COURSE CODE:	ANN 303
COURSE TITLE:	Principles of Animal Nutrition
NUMBER OF UNITS:	3 Units
COURSE DURATION:	3 Hours

COURSE DETAILS:

Course Coordinator: **Dr. Oladele Abimbola Oso**
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Other Lecturers: **Prof. Olutosin Oduguwa,**
Dr Olusegun Mark Obafemi Idowu,
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Dr. Ronke Yemisi Aderinboye

COURSE CONTENT:

Chemical composition of animal body in relation to their feed. Nutrient types: energy, protein, lipids, fibre, minerals, vitamins. Nutrients for body maintenance and production-growth, pregnancy, lactation, and egg production. Bioenergetics. Nutrient metabolism, Nutrient deficiency and symptoms. Concepts of nutrient requirement.

COURSE REQUIREMENTS:

This is a compulsory course for all Agricultural students in their third year in the University. This course is being offered in lecture format on-campus for 14 weeks, students are expected to attend lectures and practical classes, 3 hours of lecture per week. Students are expected have minimum of 75% attendance to be able to write the final examination.

The course grade will be based on 1 exams, CAT and practical work.

PRINCIPLES OF ANIMAL NUTRITION

COMPOSITION OF ANIMAL BODY

Food is any material which after ingestion by animals is capable of been digested, absorbed and utilized for physiological processes. Food can be described as an edible material that nourishes. However, not all components of ingested materials are digested. For example, grasses and hay are described as food but they contain indigestible components. The components of food which are capable of been utilized by animals are described as **NUTRIENTS.**

The feed an animal consumes may vary from very simple compounds such as salt (Nacl) or sugar ($C_6H_{12}0_6$) to extremely complex mixtures provided by some plants and most animal tissues. Not all components will be usable nutrient, although some food of animal origin such as fish meal, meat meal, milk e.t.c are utilized in limited amount hence animals will have to depend heavily on plant products and their by-products.

The study of plant nutrition is important because animals depend on them for survival. Plants are able to synthesize complex food materials using simple substances such as CO_2 from the air and water and inorganic elements from the soil by means of photosynthesis.

The greatest part of the energy is called chemical energy within the plant cells and it is this energy that the animals use for the maintenance of life and synthesis of it own tissues.

Plants and animals contain similar type pf chemical substances. These substances can be grouped according to their constitution, properties and function. The main components of food are water and dry matter. Dry matter also has a component of organic and inorganic components of food.

- Food
  - Water
  - Dry Matter
    - Organic
      - CHO
      - Protein
      - Lipids
      - Nucleic acid
      - Organic acid
      - Vitamins
    - Inorganic
      - Macro Nutrients
      - Micro Nutrients

WATER

Water is a major item in most animal's diet. The water content of animal body varies with age. New born or Neonates contains 750 – 800gkg^{-1} of water, but this reduces to about 500gkg^{-1} in mature fat animal. Water is vital to life and its contents should be maintained.

FUNCTIONS OF WATER

1. It acts as solvent in which nutrients are transported about the body.
2. Solvent in which waste products are excreted.
3. Many of the chemical reactions brought about by enzymes takes place in solution and involves hydrolysis.
4. Water helps in maintaining and/or regulating body temperature because of its high latent heat of vapourization.

Animals obtain water from three (3) main sources:

a. Drinking water
b. Water present in the food
c. Metabolic water which is formed during metabolism by the oxidation of hydrogen containing organic nutrients.

Animals will normally drink water that is required for their daily activities.

NOTE: There is no evidence that under any normal condition that an excess of drinking water is harmful.

DRY MATTER (DM)

The dry matter of food is divided into organic and inorganic material. There is however no sharp distinction between them. This is because many organic compounds contain mineral element as structural component e.g carbohydrate contains phosphorus. The animal body contains very low carbohydrate. However, animals are almost entirely made up of proteins. ***Animals' main energy store is in form of fat***. Older animals contain a much greater proportion of fat than young animals.

Proteins are the major nitrogen containing compound in the body of farm animals. Animal muscles, skin, feather, wools, nails, hoofs e.t.c contain proteins. Like proteins, nucleic acids are also nitrogen containing compounds and play a basic role in the synthesis of protein in all living organism. They carry genetic information in all living cells. Proteins are the major nitrogen containing compound in the body of farm animals. Animal muscles, skin, feather, wools, nails, hoofs e.t.c contain proteins. Like proteins, nucleic acids are also nitrogen containing compound and play a basic role in the synthesis of protein in all living organism. They carry genetic information in all living cells. Vitamins are present in animals in minute quantities. Many vitamins are important component in enzyme systems. Animals are limited in their ability to synthesize all vitamins and as such depend on external supply (supplementation). The organic matter contains all the elements other than carbon, hydrogen, oxygen and nitrogen. Potassium and phosphorus are the major inorganic component of animal tissue.

LOCATION AND DISTRIBUTION OF NUTRIENTS IN THE BODY OF FARM ANIMAL

Chemical groups which make up the gross composition of the body of farm animals are not evenly distributed throughout the various organs or tissues. They are however distributed and/or localized according to their functions. Water is available in every part of the body. Although it varies in terms of quantities in different parts e.g water is present in blood plasma up to 92%, it is between 72 – 78% in muscles. Bones have about 55% and teeth is 5%.

Protein is present in all cell tissues. It is also the principal content of all organs and tissues. Fats are deposited under the skin where they form adipose tissue. They are also seen around the intestine, kidney and in lower abdomen. The inorganic substances are mostly mineral matter and their contents increase with age. The most common of the mineral matter in the body is calcium which makes up of 33%, phosphorus 0.75%, Sodium 0.16%, Potassium 0.19%, Mg 0.04%, Chlorine occur in form of chloride 0.11%, and Sulphur 0.15%. These values are however affected by age and stage of fattening.

NUTRIENT

Short and precise definition of nutrient is somehow difficult however a nutrient may be defined as any chemical element or compound in the diet (or given parentarily special cases that support normal reproduction, growth, lactation and maintenance of life processes. There are 6 classes of nutrients:

a. Water
b. Proteins & Amino acids
c. Carbohydrates (crude fibre + Nitrogen free extract)
d. Lipids
e. Vitamins
f. Inorganic elements

Nutrients support cellular needs for water, fuels, structural constituent (Skin, muscles, bones, nerves, fat) and metabolites regulation. Nutrients that are required in the diet because they cannot be synthesized by the body in sufficient amount to satisfy metabolic needs are termed “Essential or Indispensable” nutrients.

Note: Energy is not a nutrient but a property of energy yielding nutrient is when they are oxidized during metabolism. It is required in the diet of all animals and can be provided by fat, carbohydrate and by the carbon skeleton of amino acid after removal of nitrogen.

WATER

Water often is not thought as a nutrient even though it clearly meets all definition as one. Life cannot be sustained without water. There are 5 sources of water for farm animals:

a. Drinking water
b. Water contained in/on feed.
c. Metabolic water is produced by metabolic processes in tissues mainly by oxidation of nutrients.

   Three kinds of nutrients produce different amount of water. 1g of fat produces 1.1g of water, 1g of protein produces 0.4g of water.

d. Water liberated from metabolic reaction such as condensation of amino acids of peptides

e. Preformed water associated with body tissues catabolised during the period of negative energy balance.

Note: The importance of these different sources of water differs among animal species depending on diet, habitat and ability to conserve body water.

FUNCTIONS OF WATER

1. Water takes part in digestion (hydrolysis of protein, fats and carbohydrates).
2. Water serves in absorption of digested nutrients
3. It helps in the transportation of metabolites in the body.
4. Excretion of waste products
5. The regulation of body temperature is dependent partially on the high conductive property of water to distribute heat within the body and by vapourization of excess water release by metabolic reaction within the cells.

WATER TURN-OVER

Water turn-over is a term used to express the ratio at which body water is excreted and replaced in tissues. Non ruminant species have a more rapid turn-over because they have less water in the G.I.T (Gastro-intestinal tract). Those animals that can tolerate greater water restriction e.g camel have lower turn-over than horses and cattle that are less tolerant to water restriction. Water turn-over is affected by: climatic factors e.g temperatures and humidity .

By ingestion of common salt that increases urinary or faecal excretion.

WATER LOSSSES

Water is lost by evaporation via the skin, periodic excretion in urine and faeces. Water excreted in urine act as a solvent for excretory product excreted via the kidneys. Urine concentration is related to the type of compound excreted (uric acid, urea and minerals.) for example, poultry excrete uric acid rather than urea as an end product of protein metabolism. Poultry excrete urine in semi-solid form with only small amount of water. This gives birds a slight advantage of production of more metabolic water than does urea.

Note: Urea is concentrated aqueous solution which could be toxic to tissue. In urine, the urea is diluted by water to harmless concentration and finally excreted. Faecal water loss is considerably higher in ruminants than in other species, being about the same volume to urinary losses. Cattle that consumes fibre diet excrete faeces of 68 – 80% water. Sheep faeces which form pellets contains 50 – 70% water.

WATER REQUIREMENTS

Animals are more sensitive to lack of water than food. The first noticeable effect of moderate restriction of water is a reduced intake in feed. Severe restriction of water intake will result in rapid weight loss and the body dehydrates. Water consumption is related to heat production. Other factors affecting water intake include:

a. **Dietary Factor**: Dry matter intake is highly correlated with water intake at moderate temperature, water content of feed consumed also affect total feed intake. High level of protein intake or fats may also increase water intake.

   Consumption of common salt or other salts increases consumption and excretion of water greatly.

b. **Environmental Factor**: heat stress i.e the higher the heat the higher the water intake and vice versa.

PROTEINS AND AMINO ACIDS

The word protein is a term from Greek word "PROTEIOS" meaning prime or primary. Proteins are essential organic constituent of living organism and are in the class of nutrient with highest concentration in muscle tissue of animals.

Like carbohydrate and fat, they contain carbon, hydrogen and oxygen but in addition, they all contain nitrogen and generally Sulphur. Without protein synthesis, life will not exist. Each specie has its own specific protein. A large number of protein occur in nature.

AMINO ACID

The monomer yield of protein are amino acid, they are produced when protein are hydrolysed by enzymes, acid or by alkali. Over 200 amino acids have been isolated from biological materials since protein are large molecules which cannot form the intestinal walls, so they are hydrolysed to amino acids.

Note: Carbohydrate digestion starts from the mouth.

Digestion of protein starts from the stomach.

CLASSIFICATION OF PROTEIN

1. Simple Protein
    a. Globular Protein
    b. Fibrous Protein
2. Conjugate Protein
    a. Glyco Protein
    b. Lipo Protein
    c. Chromo Protein
3. Phospho Protein

PROTEIN DIGESTION AND ABSORPTION IN NON RUMINANT

The digestion of protein takes place in the stomach and upper small intestine by enzyme from 3 sources:

1. Mucosa of the stomach
2. The Mucosa of the intestine
3. The Pancreas

The proteolitic enzymes, their production sites and specificity of action.

