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Animal Nutrition \ **Theoretical** Assist. Lect. Chalang Madad
2nd stage:1st semester \ Lecture 4

ENERGY METABOLISM

Metabolism

Metabolism is the name given to the sequence, or succession, of chemical reactions that take place in the living organism. Some of the reactions involve the degradation of complex compounds to simpler materials and are designated catabolic reactions, whereas other reactions involve the synthesis of more complex compounds from simpler substances and are designated anabolic reactions. Waste products arise as a result of metabolism and these have to be chemically transformed and ultimately excreted; the reactions necessary for such transformations form part of general metabolism. As a result of various catabolic reactions, energy is made available for mechanical work, transportation and anabolic activity such as the synthesis of carbohydrates, proteins and lipids.

Energy Metabolism

Energy may be defined as the capacity to do work. There are various forms of energy, such as chemical, thermal, electrical and radiant, all of which are interconvertible by suitable means. For example, the radiant energy of the sun is used by green plants, via photosynthesis, to produce complex plant constituents, which are then stored. The plants are consumed by animals and the constituents broken down, releasing energy, which is used by animals for mechanical work, for transport, for maintaining the integrity of cell membranes, for the synthesis of body components and for providing heat under cold conditions. Since all forms of energy can be converted to heat, heat units have been used to represent the energy involved in metabolism. Traditionally, the basic unit used has been the thermochemical calorie (cal), based on the calorific value of benzoic acid as the reference standard. However, the calorie is too small a unit for routine use and the kilocalorie (1000 cal) or megacalorie (1 000 000 cal) is more commonly used in practice.

ENERGY METABOLISM:

The topic of energy and its metabolism by animals is known as (bioenergetics).

Bioenergetics: is the part of biochemistry concerned with the energy involved in making and breaking of chemical bonds in the molecules found in biological organism.

Some of major bioenergetics processes:

1- Glycolysis: is the process of breaking down glucose into pyruvate, producing two molecules of adenosine triphosphate **ATP / 1** molecule of glucose in the process. when a cell has a higher concentration of **ATP** than adenosine diphosphate **ADP** (high energy charge), the cell can undergo glycolysis, releasing energy from available glucose to perform biological work. (pyruvate) is one product of glycolysis, and can be shuttled into other metabolic pathways. (gluconeogenesis) as needed by the cell additionally, glycolysis produces reducing equivalents in the form of **NADH** (nicotinamide adenine dinucleotide).

2- Gluconeogenesis: is the opposite of glycolysis, when the cells energy charge is low (the concentration of **ADP** is higher than that of **ATP**), the cell must synthesize glucose from carbon-containing biomolecules such as (protein, amino acids, fats, pyruvate)

3- Citric acid cycle: is a process of cellular respiration in which acetyl coenzyme A, synthesized from pyruvate dehydrogenase, is first reacted with oxaloacetate to yield citrate.

4- Oxidative phosphorylation, and the Electron transport chain: is the process where reducing equivalents such as **NADPH** and **NADH**.

5- Photosynthesis: another major bioenergetics process, is the metabolic pathways used by plants in which solar energy is used to synthesize glucose from carbon dioxide and water.

Measurement of energy metabolism

On a practical basis, energy metabolism of animals is assessed by measuring some general aspects of metabolism. for example, in the utilization of carbohydrates, lipids and amino acids as energy sources, oxygen is consumed and carbon dioxide with water and heat are end products. all of these (except water) can be measured in animals confined in special chambers called (respirometers).

Gaseous exchange is obtained by measuring oxygen consumption and carbon dioxide output.

the ratio of these gases (mole carbon dioxide produced / mole oxygen consumed) = RQ

- respiratory quotient, this gives an indication of the nature of the metabolic fuel being used.

Examples of **RQ** determinations are as follows:

Carbohydrate catabolism:

$$C_6H_{12}O6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

$$RQ = CO_2 / O_2 = 6/6 = 1$$

Estimation of feed energy

In the USA, feed energy is expressed in Calories, in most other countries, the joule is used as the measure of energy. although the use of the joule in nutrition is not logical (joules are measures of electrical energy), it has been adopted because it is the unit of energy measurements used in the metric system. feed energy is actually measured as calories by Bomb calorimetry, and then converted to joules by conversion factors below.

