellulose and hemicellulose) are less digestible in the ruminant digestive tract than nonstructural carbohydrates (sugars, starches, and other carbohydrates found inside the cells of plants). Each kilogram of dry matter may contain about 400 g cellulose and hemicelluloses, and 200 g of water-soluble carbohydrates.

The breakdown of carbohydrates in the rumen may be divided **into two stages,**

The first of which is the digestion of complex carbohydrates to simple sugars. This is brought about by extracellular microbial enzymes. The simple sugars produced in the first stage of carbohydrate digestion in the rumen are rarely detectable in the rumen liquor because they are immediately taken up and metabolised intracellularly by the microorganisms.

The **second stage**, the pathways involved in the metabolism of carbohydrates by the animal, that link pyruvate with the major end products of rumen carbohydrate digestion, which are acetic, propionic and butyric acids, carbon dioxide and methane.





The total weight of acids produced may be as high as 4 kg per day in cows. Much of the acid produced is absorbed directly from the rumen, reticulum and omasum, although 10–20 per cent may pass through the abomasum and be absorbed in the small intestine.

Role of rumen microbes in carbohydrate breakdown

Bacteria play the predominant role in the extracellular hydrolysis of dietary complex carbohydrates in the rumen, but fungi and protozoa also contribute to this process. Specially, complex carbohydrates in the plant cell walls are hydrolyzed extracellularly by **cellulases, hemicellulases, and xylanases** to their monosaccharides. These enzymes are of primarily bacterial origin, and are also released at high levels by the anaerobic fungi. The main cellulolytic bacteria are *Fibrobacter succinogenes, Ruminococcus flavefacians*, and *Ruminococcus albus*. The ruminal bacteria and fungi are essential to break down plant cell walls through the hydrolysis of β-1-4 glycosidic bonds in membrane polysaccharides.

Ruminal protozoa also produce cellulases, hemicellulases, xylanases, and α-amylase like bacteria and fungi. The protozoa swallow bacteria, as well as water-insoluble feed particles and starch granules through pinocytosis (swallowing). The swallowing of bacteria is a way for the rumen to control the number of its bacteria. Within the protozoa, the above enzymes act in performance to hydrolyze the polysaccharides to the basic monosaccharides.

Carbohydrate Metabolism

Terminology

Catabolism: Nutrient or tissue breakdown (release energy)

Anabolism: Nutrient or tissue synthesis/creation (use energy)

Oxidation: Utilisation of a nutrient to generate ATP, CO_2 and H_2O. Loss of electrons, addition of O_2, removal of H_2

Glycolysis: Breakdown of glucose into pyruvate.

Gluconeogenesis: Glucose synthesis from non-carbohydrate precursors. Non-carbohydrate precursors e.g. amino acids, lactate, glycerol, pyruvate and propionate. It never uses fatty acids. Occurs primarily in the liver.

Glycogen: Storage form of glucose (animal version of starch). Found in the liver and muscle

–Glycogenesis ⟹ glycogen synthesis

–Glycogenolysis ⟹ glycogen breakdown

TCA cycle (Tricarboxylic acid cycle): Glycolysis products enter TCA cycle to generate ATP.

Glucose uptake to cells from blood usually mediated by insulin and glucose transporters. The liver is the central site for glucose metabolism.

Sources of glucose

1-Carbohydrate digestion

- **Non-ruminants**: glucose from small intestines
- **Ruminants**: propionate from the rumen

2-Glycogen breakdown in the liver

3-Gluconeogenesis in the liver

Absorptive glucose metabolism

- Options for absorbed glucose

Catabolic
- 1) Oxidation: produces CO_2 and H_20
- 2) Glycolysis: production of pyruvate
  - TCA cycle (with O_2)
  - Lactate (with no O_2)

Anabolic
- 3) Stored as glycogen
- 4) Stored as fat
- 5) Carbons utilized for amino acid synthesis