Enzymes	Site of Production		pH of optimal activity
Pepsin	Mucosa of stomach	Tryptopphan, Phenyl-amine, Tryoxine, Methionine	1.3-2.0
Trypsin	Pancreas	Arginine, lysine	8 - 9
Chymo-trypsin	Pancreas	Aromatic amino acid	8 - 9
Elastase	Pancreas	Aliphatic amino acid	8 - 9
Carboxyl Peptase “A”	Pancreas	Aromatic amino acid	7.2
Carboxyl Peptase	Pancreas	Arginine	8.0

"B"			
Amino peptidase	Mucosa of stomach	Amino acid with free NH_2 groups	7.4

All this protein dis-integrating enzymes are called **ZYMOGENS,** converging of zymogens into Aliphatic amino acids are amino acid formed in form of ring active form takes place in the GIT, the main products of protein digestion is amino acid which are absorbed from the small intestine to the portal blood and then to the liver.

PROTEIN DIGESTION AND METABOLISM

The major difference between ruminant and non-ruminant is the fermentation on microbial digestion in the recticulo-rumen where feed or food stays for a longer time in the alimentary tract (Digestive tract i.e GIT).

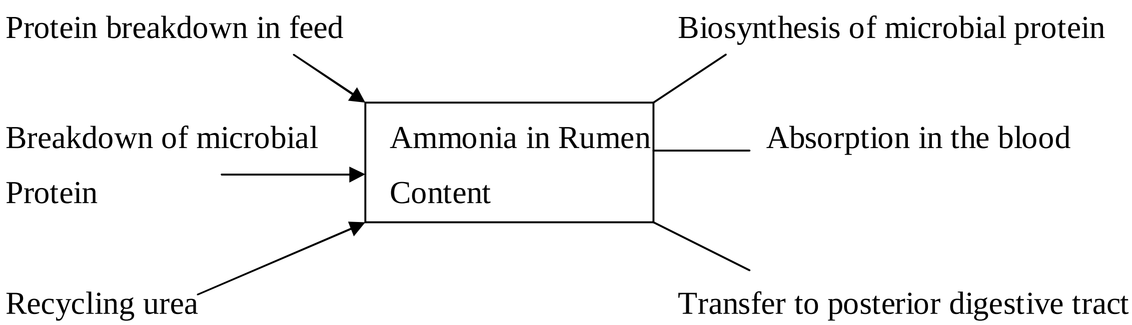
The rumen micro-organism produce proteolitic enzymes which hydrolyse, the dietary protein to peptide and amino acid which are further fermented by de-amination to carbon IV oxide, ammonia and short chain fatty acid. The proteolitic activity of the micro-organism in the rumen is responsible for the liberation of amino acid from the dietary protein taken by the farm animal which may further be de-aminated. Ruminants are almost independent of the quality of ingested protein. Apart from the nitrogen in the ruminant feed supply in form of simple nitrogen compound such as ammonium or urea. Protein ingested by ruminant takes the following pathways:

1. During passage of the food through the rumen, much of the protein is de-graded to peptide by action of proteases, the peptides are further catabolised to free amino acid and later to ammonia, fatty acid and carbon IV oxide.
2. The de-gradation product formed in the rumen particularly ammonia are used by micro-organisms in the presence of adequate energy sources for the synthesis of protein and other microbial cell constituents such as nitrogen containing cell wall components and nucleic acids.
3. Part of the ammonia liberated in the rumen cannot be fixed by the micro-organism. It is absorbed into the animal blood and transformed in the liver to

urea (urea cycle) the greater part of which is not utilized by the animal, it is excreted in the urine.

4. Bacterial cell (Bacterial protozoa) containing protein as their main component pass together with unaltered dietary protein from the reticulo-rumen through the omasum and the abomasums into the intestine. The digestion and absorption of microbial dietary protein occur in the small intestine of ruminant animals in a similar way to that with a monogastric species. The microbial protein and non-degraded food protein are digested in the small intestine by proteins. Amino acid originating from microbial protein from feed and endogenous protein contribute to the failure of amino acid absorption from the gut into the intestinal tissue and blood.

Note: Ruminant animals depend on microbial protein plus dietary protein that escape through digestion in the rumen for its supply of essential amino acids. Proteins are degraded by rumen microbes according to the schematic diagram below leading finally to the production of ammonia, volatile fatty acid and CO_2

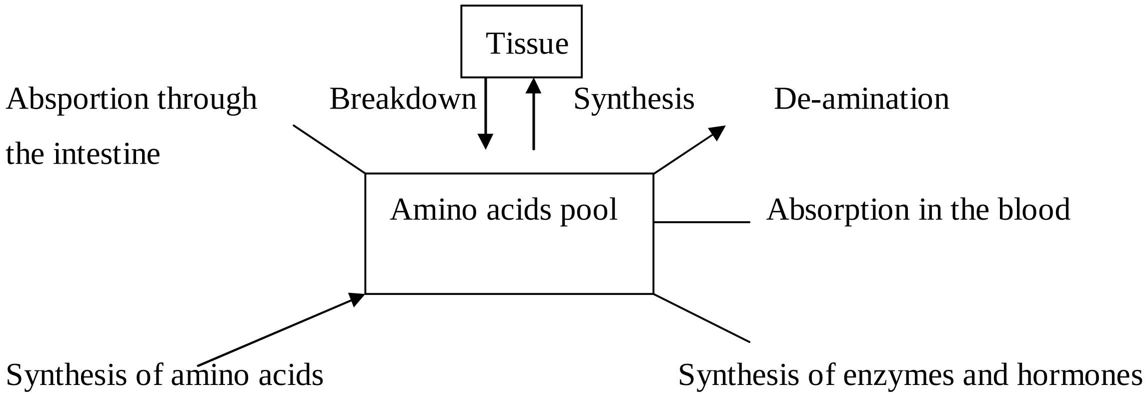


METABOLIC PATHWAY OF AMMONIA

The amino acids are absorbed from the small intestine by active transport mechanism which is sodium dependent. Vitamin B_6 (pyridoxine) also enhances normal amino acid transport across the cell. The main objective of protein digestion is achieved by protein and peptide degrading enzymes which are specific for certain linkages acting in a definite sequence. Ruminant animals are practically independent of the supply of essential amino acids in the diet since ruminant micro-organisms synthesize the amino acid required by the host animal.

PROTEIN METABOLISM

The process of tissue protein synthesis of amino acid and breakdown of tissue protein into amino acid takes place simultaneously. The various reactions involving amino acids are shown below:



Note: Amino acids act in the body as a common pool irrespective of their origin and source.

PROTEIN SYNTHESIS

Biosynthesis of protein comprises a series of processes involving DNA, which carries the genetic information, determines the exact structure of the protein to be synthesized. DNA controls the formation of the 3 types of RNA which determine the sequence of the amino acid and the molecular size of the protein been formed.

BIOSYNTHESIS OF AMINO ACID

Of the 19 amino acids found in animal body, about 9 can be synthesized in animal body particularly the liver cell. The carbon skeleton of the non-essential amino acid can be formed from carbohydrate, fats or essential amino acid. The α-amino acid originates either from ammonium ion or from the amino group of the amino acid according to the following 2 pathways.

1. Formation of amino acid by fixation of ammonia.

   Glutamic acid is formed by reductive amination of α-keto-glutamate on intermediate product of sugar breakdown.

$$\begin{array}{l} COOH \\ | \\ CO \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ COOH \end{array} \quad + \quad NH_3 + \quad NADH \xrightarrow{\text{glutamate synthase}} \begin{array}{l} COOH \\ | \\ CONH \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ COOH \end{array} + NAD^+ + H_2O$$

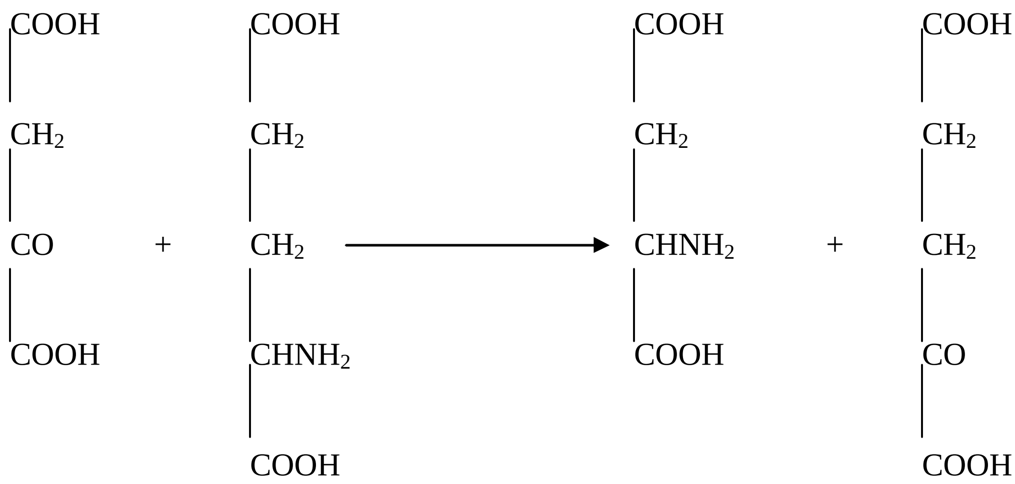
α-keto-glutarate — glutamic acid

Glutanate can be easily converted by tran-amination into other non-essential amino acids. Hence glutamate (glutamic acid) formation is important for the synthesis of non-essential amino acid and amino acid catabolism. Since the ammonia incorporated into the glutamate can be transformed into urea.

2. Trans-amination: It is a reversible reaction between amino acid and α-oxo acid leading to an exchange of the amino acid and a ketone group. Pyridoxial phosphate, the co-enzyme formed or vitamin B_6 catalyze such reaction e.g oxaloacetic acid and glutamate leading to aspartic acid and keto-glutanic acid.

Note: that trans-amination is catalysed by enzymes formed.

Transaminases occur in most animal tissues particularly liver and it enables transformation of one amino acid into another. In trans-amination, pyridoxial phosphate acts as an acceptor of amino group. The resulting pyridoxamine transform the amino group to a new α-keto-acid resulting in the regeneration of pyridoxial phosphate and the formation of a new amino acid. Other amino acids formed by trans-amination from the breakdown of carbohydrate metabolism are alanine from pyruvic acid, serine from 3-phospho-glyceric acid and glycine.



Oxalo-acetic acid + glutamate → aspartic acid + α-keto-glutamate acid

AMINO ACID DEGRADATION

Amino acids that are not used for synthesis undergo catabolic reaction such as de-amination or de-carboxylation.

Oxidation de-amination of amino acids in tissues results in the liberation of ammonia and the conversion of amino acid to the corresponding keto acid.

$RCH(NH_2).COOH + ½ O_2 + RCOCOOH + NH_3$

De-amination is a process whereby amino acids are converted to the corresponding α-keto acid with the liberation of ammonia.

De-amination is therefore a process in which the amino group of amino acids are removed and keto acids are formed with the liberation of ammonia. Keto acids formed from amino acids can be oxidized for energy supply or used for glucose synthesis or converted to fat.

Free ammonia becomes harmful to the cell when its concentration exceed certain limits and thus it is ultimately excreted as urea in mammals or uric acid in birds and reptiles.

