

COURSE CODE:	ANN 503
COURSE TITLE:	Ruminant Animal Nutrition
NUMBER OF UNITS:	3 Units
COURSE DURATION:	3 Hours

COURSE DETAILS:

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COURSE CONTENT:

The nature of ruminant stomach reviewed. Physiology, microbiology and biochemistry of rumen. Utilization of roughages in ruminant feeding. Use of agro-industrial by-products in ruminant feeding. The importance and methods of protein by-pass in ruminant feeding. Non-protein nitrogen utilization, nutrient partition, nutritional disorders.

Practicals: methods of protecting protein. Ration mixing. Examination of a typical ruminant's stomach and compartments. Balance trials. Nutritional disorder. Agro-industrial by-products used in ruminant animal feeding and their processing methods.

COURSE REQUIREMENTS:

This is a compulsory course for all final year students of College of Animal Science and Livestock Production. 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.

READING LIST:

Basic Animal Nutrition and Feeding, W.G. Pond, D.C. Church and K.R. Pond, Wiley, Fourth Edition, 1995

LECTURE NOTES

COURSE OUTLINE

- Course introduction , preview and expectation
- The Nature of ruminant Stomach
- Physiology, microbiology and biochemistry of rumen
- Utilization of roughages in ruminant feeding
- The use of agro industrial by-products in ruminant feeding
- Importance and methods of protein by-pass in ruminant feeding
- Non protein Nitrogen utilization
- Nutrient partition
- Nutritional disorder

The Nature of ruminant Stomach

The stomach of ruminants has four compartments:

The rumen

The reticulum

The omasum

The abomasum

Collectively, these organs (i.e stomach) occupy almost 3/4ths of the abdominal cavity. It fills virtually all of the left side and extending significantly into the right.

The rumen

The rumen is the largest of the fore stomachs. It is sacculated by muscular pillars into what are called the dorsal, ventral, caudo-dorsal and caudo-ventral sacs.

The Function of the Rumen

The rumen is the largest portion of "stomach". It is a fermentation vat filled with microbial populations which collaborate to digest cellulose and other polysaccharides, producing carbon dioxide, methane and organic acids.

The rumen is an **anaerobic** environment; i.e. no oxygen. Ingested food first enters the rumen (pH 6.5, temperature of 30⁰C) where it is microbially digested for ~ 9 hours.

The gaseous products of the microbial degradation are expelled from the animal (eructation). The material from the rumen, called the cud, is regurgitated.

This regurgitated mixture of microorganisms and partially digested materials then travels through the abomasum, the omasum (pH ~ 2), and the rest of the digestive tract, for further digestion.

Microbes are also capable of producing protein from simple nitrogenous compounds. Microbes produce B-complex vitamins. Microbes eventually die and are digested and absorbed for nutrients in the Small Intestine. Microbes are very useful for the digestion of forages but inefficient in the use of starches and proteins digestion.

The abundant volatile fatty acids produced by fermentation in the rumen are readily absorbed across the rumen epithelium.

The Reticulum

The **reticulum** lies against the diaphragm and is joined to the rumen by a fold of tissue.

In many respects, **the reticulum** can be considered a "cranioventral sac" of the rumen; for example, ingesta flow freely between these two organs.

The reticulum is connected to the spherical **omasum** by a short tunnel.

Function in the Reticulum

Honeycomb appearance which interacts with rumen to mix and stir feed. It provides additional area for fermentation.

The Omasum

The omasum is sometimes referred to as the "manyplies" because of its many layers of muscular tissue.

In the omasum, the particle size of digesta is reduced, and any excess water is removed before the digesta enters the abomasum. The omasum can contain up to 16 litres of digesta.

It may function to absorb residual volatile fatty acids and bicarbonate. The tendency is for fluid to pass rapidly through the omasal canal, but for particulate matter to be retained between the omasal leaves.

Periodic contractions of the omasum knocks flakes of material out of the leaves for passage into the abomasum.

The Abomasum

The fourth compartment is the abomasum or "true stomach."

This is where acids and enzymes are secreted to further digest the digesta. It is the first true glandular portion of the gastrointestinal tract where the stomach walls secrete enzymes.

It functions very similarly to the stomach of many simple stomached animals such as the pig.

This stomach compartment can hold approximately 20 litres of material in cattle. The time that digesta remains in the abomasum is very short compared to the retention time of feeds in the rumen.

The presence of food in the abomasum stimulates hydrochloric acid production.

Hydrochloric acid converts pepsinogen to pepsin, which breaks down protein to shorter molecular chain compounds such as peptides and amino acids for further digestion and absorption in the small intestine.

The true stomach has a low pH of 2 to 4, due largely to this acid production.

Some fat digestion also occurs in the true stomach.

Digesta flowing from the abomasum to the small intestines is composed of small particles suspended in liquid digesta.

One fascinating specialization of this organ relates to its need to process large masses of bacteria.

In contrast to the stomach of non-ruminants, the abomasum secretes lysozyme, an enzyme that efficiently breaks down bacterial cell walls.

Rumen Physiology and Rumination

The rumen is a fermentation vat *par excellence*, providing an anaerobic environment, constant temperature and pH, and good mixing.

Well-masticated substrates are delivered through the oesophagus on a regular schedule, and fermentation products are either absorbed in the rumen itself or flow out for further digestion and absorption downstream.

Ruminants evolved to consume and subsist on roughages - grasses and shrubs built predominantly of cellulose. Although some ruminants, feedlot steers for example, are fed large quantities of grain.

Feed, water and saliva are delivered to the reticulo-rumen through the esophageal orifice.

Heavy objects (grain, rocks, nails) fall into the reticulum, while lighter material (grass, hay) enters the rumen proper.