1- calorie (small calorie) = the amount of heat required to raise the temperature of 1 gm of water by 1° C degree.
1 Kilocalorie (kcal) = 1000 calories.
1 Mega calorie (Mcal) = 1000 kcal.
1 calorie = 4.184 joules (j).
1 kilocalorie = 4.184 kilojoules (KJ).
1 kilojoule = 0.239 kcal.

The caloric content of biological materials is determined in a bomb calorimeter. in brief, the sample is burned in a combustion chamber (bomb) inserted in a vessel containing a known weight of water .as the sample burns, it releases heat, which is taken up by the water. from the weight of the sample, weight of the water and rise in temperature of the water, the number of calories of heat energy released can be calculated.
When a feed sample is burned in a bomb calorimeter, its Gross energy is determined. to determine the fraction of the gross energy that the animal can actually utilize, a metabolism trial must be conducted to account for various losses, yielding values for digestible, Metabolizable and net energy.

Digestible energy (DE) = Gross energy (GE) – Faecal energy

Metabolizable energy (ME) = DE – (Urinary energy + Rumen Gas losses)

Net energy (NE) = ME – Heat loss

Gross Energy (GE) values (dry basis) of various tissues, metabolites or feedstuffs.

Gross energy (GE)

Energy is stored in the chemical components of food as chemical energy. The amount of chemical energy in a food is measured by converting it to heat and determining the heat production. This is carried out by oxidising the food by burning. The amount of heat arising from the complete oxidation of a unit weight of food is known as its gross energy (GE).

Digestible energy (DE)

Digestible energy represents energy absorbed by the animal. Apparent digestible energy is calculated as the GE provided by a unit of food minus the GE content of the faeces resulting from the consumption of that unit of food.

Metabolisable energy (ME)

In addition to energy lost in faeces, energy is also lost as energy-containing compounds in urine, and as combustible gases such as methane produced as a consequence of microbial fermentation in either the rumen or hind gut. Metabolisable energy represents energy that is available for use by the animal and is calculated as DE minus energy lost in urine and combustible gases. The energy lost in urine is present as nitrogen-containing compounds such as urea, hippuric acid, creatinine and allantoin, and in non-nitrogenous compounds such as glucuronates and citric acid.

Hibernation:

Is a state of hypo metabolism entered into by some animals as a response to anticipated nutritional stress, while generally viewed as a means of avoiding winter –feed scarcity and cold.

Hibernators are of two types:

1- fat storing: do not consume food during the hibernation season and instead rely on metabolism of stored fat.

2- food storing: are store caches of food, which they ingest during their periodic arousals.

During hibernation, several mechanisms shift metabolism from carbohydrate to lipids during the transition to torpor, several key carbohydrates – metabolizing enzymes are phosphorylated, and thereby inactivated. these include glyceraldehyde 3- phosphate dehydrogenase and pyruvate (end product of glycolysis) to acetyl coenzyme A. (entry to citric acid cycle).

Catabolism of Amino acid

The use of amino acid as energy sources begins with deamination (removal of the α-amino group) in the liver. the remaining of carbon skeleton is then converted to intermediates of either glycolysis or citric acid cycle reaction.

Catabolism of Lipids

Fatty acids are catabolized by β-oxidation to yield acetyl CoA. Which enters the citric acid cycle reactions. the glycerol liberated from triacylglyceride **TAG** is converted to pyruvate. the final step of β-oxidation yields a three carbon short-chain fatty acids, propionate which is converted to succinate in the citric acid cycle.

Basal metabolism:

May be defined as the condition in which a minimal amount of energy is expended to sustain the body. determination is carried out under standardized conditions. And many factors affecting on it (age, neuroendocrine, species and breed).

Maintenance

May be defined as a condition in which a nonproductive animal neither gains nor loses body energy reserves.