α-ketoglutaric acid + alanine -------------glutamic acid + α-keto acid

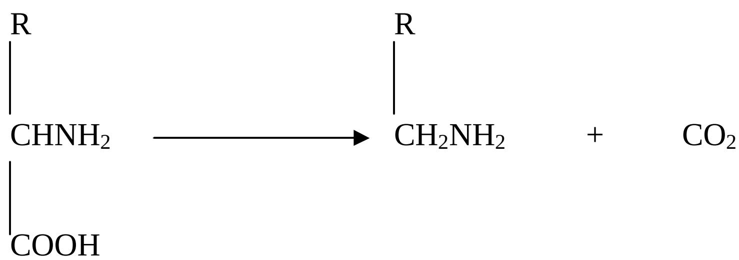
Glutamic acid + NAD^+ + H_2O----------- α-keto acid + NADH + H^+ + NH_3

Amino acid + NAD^+ + H_2O----------- α-keto acid + NADH + H^+ + NH_3

De-amination of amino acid is effected by NAD^- or NADP linked dehydrogenases in tissues is glutamic acid dehydraogenase. In conjunction with trans-amlyase, glutamic acid dehydragenase is taken to be responsible for the liberation of ammonia from other amino acids. All the amino nitrogen from amino acids which undergo trans-amination can be transferred to glutamate which is easily deaminated.

DECARBOXYLATION

The breakdown of amino acid by decarboxylation occurs in animal tissues of many micro-organisms particularly intestinal ones.



Read about the following

a. Amino acid antagonism

b. Metabolic Nitrogen

c. Endogenous Nitrogen

d. Nitrogen balance

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 (CH_2O). 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 hydrolsed 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 splis the α-1,4- linkages. α-amlyase 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 mongastric 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 hydrolsed 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 reserviour 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.

EMBDEM MAYERHOFS 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 derivates.

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 ***GLYCONEOLYSIS***.

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-isomerate.

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.

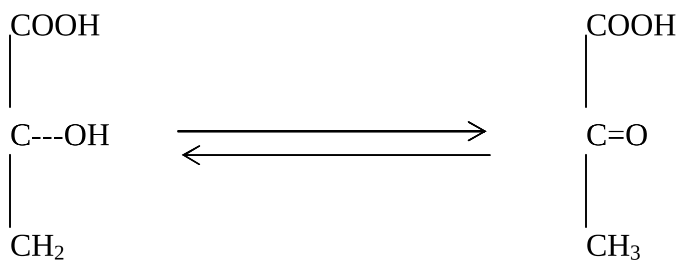
3-phosphoglyceraldehyde is converted to 1,3 biphosphoglycerate, this need an energy compound called NAD (nicotinic adenine dinucleotide).

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 gylcolysis is usually pyruvate.



Pyruvic acid Ketopyruvic acid

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 CO_2 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.

GLUCONEOGENESIS

This is defined as the bio-synthesis of CH_2O from 3 carbon and 4 carbon precursors generally non-carbohydrate in nature (production of carbohydrate from non-carbohydrate precurssors). Principal substrates for gluconeogenesis are lactate produced from glycolysis, amino acid and glycerol. Gluconeogeneisis occurs primarily in the cytosome. Although some precursors are generalized in mitochondria which must be transported to the cytosome.

The major gluconeogenic organ in animals is the liver with kidney cortex contributing in a minor way. The major fate of glucose formed in gluconeogenesis are catabolised by nervous tissues and utilization by skeletal muscle.

Note: Those points that you have energy been used on the pathway or gluconeogenetic chart is called critical points and they are irreversible. They are called control point. Gluconeogenesis (starting from protein, glycerol, lactate until you get to glucose) is a direct reversal of glycolysis.

Question

Explain in details how an animal can regain its exhausted glucose.

Glycogen is many glucose joined together by α 1-6 and α 1-4 reaction.

Gluconeogenesis simply resemble glycolysis and run in reverse, there are important steps which allow it to run in the direction of glucose synthesis. The reduction from glucose to pyruvate is strongly Exergonic. Conversion of pyruvate to glucose is made possible by the fact that 3 reaction of glycolytic pathway are strongly exergonic and are irreversible. They are catalysed by the following enzymes;

1. Hexokinase
2. Phospho-fructoskinase.
3. Pyruvate kinase.

In gluconeogenesis, different enzymes are used at each of these steps, these 3 irreversible reactions of glycolysis are by-passed by enzymes specific to gluconeogenesis at energy cost. The remaining reactions of gluconeogenesis are catalysed by glycolytic enzymes. The focus of glyuconeogenesis is on the 3 reactions that by-pass the irreversible reactions of glycolysis.

The process of gluconeogenesis is needed in the body because it provides the animal with glucose when it is not supplied in the diet in sufficient quantity. There are certain tissues which require a continuous supply of glucose at all times e.g brain, nervous system, red blood cell (erythrocytes) and the placenta. Apart from these needs, glucose helps to maintain the levels of intermediates participating in the TCA cycle. Glucose is the only source of fuel that will supply energy to skeletal muscle under anaerobic condition. This is required in the placenta because it is actively taken up by the foetus. Glucose which is the precursor of lactase is also useful in the production of milk in the mammary gland.

Gluconeogenesis therefore effects the conversion of non-carbohydrate precursors to glucose. And by virtue of this gluconeogenesis act as a clearing agent or house for the end products of metabolism of other tissues from the blood. Some of these metabolites can be injurious to the body if allowed to accumulate. The site of gluconeogenesis is chiefly liver and secondly the kidney.

Energy barriers in the glycolytic pathway obstruct the direct reversal of the pathway.

1. From pyruvic acid(enol) to 2-phospho-enol pyruvic acid.
2. From fructose-1-6 biphosphate to fructose-6-phosphate.
3. Conversion of glucose-6-phosphate to glucose.

In the first point1-2 things happen in the reaction.

a. The conversion of pyruvic to oxalo-acetic catalysed by enzyme pyruvate carboxylase in the presence of ATP, biotin and CO_2.

Pyruvate + HCO_3^- + ATP $\longrightarrow$ Oxalo-acetate + ADP + Pi

Pyruvate + HCO_3^- + ATP $\longrightarrow$ Oxalo-acetate + ADP + Pi (inorganic) + H^+

Question: Is biotin a dependent reaction ? Biotin helps to transport CO_2

b. Oxalo acetic is converted to phospho-enol pyruvate by the enzyme phospho-enol pyruvate carboxy kinase.

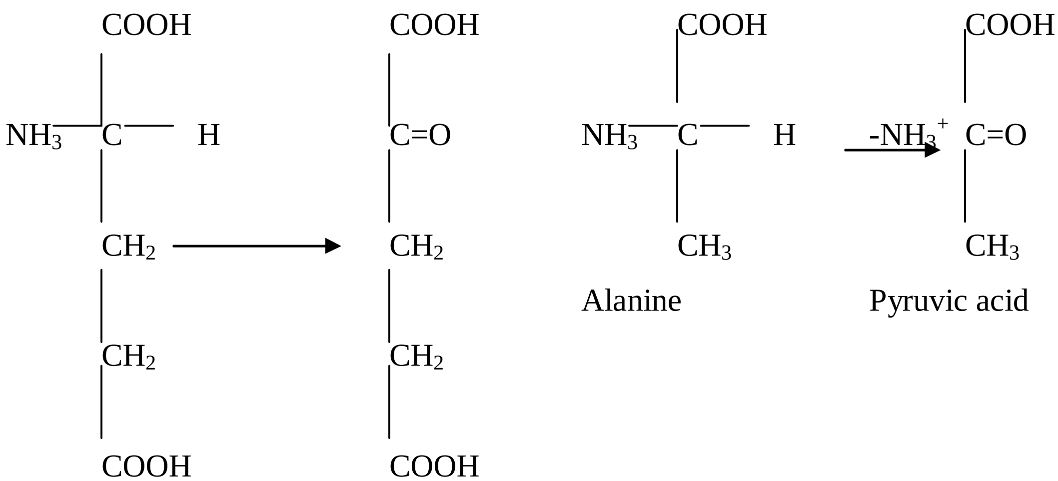
Second point phospho-enol pyruvate is converted to fructose-1-6-biphosphate or biphosphate by glycolytic enzyme acting in reverse, since the phoshphofructokinase reaction of glycolysis is essentially irreversible and also by pass in gluconeogenesis by a simple irreversible hydrolytic removal of 1-phosphate group.

Third point Fructose-6-phosphate undergoes isomerization in the presence of phospho-glucoisomerase to glucose-6-phosphate. This is converted to glucose by reversible action of hexokinase or glucokinase. Another enzyme specific to gluconeogenesis, glucose-6-phosphate come into play instead this by-pass reaction involves a simple hydrolysis in the presence of magnesium ion.

Glucose-6-phosphate + H_2O → Glucose + Pi

All the enzymes that are specific for these by-pass reactions are referred to as key ENZYMES OF GLUCONEOGENESIS. Their counterpart in glycolysis is called KEY ENZYEMS OF GLYCOLYSIS.

For amino-acid, 1st deamination occurs and after this, the amino acid form pyruvic acid or other intermediates of TCA.



Glutamic acid α-Ketoglutamic acid Alanine Pyruvic acid

In the case of ruminant, propionic acid plays a major role and is converted to succinylCoA and enters the TCA.

GLYCOGENESIS (FORMATION OF GLYCOGEN)

The formation of glycogen occurs practically in every tissue of the body but chiefly in the liver and muscles. In humans, the liver may contain as much as 60% of its weight as glycogen when analysed shortly after a meal high in carbohydrate. After 12 to 18 hours of fasting, the liver becomes almost totally depleted of glycogen. Muscle glycogen is only rarely elevated to about 10% and its only depleted significantly after prolonged vigorous exercise.

Muscle glycogen is a readily available source of hexose units for glycolysis in the muscle. Liver glycogen is largely concerned with export of hexose units for maintenance of blood glucose practically between meals.

Glycogenesis involves 4 stages/steps:

1. Phosphorylation of glucose to give glucose-6-phosphate by enzyme glucokinnase.
2. Glucose-6-phosphate is converted to glucose-1- phosphate by the enzyme phosphoglucomutase.
3. Glucose-1-phosphate reacts with UTP (Uridine Triphosphate) to form UDPG (Uridine Diphosphate glucose) and the enzyme responsible for its pyrophosphorylase (PP).
4. As the UDPG brings glucose units one after another, the C_1 of the glucose join with the C_4 of the already existing molecule. This will continue until time for branching. The enzyme responsible for this joining is glycogen synthase or glycogen transferase. The body prefers to start with an oligosaccharide. This is called a Primer. The glycogen primer may in turn be from a protein backbone which may be similar to the synthesis of other glycoprotein when the chain length is up to 6 molecules, another enzyme come into play, it is called A BRANCHING ENZYME named AMYLO-1-4,1-6-TRANSGLUCOSIDASE which transfers part of 1-4 chain to a neighbouring chain to form an α-1-6chain. Thereby establishing a branched chain.

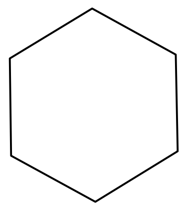
o o o o o

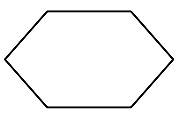
o o o o o

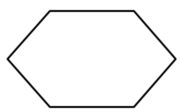
o o o

o o o o

o o







GLYCOGENOLYSIS

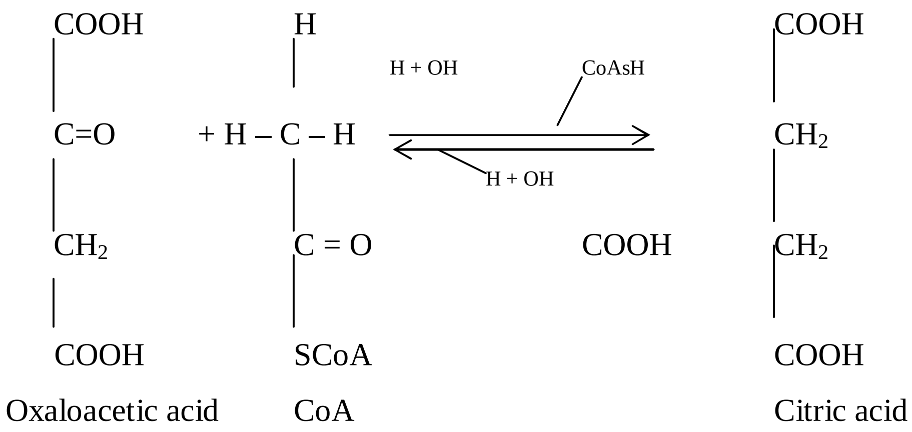
The importance of glycogenolysis and gluconeogenesis is to maintain a balance in the glucose content of the blood.

Glycogenolysis is the opposite of glycogensis. The breakdown of glycogen that is glycogenolysis is activated by the enzyme phosphorylase which breaks the 1 – 4 linkages. Each time it breaks the linkages, it yields glucose-1-phosphate one at a time. Phosphorylase enters from the free end and available glycogen unit and start chopping off the molecule left on either side of the branch point i.e α—1-6-glycosidic bond are not susceptible to cleavage by phosphorylase but before this a transferase enzyme comes to play such that α-1-6 linkage is exposed. The transferase cleave the remaining 3 – 4 molecule to reach α-1-6 linkage thereby exposing it to another enzyme- debranching enzyme (amylo-1-6glucosidase) to break it down.

Glucose is transported in the blood as natural glucose not glucose-1-phosphate, so to convert this to glucose, first glucose-1-phosphate is converted to glucose-6-phosphate, the enzyme is phospho-glucomutase. The glucose-6-phosphate is converted to glucose by glucose-6-phosphatase.

TRICARBOXYLIC ACID CYCYLE (TCA)

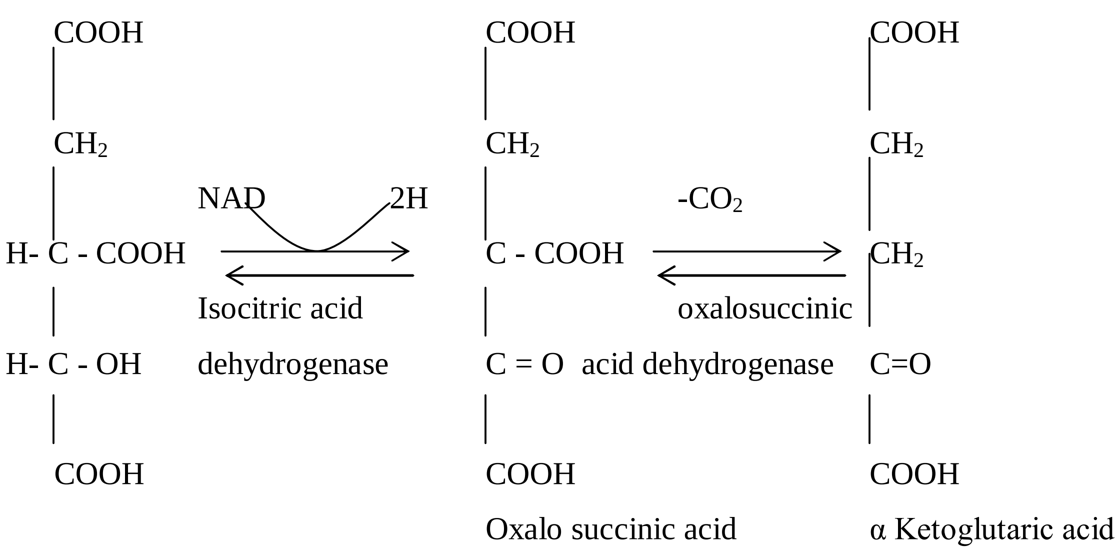
The TCA completes the oxidation of glucose to generate energy. The first thing that happens is the conversion of pyruvic acid to acetyl CoA. It is the CoA that enters the TCA cycle. The TCA is very important for plants because it is a way of metabolizing their organic acids. It is called the TCA because most of the compounds formed have 3 or more carboxylic groups, also called citric acid cycle because citric acid is the first tricarboxylic acid produced in the cycle. The acetyl CoA now condenses with oxaloacteic acid to yield citric acid.



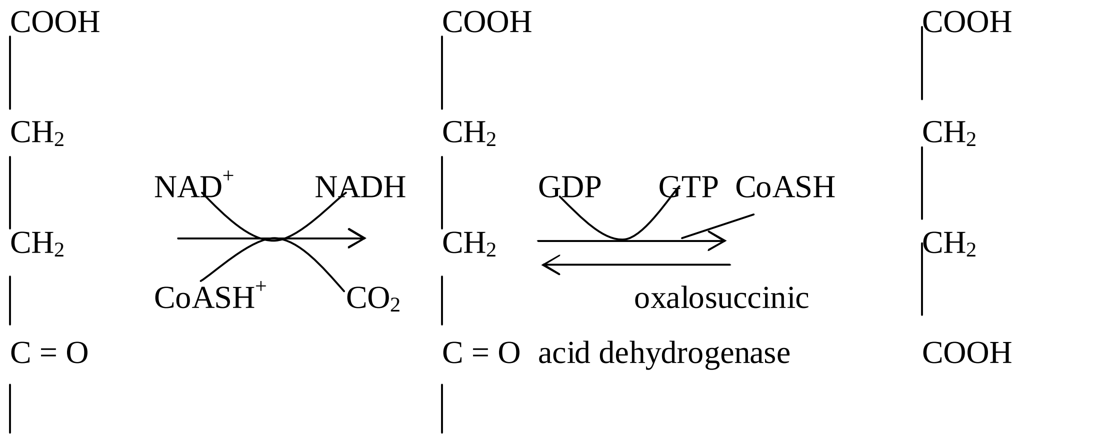
Assignment

Write a short note on the biosynthesis of a named amino acid in the glutamate family giving the structural formula amylation.

The citric acid losses water to form cis aconitic acid. The cis aconitic acid adds on water to form isocitric acid. The above two reactions are catalyzed by aconitase. Isocitric acid is dehydrogenated to yield oxalo succinic acid with the help of the enzyme isocitric dehydrogenase. At this point, 3 moles of ATP is generated.



Afterwards, oxalosuccinic acid is decarboxylated to form α-keto glutaric acid. This can be linked to protein metabolism i.e amino acids can be incorporated to give energy if need be. Also α-keto glutarate can be used to form backbone of some amino acid. The reaction is catalysed by oxalo-succinic acid decarboxylase. The α-keto glutaric acid adds on H_2O, decarboxylated and dehydrogenated to give succinic acid.



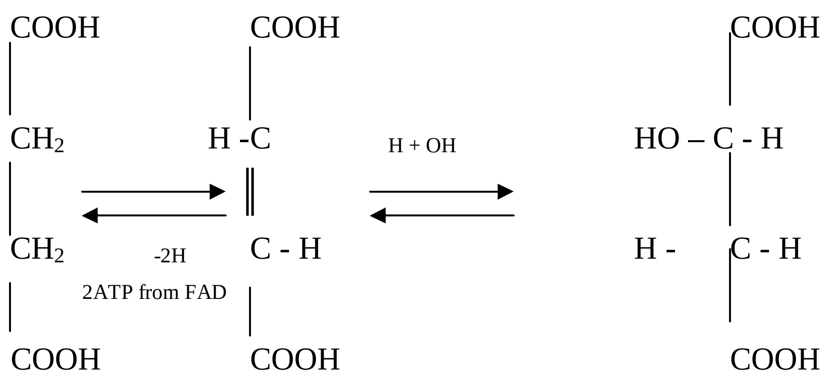
Succinate acid

α-Ketoglutaric acid Succinyl CoA

GTP – Glutamine triphosphate

GDP – Glutamine Diphosphate

The reaction is catalysed by α Ketoglutaric acid dehydrogenase and produces 4 ATP molecules.



Succinic acid Fumaric acid Malate

Fumaric acid is formed by the dehydrogenation of succinic acid with the help of succinic dehydrogenase. 2 molecules of ATP by another kind of high energy compound FAD (Flavine Adenine Dinucleotide). Oxidation of energy is through respiration of FAD to produce 2 moles of ATP Fumaric acid add on H_2O to form L-malic acid. The enzyme responsible for this is fumarase.

ENERGY GENERATION

The total energy generated by 1 mole of pyruvic acid is 8 ATP. After glycolysis and TCA, a net total of 38 ATP would have been produced. After glycolysis and TCA, a net total of 38 ATP would have been produced.

Pathway	**Reaction catalyzed by**	**Method of P production**	**No of ATP formed per mole of Glucose**
Glycolysis	Glyceraldehyde-3-phosphate dehydrogenase	Respiratory organ Oxidation of 2NADH	6
	Phosphoglycerate kinase	Oxidation at substrate level	2
	Pyruvate kinase	Oxidation at substrate level	2
	Reaction catalysed by hexokinase	Phosporylation reaction	-1
	Phosphofructokinase	Phosphorylation	-1
		Net Total	**8 ATP**
TCA	Pyruvate dehydrogenase	Respiratory chain oxidation of 2NADH	6
	Isocitrate dehydrogenase	Respiratory chain oxidation of 2NADH	6
	α-Ketoglutarate dehydrognase	Respiratory chain oxidation of 2NADH	6
	Succinate thiokinase	Oxidation at substrate level GTP	2
	Succinate dehydrogenase	Respiratory chain oxidation of 2FADH2	4
	Malate dehydrogenase	Respiratory chain oxidation of 2NADH	
		Net Total	**30 ATP**

LIPIDS METABOLISM

Series of reactions that occurs in the body are called pathways. They are processes by which the cell regulates itself, various myriad of enzymes that catalyse chemical reactions that take place in living celsl are referred to as metabolism.

Metabolism therefore is the totality of chemical reactios in living matter. Metabolism has specific functions.

1. Metabolism obtain chemical energy from degradation of energy nutrients from the environment or from captured solar energy.
2. To convert nutrient molecules into building block precursors of cell macro-molecules.
3. To assemble this building block into protein, nucleic acid, lipid, polysaccharides and other cell components.
4. To form and degrade bio-molecules required in specialized functiosn of cell.

Metabolism consists of 2 major pathways namely:

Catabolic (degradation) pathway

Anabolic (Biosynthesis) pathway

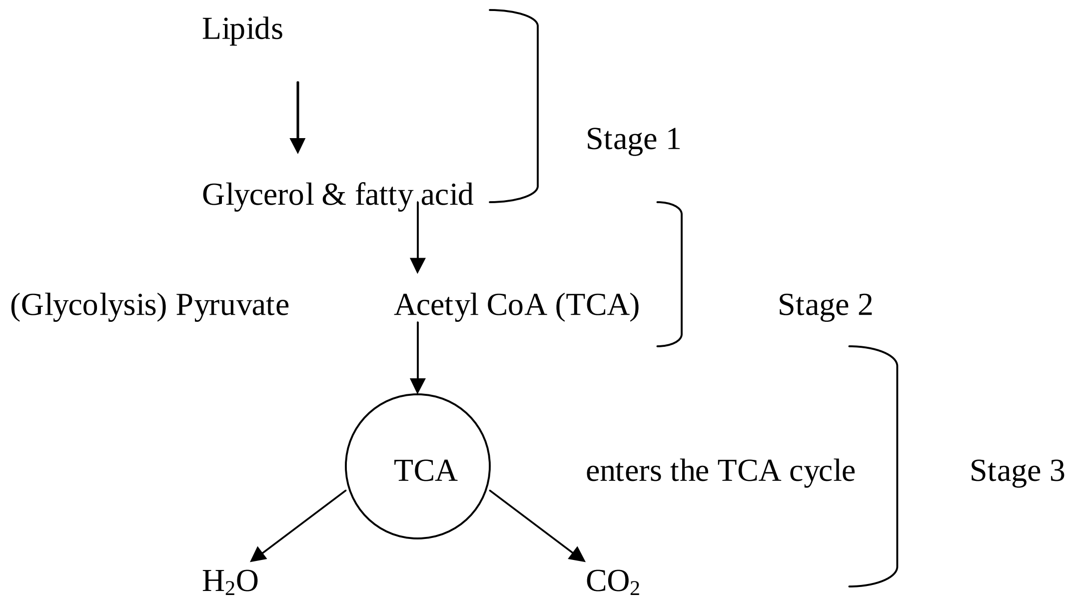
Anabolic takes place in 3 stages beginning with small precursors. Acetyl CoA are built up with fatty acid which are in turn assembled to form lipids.

Catabolism is a converging process, since it begins with few simple precursors from which large varieties are made.

REGULATION OF METABOLIC PATHWAY

The regulation of metabolic pathway is brought about by 3 different types of mechanisms;

1. Through the allosteric enzyme
2. By hormonal regulation
3. By concentration of a given enzyme on the cell.



Catabolism of lipids is divided into 3 stages.

In stage 1, hundreds of lipids are broken down into their building blocks which are few in number. Lipid in most organisms are in the form of tri-acyl glycerol. The term fat refers to this most abundant class of lipids. Triacyl glycerol plays no other role than energy storage. Most of the energy derived from fat comes from the oxidation of the constituent fatty acids. The brain is the only tissue that is unable to use fatty acid as a significant energy supply. However, under conditions of starvation and long fasting, the brain can adjust to use lipid related compounds like ketone bodies.

In stage 2, the building block molecules are further degraded into common products acetyl CoA and pyruvate.

In stage 3, the cell catabolism converge into the TCA cycle with the formation of 2 major products water and CO_2.

FAT DIGESTION AND ABSORPTION

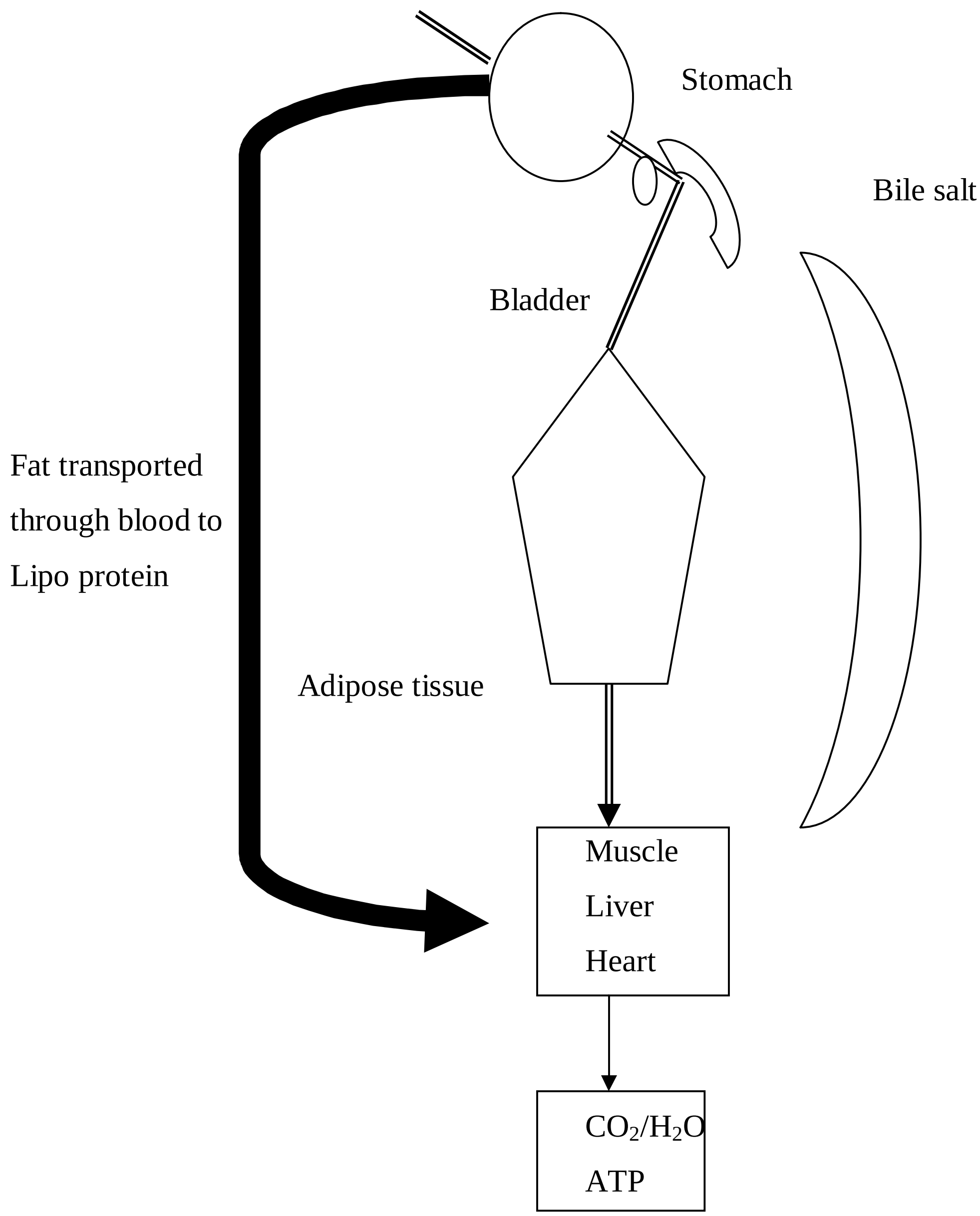
The product of fat digestion is a mixture of free fatty acids (FFA), mono and diacyl glycerol. During the absorption through the mucosa cells, some of these products from hydrolysis condense to re-synthesize triacyl glycerol. This is known because much of the absorbed lipids is in form of triacyl glycerol complexed with protein, sometimes it can form complexes with cholesterol and sometimes complexes with phospholipids. When it forms complex with protein, it is called lipoprotein. When it forms complex with cholesterol, we call it chylomicrons or portomicrons.

Fats are derived from 2 primary sources in the body;

a. The diet

b. Mobilization of fat stored in the adipocytes.

OVERVIEW OF FAT DIGESTION AND ABSORPTION



After absorption of lipids, it can be associated with protein to form lipoprotein which aid in the transportation of lipid for energy storage. The lipoprotein are synthesized mainly in the liver. Lipoproteins are classified according to their density into;

1. Chylomicrons
2. Very low lipoprotein
3. High density lipoprotein
4. very high density lipoprotein

MOBILIZATION OF FAT

The release of energy stored in the fat is comparable to the mobilization of carbohydrate stored in animal glycogen. The steps involved are;

STEP I: Activation of adenylate cyclase ephinepherine.

STEP II: Active adenylate cyclase in turn activates protein kinase by phosphorylation.

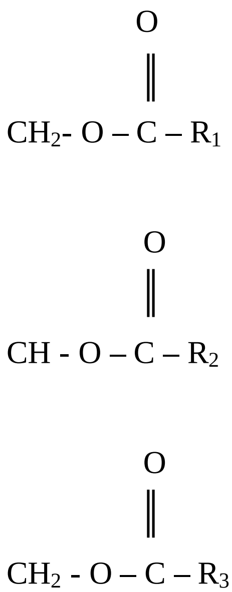
STEP III: Active protein kinase activates an enzyme called triacyl glycerol lipase.

STEP IV: This enzyme catalyses hydrolytic released of fatty acid from carbon 1 or 3 of the glycerol.

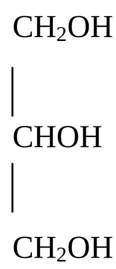
STEP V: The fatty acid released is followed by the action of a di and mono acyl glycerol lipase. These three enzymes degrade the original molecule to glycerol and 3 un-esterified fatty acid.

The hormones are mediated by epinepherine in stress situation and it is also mediated by glycogen during fast.

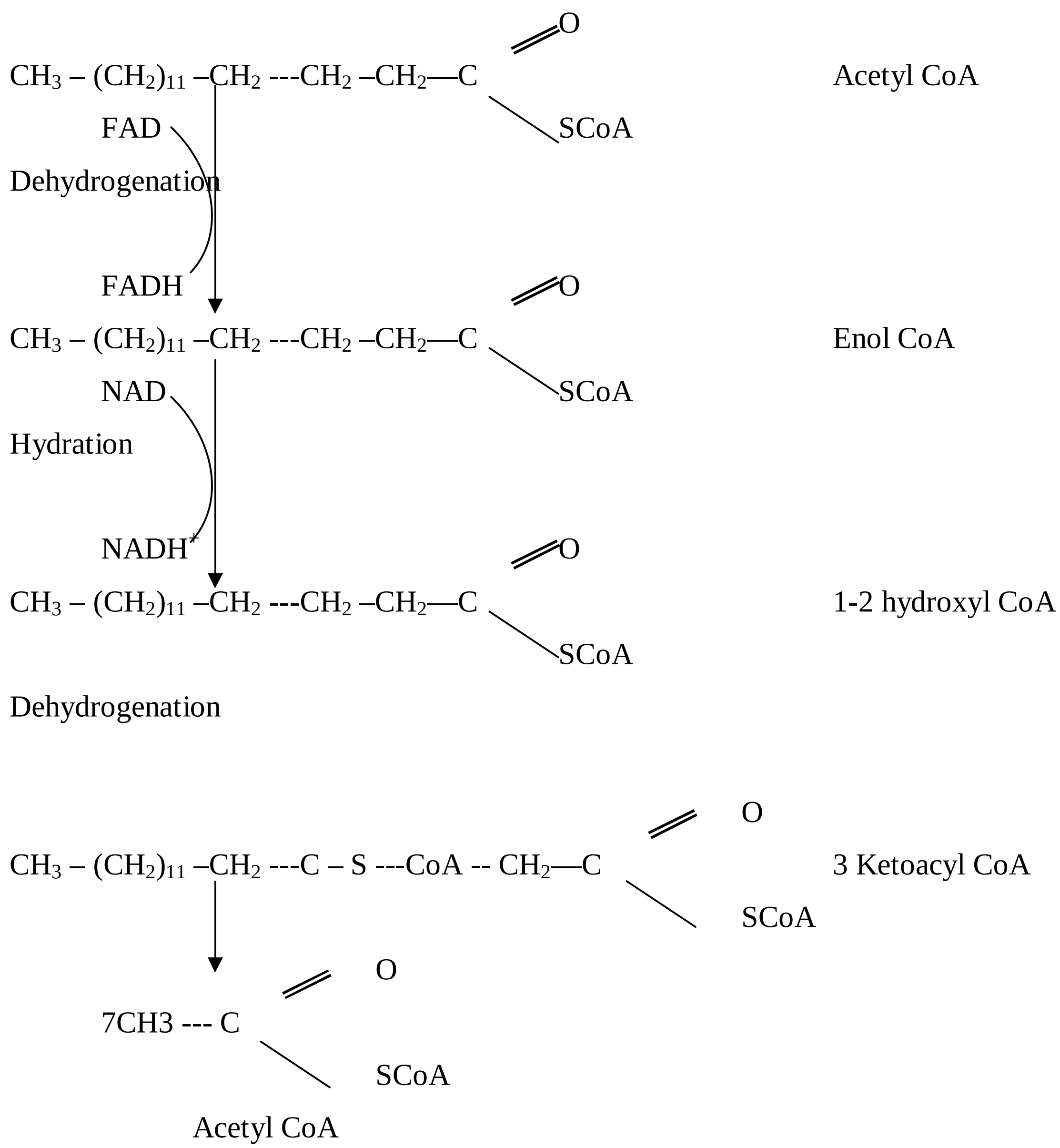
FATTY ACID OXIDATION OF PALMITYl CoA



Triacylglycerol



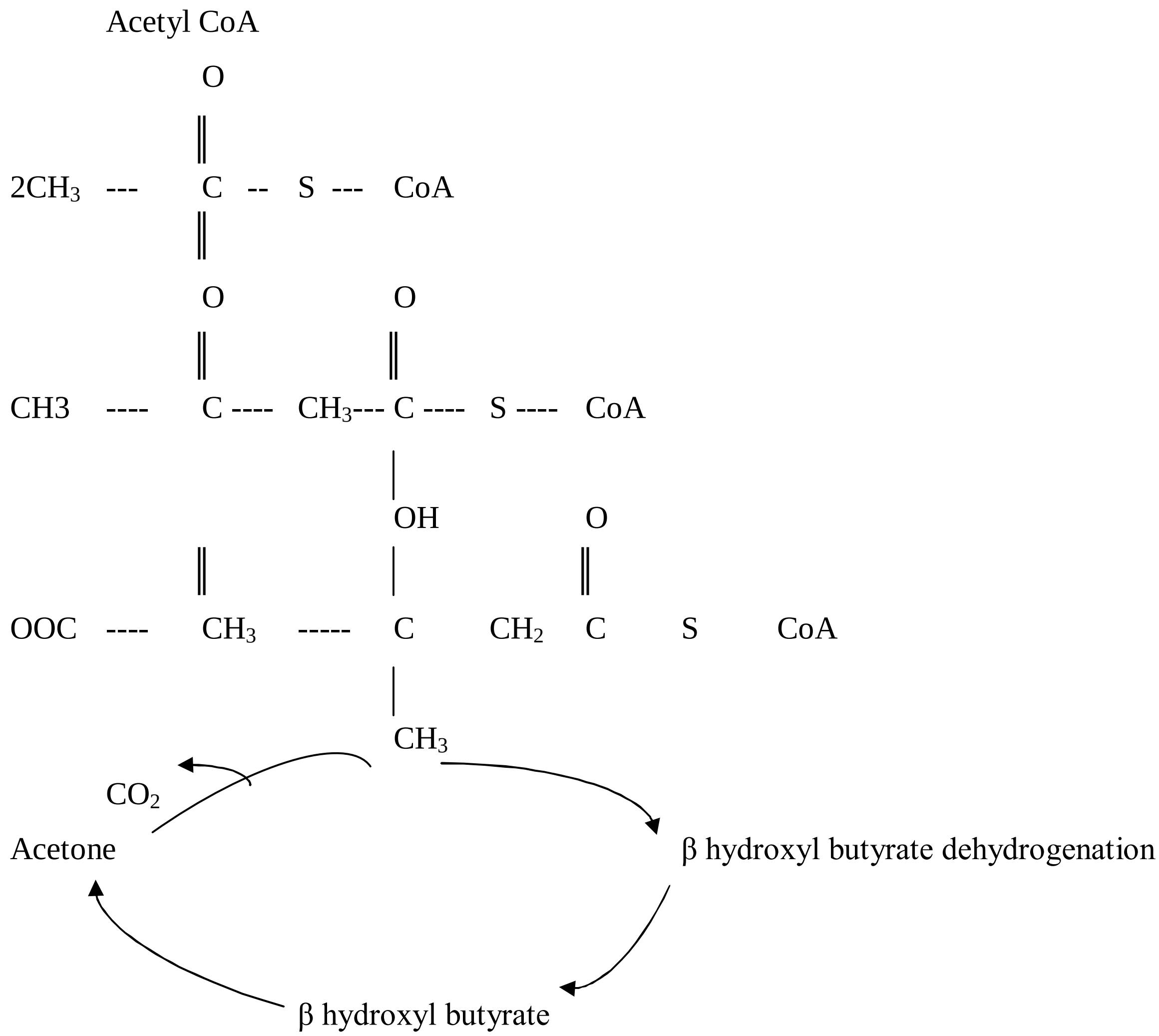
Glycerol



Palmitoyl CoA + 7 CoA – SH + 7 FAD + 7NAD + 7H_2O ⟶ 8 Acetyl CoA + 7$FADH_2$ + 7NADH + & H

Reactions		ATP yield
Activation of Palmitoyl CoA		-1
Oxidation of 8 Acetyl CoA	8 x 12	96
Oxidation of 7 $FADH_2$	7 x 2	14
Oxidation of 7 NADH	7 x 3	21
		130 ATP

CHAINS OF KETOGENSIS



When FADH is been dehydrogenated, it will be converted to flavine adenine dinucleotide hydrogenase likewise NAD.

NOTE: Acetyl CoA is 8 times because molecule of fats gives 130 ATP that is why fatty acid gives a higher energy than carbohydrate.

Catabolism of fats begins with hydrolysis of triacylglycerol to yield glycerol + 3 molecules of fat comes from fatty acids with 5% of glycerol. Most of the fatty acids arise in the cytosol, either through biosynthesis or through triacylglycerol transported from fats depot outside the cell. There is a formation of acyl CoA made up of long chain of fatty acids instead of 2 carbon acetic acids. The endoplasmic recticulum at the outer membrance of mitochondria uses this as fuel within the mitochondria, these reactions are catalysed by carnitine acyl transferase which transverse within the inner membrane. The oxidation of fatty acids is a series of steps in which each step release 2 carbon fragments in form of acyl CoA the pathway is cyclic which involves 4 reactions and ends with the formation of acyl CoA short ended by 2 carbon which undergoes the same process in the next step.

e.g. Palmitoyl CoA undergoes 7 cycles of oxidation to form 8 molecules of acetyl CoA. Each cycle release 1 -2 carbon units with 2 electrons.

Oxidation of saturated fatty acyl CoA involves the following reactions:

1. dehydrogenation to form Enol CoA
2. Hydration of the double bond forming 1,3 hydroacyl CoA.
3. Dehydrogenation of the hydroxyl group to form 3 ketone CoA
4. Cleavage of the 2^{nd} molecule co-enzyme to release acyl CoA.

KETOGENESIS

Acetyl CoA has 2 metabolic fates;

1. Oxidation to CO_2 in the TCA cycle
2. Biosynthesis of fatty acid

Another major pathway comes into play in the mitochondria when acetyl CoA accumulate beyond its capacity to be oxidized or used for fatty acid synthesis. That pathway is called ketogenesis and it leads to a class of compounds **called Keton bodies**.

BIOENERGETICS

Foods are needed for synthesis of products in the body. They are needed as source of energy. Foods are involved in the transfer of energy such as when chemical energy is converted to mechanical energy of heat. The ability of a food to supply energy is therefore of great importance in determining its nutritive value.

Energy is needed for mechanical work (i.e muscular activities), for chemical works such as movement of substance against concentration gradients, synthesis of enzymes and hormones.

When the chemical energy of the food is used for muscular and chemical work involved in body maintenance, the animal does not work on its surroundings and the energy used is converted to heat. In fasting animal, the quantity of heat produced is equal to the energy of the tissues catabolised. Energy supplied by the food in excess of that needed for maintenance is used for various forms of production. A young growing animal will store energy principally in the protein of its new tissues whereas an adult will store relatively large energy in fat. Whereas,a lactating animal will transfer food energy into energy contained in milk constituent.

TYPES OF ENERGY

1. **Heat Energy:** This is the energy produced only to keep the body warm. Its production is taken into account in measuring the efficiency of body processes. The basic unit of energy is called Calorie (Cal). A calorie is defined as the amount of heat energy required to raise 1g of water from 14.5^oC to 15.5^oC. This is small, hence in practical nutrition a large calorie is used i.e Cal.

   Calorie (Cal) is defined as the amount of heat energy required to raise 1 kg of water by 1^oC.

2. **Gross Energy:** When a substance is completely burnt to its ultimate oxidation product i.e CO_2 and water and other gases, heat is given off and that heat is referred to as Gross energy. The quantity of heat resulting from complete oxidation of a unit weight of food is known as Gross energy. Gross Energy (G.E) is sometimes called heat of combustion.

   The oxidation of hydrogen and carbon atom in food leads to gross energy. CH_2O have enough oxygen in the molecule to oxidize the hydrogen. Hence the only produced heat is from the oxidation of carbon.

   In fats, less oxygen is present in the molecule hence heat is produced from the oxidation of carbon and hydrogen. This gives the reason why the heat produced in fat is higher than CH_2O.

   In protein, heat is generated also from the combustion of carbon and hydrogen but the nitrogen that is present in protein gives rise to no heat at all since it is set free as gaseous form. The gross energy values of the 3 classes of feed ingredients is stated below;

CH_2O = 4.15Kcal/g

Protein = 5.65Kcal/g

Fat = 9.4 Kcal/g

3. **Digestible Energy:** Apparent digestible energy of a food is the gross energy content of a weight of the food less the gross energy content of feaces resulting from the consumption of a unit weight of that food. Apparent digestible energy is the energy generated from the food minus the energy generated from the feaces.

4. **Metabolisable Energy (M.E):** M.E of a food is the digestible energy less the energy lost in the urine less the energy lost in combustible gases. Energy in urine is present in nitrogen containing substances such as urea, allantoin, uric acid, hippuric acid, creatinine, glucuronate. The combustible gases lost from rumen consist of methane. Methane production is directly proportional to food intake.

   At maintenance level of nutrition, 7-9% of G.E is lost as methane. For poultry, metabolisable energy is measured easily than digestible energy. Why? This is because in poultry the feaces and urine are mixed together so the M.E can be easily measured during the process.

VITAMINS

Vitamins are organic molecules that function in a wide variety of capacity within the animal's body. The most prominent function is as co-factors for enzymatic reactions. The distinguishable feature of vitamins is that they generally cannot be synthesized by mammalian cells and therefore must be supplied in the diet.

WATER SOLUBLE VITAMINS

1. **Thiamine**: It is also known as vitamin B_1.

Functions

a. Acts as catalyst in carbohydrate metabolism enabling pyruvate to be metabolized and carbohydrates to release their energy.
b. Also plays an important role in synthesis of nerve regulating substances.

Deficiency symptoms

1. Constipation
2. Suppressed appetite
3. Mental depression
4. Peripheral neuropathy and fatigue.
5. Chromic thiamine deficiency leads to a more severe neurological symptom e.g mental confusion, lost of eye co-ordination.
6. Severe thiamine deficiency is known as beriberi.

Sources

1. Brewers yeast
2. Eggs
3. Leafy green vegetables
4. Whole or enrich cereals, wheat, nuts and legumes.

NOTE: Milling of cereals removes these portions of the grain rich in thiamine.

2. **Riboflavin:** Vitamin B_2**,** it serves as a co-enzyme i.e one that combines with a portion of another enzyme to be effective in the metabolism of carbohydrates, fats and especially respiratory protein. It also serves in the maintenance of mucus membrane.

Deficiency symptoms

1. Photophobia
2. Angular stomachtitocs

Sources

1. Eggs
2. Milk
3. Meat
4. Cereals

3. **Niacin:** Also known as vitamin B_3 or nicotinic acid (old name)

Functions

1. Required for the synthesis of active form of vitamins B_3 NAD (Nicotinamide adenine dinucleotide phosphate). Both NAD and NADP function as co-factors for numerous dehydrogenase systems examples include lactose maltose dehydrogenase, succinyl CoA dehydrpogenase).

Deficiency Symptoms

1. Dermatitis
2. Weight loss
3. Diarrhoea
4. Depression
5. Demaentia

Sources

1. Liver
2. Poultry
3. Meat
4. Salmon
5. Whole grain
6. Enriched cereal
7. Dried beans
8. Pea nuts

4. **Panthotenic Acid:** Also known as Vitamin $B_{5.}$

Function

For the synthesis of co-enzyme A and is a compound of the acyl carrier protein (ACP) domain of fatty acid synthase. Panthotenic is therefore required for the metabolism of carbohydrates via the TCA cycle and all fats and proteins.

Sources

1. Whole grain cereals
2. meat
3. Legumes

5. **Pyridoxine, pyridoxamine** are collectively known as vitamin B_6 all the 3 compounds are converted to the biological active form of vitamin B_6 called pyridoxal phosphate. This conversion is catalysed by the ATP requiring enzyme called Pyridoxal kinase.

Functions

1. Pyridoxal phosphate functions as a co-factor in enzyme involved in transamination reactions required for the synthesis and catabolism of the amino acids.
2. It also functions in glycogenolysis as a co-factor for glycogen phosphorylase.

Deficiency of vitamin B_6 are rare and usually related to overall deficiency of the B-complex vitamins.

6. **Biotin**

Function

It functions as a co-factor required of enzyme that are in carboxylation reaction e.g acetyl CoA carboxylase

Deficiency of the vitamin is very rare. Deficiency is generally seen after a long antibodies therapy which depleted the intestinal fauna or following excessive consumption of raw eggs. The latter is given to the affinity of the egg white protein (avidine) for biotin preventing intestinal absorption of biotin.

Source

Biotin is found in numerous foods and synthesized by intestinal bacteria.

7. **Cobalamin:** is more commonly known as vitamin $B_{12.}$

Functions

1. As a co-factor
2. During the catabolism of fatty acid with an odd no of carbon atom and the amino acid; valine, iso-leucine and threomine, the resultant propanyl CoA is converted to succinyl CoA for oxidation in the TCA cycle. One of the

enzymes on this pathway methyl malonyl CoA mutase require vitamin B_{12} as a co-factor in the conversion of methyl B_{12} to succinyl CoA.

Deficiency

Severe or alteration in the normal architecture of membranes of nerve cell.

Sources

Exclusively vitamin B_{12} is synthesized by micro-organism found in the liver of animal..

8. **Folic Acid**

Function

Helps to remove some of the glutamate residues through the action of lysosome enzyme.

Sources

Obtained primarily from yeast and leafy vegetables

Deficiency

Results are complications nearly identical to those described from vitamin B_{12}.

9. **Ascorbic Acid**

Functions

a. In the formation and maintenance of collagen. Collagen is the protein that supports the body structure and plays a major role in the formation of bone and teeth.
b. It enhances the absorption of iron (Fe) from food of vegetable origin.

Deficiency

Scurvy: These symptoms are due to loss of cementing action of collagen and it includes loss of teeth and cellular changes and long bone of young animals.

Sources

1. Citrus fruits
2. Fresh straw berries
3. Pineapple
4. Tomatoes
5. Green pepper
6. Cabbage
7. Spinach.

NUTRIENT REQUIREMENTS FOR MAINTANANCE AND PRODUCTION

For a given no of animal species, the G I T very largely determines the types of food that will be nutritionally adequate, consequently, the Avian species with the relatively short intestinal tract would require food that is highly digestible in the same way, ruminants are better adapted to utilizing foods or feeds of lower digestibility than poultry this is an account of the extensive G I T which facilitates the microbial degradation of dietary fiber. There are also some animal species like the horse which may neither be considered ruminant or monogastric, they do, however, have extensive caecum wherein considerable fibre degradation occurs. Carnivorous animals have a relatively short alimentary canal while herbivores have an extensive G I T.

The relationship of the length of body to the digestive tract for wide range of animals usually provides a useful guide in the dietary formulation. Such a relationship length to length is about 1:4 for cat and chicken, 1:6 for dogs 1:27 for sheep and goat and 1:14 for swine. It follows therefore that the type of food most useful for chicken closely resembles those for cat and dog rather than for cattle and sheep.

The absence of lips and teeth both of which, are replaced by a horny-mandible. The tongue in the chicken and turkeys is shaped like the barb end of an arrow with the point directed in such a way as will help the movement into the oesophagus. Salivary glands secret mucus saliva which lubricates the feed as it passes into the oesoghagus. The crop is a pouch which forms an enlarged specialized area of the oesophagus, little digestion takes place in the crop as it’s function is largely that of storage. Posterior to the crop is an acid secretory section of the G I T of the bird called the PROVENTRICULUS; it is similar to the stomach of such animals as pigs, dogs and cat. The stomach usually opens up into the small intestine (SI) but in the chicken the proventriculus leads into the gizzard which in turn opens into the duodenum. Hcl and pepsin which aid the digestion of protein are secreted by the wall of proventriculus. No rennin secreted since no milk is produced by the bird. Food usually spends a short time in the proventriculus hence little digestion takes place in the proventriculus. Lying between the proventriculus and the duodenum is an oval shaped organ the GIZZARD; it comprises two pairs of red powerful organ, covered internally with a thick horny epithelium. The chief function of the organ is to grind coarse food particle. The process of grinding is aided by the ingested grit or gravel.

With properly ground ration the role of gizzard is diminishing. Immediately after the gizzard, the small intestine is folded into a loop called the duodenum and in between the duodenal loop we have the pancreas supplied with numerous ducts which lead into the duodenum. The pancreatic juice is slightly alkaline and neutralizes acid secreted by the proventriculus. The pancreatic secretion contains enzymes which hydrolyze protein, CHO, and fats. The bile is a pigment secreted by the liver and it is important for proper absorption of fat in the small intestine. The bile is conveyed to the lower end of the duodenum via the duct. The duct from the right loop of the liver is enlarged to form the gall-bladder in which bile is stored and concentrated. The elaboration of the bile is triggered off by the presence of food in the S.I. The S.I consists of 2 distinct parts i.e. the duodenum and lower intestines. The enzymes of lower small intestine complete the digestion process started or initiated by the pancreatic enzymes. Here the peptides are broken down into amino acids, fats to glyceride and fatty-acid, disaccharides into simple sugars.

Since there is no specialized area in the G I T of the chicken for bacteria to aid the break-down of food stuffs only feed materials which can be digested by enzyme secreted by the chicken are useful as food for the chicken.

The epithelial lining of the S.I. has a tremendous surface area, which makes rapid absorption of nutriment possible. The chicken can digest and absorb a full meal in 3 hours. The caecum (a) is represented by 2 blind pouches giving off from either sides of the junction between the lower intestine and large intestine It is about a few “cm” in length usually filled with faecal matter. With highly digestible ration the caecum has little functions in digestion, however, in adult birds fed highly with fibrous ration, some digestion of fibre may occur in the caecum due to microbial action. Since this microbial fermentation takes place at sites posterior to the absorption area of G I T, the significance of short chain volatile fatty acid so produced is still questionable. Large intestine in the avian specie is usually short and consists of a short rectum which leads to the cloaca (which is a chamber common to digestion, urinary, reproductive which opens external through a vent and the urinary is discharged in this chamber and excreted with feaces.

THE RUMINANT GIT &PHYSIOLOGY OF RUMINATION

The ruminant animals such as the sheep, goat and cattle are characterized by possession of complex digestive tract being an anatomical adaptation to their dietary habit. The ruminant animals handle a considerable amount of digestive fibre and therefore require considerable and prolong physiological processes before being broken down into utilizable form.

The various compartments of the ruminant stomach are:

I Rumen – 1st or fore- stomach.

Ii Reticulum

Iii Omasum

1v Abomasum

The rumen and the reticulum are contiguous and hence communicate freely with each other. The rumen represents the most extensive portion of the ruminant stomach and it is endowed with numerous muscular folds which aids the mixing up of ingested food substances. The reticulo-rumen serves as the initial storage units where the food substances are initially reduced in size by various digestive processes.

The reticulum and omasum communicate by means of reticulo-masal orifice. In the young ruminant animal, there is a development of an esophageal tube or grove that enables the liquid diet of the young animal to enter directly into the abomasum without passing through the reticulo-rumen. A rather oval organ which lies to the right of the reticulum is the omasum, which is filled with a no of laminae (finger- like processes), the omasum is linked with the abomasum by means of a grove called sulcus-omasi. The abomasum or true stomach is analogous in no of respect to the small stomach of the canivores.

The abomasum is linked with duodenum by the pylorus. It must be emphasized that a matured rumen is richly supplied by a no of tongue-like projection called papillae which give the rumen its fur-like appearance. The S.I of the ruminant animals is similar to that of the monogastric animal and terminates at its Ileo-caecal junction. The caecum a blind sac-like out- grow of the large intestine where in some food may first enter for some degrees of digestion although the actual function is still largely speculative.

RUMINATION

In the ruminant animal both the rumen & the reticulum serve as fermentation vat while both omasum & abomasum serve to prepare food for gastric digestion by enhancing the removal of excess water and facilitating the normal acid-enzymes digestion in the glandular stomach. The rumen harbors millions of micro-organisms whose functions are not only to break down cellulose into digestible poly-saccharide but also synthesize a host of other chemical substances which will serve as ruminant food. The chief product of ruminal fermentation are the short chained fatty acids which include acetic acid 60%, prop ionic acid 20%, butyric acid < 20% and others such as methane. These short chained fatty acids are usually absorbed through the ruminal wall. These volatile fatty acids provide energy sources and may also be synthesized into fatty acid and ketone bodies. Propionic acid is of great importance in ruminant nutrition because it's configurations $CH_3CH_2C=0$ makes it highly glucogenic within the liver cell and thus provide about 50% of the glucose that enters the ruminant metabolic system. Butyric acid or butyrate may be glucogenic as well as ketogenic and therefore less useful nutritionally as propionic acid.

The cow and most other ruminants are endowed with the ability to synthesize protein from fatty acid owing chiefly to symbiotic activities of the ruminal micro-organisms; this represents a marked contrast to the metabolism of non-ruminant mammals that lack such specialization. It must be emphasized that the ability to effectively utilize dietary fibre is not to be found in the ruminal animal at birth thus a young calf feeding on the mother's milk metabolizes in much the same way as monogastric animal until it is about 4 months when the rumen would have sufficiently developed to assumes its full nutritional responsibilities. Although several advantages accrue to the ruminant digestive system as far as food is concerned, the process of fermentation generates so much gas which needs to be eliminated through belching. Any interference with the mechanism of elimination of gas in the rumen produces a spectacular syndrome called BLOAT and it is a disease condition usually associated with cattle grazing on lush legume pastures. Another defect of ruminant metabolism is the formation of ketones body which is a specific disease of ruminant. Ketosis is believed to be caused by liver inability to detoxify or metabolize short chain fatty acids in the blood stream due to increase stress brought about by lactation and pregnancy.

NUTRIENTS FOR BODY MAINTENANCE AND PRODUCTION.

Nutrients for Maintenance

Maintenance can be defined as that state in which there is neither gain nor loss of a nutrient by the body. Maintenance requirements are estimates of the amounts of nutrients needed to achieve such equilibrium states. Whether an animal is being fed for growth, fattening, milk secretion etc, a substantial part of its food is used for supporting body processes which must go on.

Maintenance Requirement

The term requirement implies the minimum amount of a given nutrient needed to promote a given body function to the optimum in a perfectly balanced ration.

Note – such a minimum value will not be the same for any two individual.

Energy requirement for maintenance.

The energy required for maintenance is the minimum amount needed to keep the animal in energy equilibrium i.e. to prevent any loss from its tissue.

Therefore, an intake sufficient to offset the loss represented or cause by the fasting metabolism would be the requirement for any given animals. It is usually expressed as Net Energy. The maintenance energy consists of 2 parts.

1. The basal metabolism – which is defined as a state of minimum energy expenditure by the animal in the post absorptive condition. The basal metabolic rate (BMR) is a direct and constant function of the metabolic size of the animal.

$$BMR^{24hrs} = 70\ (W\ kg^{0.75})\ Kcal.$$

2. Metabolizable Energy – This is used for maintenance or sustenance of certain unavoidable activities by the animals that are not using energy for work or production of any tissue or product. With most animal including human, basal metabolic rate represent 75% of ME used for maintenance.

Maintenance energy requirement can be computed as BM increased by 1/3 .

:. BM =1.33 (70) W kg $^{3/4}$) Kcal.

Protein requirement for maintenance

The absorbed protein required for maintenance needs must make good the endogenous urinary losses and the metabolic feacal losses incident to the digestion of the ration in question and also provide for **"adult growth"-** this refers to the growth and renewal of hair, nails, feathers etc, a process which continues throughout life. Generally speaking, the amount of protein required for adult growth is very small compare to the over all need.

Theoretically, the minimum required for absorbed protein might be met by supplying the amounts needed for the above mentioned functions in an otherwise adequate diet.

Mineral and vitamins needs for maintenance

Many of the mineral elements undergo active metabolism in connection with various processes which are essential for the normal functioning of the body on maintenance. Different from the energy and protein metabolism, they are not necessarily used up and excreted in the process. For example, the Iron (Fe) released from the constant breakdown of red cells is re-utilized for haemoglobin synthesis, also chlorine (Cl) which is secreted in the gastric juice to provide for digestion can be reabsorbed from the digestive tract and reutilized.

PROTEIN AND ENERGY REQUIREMENTS FOR GROWTH

The total requirement for a given nutrient during growth must include the amount needed for in maintenance as well as the amount required for the new tissue formed of the various nutrient needs for growth. The requirement for energy is by far the largest and primarily governs the total food allowance. The maintenance component of the total energy requirement during growth increases regularly with body size, but the additional demand for the growth itself varies with the rate and with the composition of the tissue formed. Per unit of body weight, the amount of energy represented by the growth tissue formed decreases with age, but the amount of energy store per unit of body increases becomes larger with age. Also, the energy requirement per unit of body gain increases in accordance with its fat contents.

Tissue growth in young animal is largely protein in nature hence protein ration of growing animals. The protein content of the ration of a growing animal will be affected by the size of the animal and by the rate at which new protein tissues are being synthesized. It has been established that the energy and protein requirement being a definite relation to each other for adult animal in a situation which could be true for growing animals. It has been established that at physiologically equivalent age the requirement for protein, Ca, S, P are similar for various specie if expressed as % of TDN. By expressing the digestible protein as % of the TDN requirement, a generalized recommendation for protein applicable to most specie of animal could be arrived at.

Mineral/vitamin requirement for growth

They are organic compound not synthesized by the body and needed in the smallest amount in the diet. There are no of major structural component of the body which they most commonly function as co-enzymes or regulation of metabolism. Birds for example have an absolute requirement for about 13 vitamins, this includes fat soluble vitamin A,D,E,K, water soluble vitamins such as thiamine, riboflavin, choline, vitamin B6, B12 etc. More is known about the vitamin requirement for growth than for other phases of the life cycle. This is because deficiencies are more frequent or pronounced in rapidly growing animals. According to Guilbert *et al.* (1940) vitamin A requirement for growth and freedom from night blindness is proportional to body weight rather than metabolic size. Vitamin D plays a critical role in normal bone growth and development. Most animals that have access to sunlight daily do not need a dietary supply of vitamin D, because of the activation of vitamin precursors in the skin by ultra violet light. Vitamin E is a dietary essential for young nursing lambs and calves.

PROTEIN REQUIREMENT FOR LACTATION

It is somewhere more easily computed than that of growth because lactation represent a direct loss of protein to the body which needs to be replaced and the extent of this loss can be computed in a relatively straight forward manner .

There is ample indication that animals can adjust themselves to lactation over a relatively long period with ranges of protein intake. It is believed that if enough protein is added to the maintenance requirement to replace that loss to the body in the milk produced plus about 25%, the minimum requirement for lactation would have been met.

Requirement for minerals (poultry production)

The mineral elements for poultry are Ca, P, Na ,K, Mg, Cl, I, Fe, Mn, Mb, Co, Cu and Zn. Ca, P, Na, K, Mg, & Cl are usually designated as major elements since they must be present in relatively large amount of the diet. Ca can be up to 1% of the diet for growing chicks or over 3% or layers. Mg could be up to 0.03-0.05% of diet. Although, the remaining minerals are required in diet in trace amount, it must be emphasized that their deficiency could just be as detrimental to the animal as the deficiency of the major ones.

Requirement for Ca,P,& Mg

The 3 elements are important in bone formation as they are important bone constituents. The Ash or bone contains-25% Ca

-12% P

-0.5% Mg.

Insufficiency of these elements or mineral could result in poor bone mineralization and general condition of rickets. The major mineral needed in the diet of a laying hen is calcium for every larger egg the hen lays it must use about 2g calcium for egg shell formation. A hen that lays 250 eggs per year for example deposits about 500grams calcium in the egg primarily as $CaCO_3$.This amount represents about 1,300grams $CaCo_3$ deposit in the egg annually per hen. Ca is not efficiently utilized in laying hens and probably only about 50-60% of the Ca consumed is actually absorbed and retained and deposited in the egg. To produce egg shell required, thus, hens have to consume

2,600 grams CaCo3 during the laying year an amount considerably in excess of the body weight.

The magnitude of Ca metabolism in the laying hen is considerably greater than any other specie of farm animals. Eggs quality characteristics are largely influenced by dietary calcium level. Eggs laid at the end of the production tend to have thinning shell than those laid at the beginning of the production year

High temperature causes the deposition of thinner egg shell but the most important cause of thin egg shell is Ca deficiency.

Feed consumption is also important in determining Ca requirement when expressed as % of the diet. For old layer in hot weather 4- 4.5% Ca is recommended for good egg shell quality. In addition to their structural roles, Ca and P have other functions in the animal body. For example P is essential for energy metabolism as it is constituent of nucleic acid and plays major roles in several enzymic systems. Ca is also important in blood clotting and muscles contraction. Much of the Mg is found in the bone and it is also an important activator of a number of enzymes involved in energy metabolism

Inter-relationship between Ca and P-:

Chicks are especially sensitive to imbalances in Ca, P ratio. In any ration it should be 1.5:1- 2:1.

1. An imbalance could result in poor utilization of either Ca or P.

2 Vitamin D must be present in adequate amount for the proper utilization of dietary Ca and P.

Requirement for Na, Cl, K

Na, Cl, and K are principally in-organic ion of body fluid. Na is found in the extra-cellular fluid while K occurs mainly in the inter-cellular fluid. These mineral are important in the maintenance of acid- base fluid balance in the body tissue.

Cl is an important component of HCL found in the proventriculus.

Deficiency of any of these, result in poor growth, dehydration or death while excess may result in excessive retention of body fluid.

Trace minerals

Generally, the trace minerals are component or activators of a series of enzymes system found in the animal body. Examples are Cu, Zn, Fe, Mo, etc. Fe is an important constituent of blood in form of haemoglobin. It is also present in muscles as Myoglobin and also in cytochrome system.

ENERGY AND PROTEIN REQUIREMENT FOR REPRODUCTION

The energy requirement for production consists of the energy stored in the new tissue formed plus the energy expended in the process. In practice, most pregnant animals must be given a sufficient energy allowance to enable them gain some weight during the period as a whole with special attention given to the last quarters when the specific needs are substantial.

Low protein diet has been shown to cause a cessation of estrus and that, if fertilization occurs, foetal resorptions or the birth of premature, dead or weak offspring results, therefore, quality as well as the quantity of protein is important. Rations that are adequate in protein for maintenance and for growth should be adequate also for conception and the initiation of foetal growth. Since, the products of a conception arises largely of protein, it is evident that there is an increased need as foetal growth proceeds. It has been shown that pregnancy in sow and cow increases the need for protein much more than for energy.