Added to this mixture are voluminous quantities of gas produced during fermentation. Ruminants produce prodigious quantities of saliva. Published estimates for adult cows are in the range of 100 to 150 liters of saliva per day!

Aside from its normal lubricating qualities, saliva serves at least two very important functions in the ruminant:

- (a) Provision of fluid for the fermentation vat
- (b) Alkaline buffering - saliva is rich in bicarbonate, which buffers the large quantity of acid produced in the rumen and is probably critical for maintenance of rumen pH.

All these materials within the rumen are partitioned into three primary zones based on their specific gravity.

Gas rises to fill the upper regions

Grain and fluid-saturated roughage ("yesterday's hay") sink to the bottom

Newly arrived roughage floats in a middle layer.

The rate of flow of solid material through the rumen is quite slow and dependent on its size and density. Water flows through the rumen rapidly and appears to be critical

in flushing particulate matter downstream. As fermentation proceeds, feedstuffs are reduced to smaller and smaller sizes and microbes constantly proliferate.

Reticuloruminal Motility

Ruminal contractions constantly flush lighter solids back into the rumen, the smaller and more dense material tends to be pushed into the reticulum and cranial sac of the rumen, from where it is ejected with microbe-laden liquid through the reticulo-omasal orifice into the omasum.

An orderly pattern of ruminal motility is initiated early in life and, except for temporary periods of disruption, persists for the lifetime of the animal. These movements serve to mix the ingesta, aid in eructation of gas, and propel fluid and fermented foodstuffs into the omasum.

If motility is suppressed for a significant length of time, ruminal impaction may result. A cycle of contractions occurs 1 to 3 times per minute.

The highest frequency is seen during feeding and the lowest when the animal is resting.

Two types of contractions are identified:

Primary contractions originate in the reticulum and pass caudally around the rumen. This process involves a wave of contraction followed by a wave of relaxation, so as parts of the rumen are contracting, other sacs are dilating.

Secondary contractions occur in only parts of the rumen and are usually associated with eructation.

Conditions inside the rumen can significantly affect motility. If, for example, ruminal contents become very acidic (as occurs in grain engorgement), motility will essentially cease.

Also, the type of diet influences motility: animals on a high roughage diet have a higher frequency of contractions than those on a diet rich in concentrates.

Rumination and Eructation

Ruminants are well known for "cud chewing". Rumination is regurgitation of ingesta from the reticulum, followed by remastication and reswallowing. It provides for effective mechanical breakdown of roughage and thereby increases substrate surface area to fermentative microbes.

Regurgitation is initiated with a reticular contraction distinct from the primary contraction. This contraction, in conjunction with relaxation of the distal oesophageal sphincter, allows a bolus of ingesta to enter the esophagus. The bolus is carried into the mouth by reverse peristalsis.

Fermentation in the rumen generates enormous, even frightening, quantities of gas, about 30-50 liters per hour in adult cattle and about 5 liters per hour in a sheep or goat.

Eructation or belching is how ruminants continually get rid of fermentation gases.

The fluid in the bolus is squeezed out with the tongue and reswallowed, and the bolus itself is remasticated, then reswallowed.

Rumination occurs predominantly when the animal is resting and not eating, but that is a considerable fraction of the animal's lifespan. An eructation is associated with almost every secondary ruminal contraction.

Eructated gas travels up the oesophagus at 160 to 225 cm per second and, interestingly, a majority is actually first inspired into the lungs, then expired.

Anything that interferes with eructation is life threatening to the ruminant because the expanding rumen rapidly interferes with breathing. Animals suffering bloat die from asphyxiation

The processes described above apply to adult ruminants. For the first month or so of life, the ruminant is functionally a monogastric. The fore stomachs are formed, but are not yet fully developed. If milk is introduced into such a rumen, it basically rots rather than being fermented. To avoid this problem in such young ruminants, suckling causes a reflex closure of muscular folds that form a channel from the esophageal orifice toward the omasum (the esophageal groove). This helps in shunting milk away

from the rumen and straight toward the stomach where it can be curdled by rennin and eventually digested enzymatically.

Microbiology of the rumen

The rumen is an organ where microbial populations collaborate to digest cellulose and other polysaccharides producing carbon dioxide, methane and organic acids.

Microbial content of rumen comprises of:

Fungi - digest lignin and cellulose

Bacteria - a thick paste of 10^{10} - 10^{11} cells/mL (compare to stationary phase *E. coli* cultures that contain $\sim 4 \times 10^8$ cells/mL)

Protozoa - $\sim 10^6$ /mL, mostly ciliates that prey on bacteria and ferment some carbohydrates

Protozoa, predominantly ciliates, appear to contribute substantially to the fermentation process.

Several experiments have demonstrated that lambs and calves deprived of their ruminal protozoa show depressed growth rates and are relative "poor-doers" compared to controls with both bacteria and protozoa.

In general, protozoa utilize the same set of substrates as bacteria and, as with bacteria, different populations of protozoa show distinctive substrate preferences.

Many utilize simple sugars and some store ingested carbohydrate as glycogen.

An interesting feature of some protozoa is their inability to regulate glycogen synthesis: when soluble carbohydrates are in abundance, they continue to store glycogen until they burst.

An additional feature of protozoa is that many species consume bacteria, which is thought to perhaps play a role in limiting bacterial overgrowth.

The distribution of microbial species varies with diet. Some of this appears to reflect substrate availability; for example, populations of cellulolytic bugs are depressed in animals fed diets rich in grain.

Environmental conditions in the fermentation vat also can have profound effects on the microbial flora.

Rumen fluid normally has a pH between 6 and 7, but may fall if large amounts of soluble carbohydrate are consumed. If pH drops to about 5.5, protozoa populations become markedly depressed due to acid intolerance. More drastic lowering of rumen pH, as can occur with grain engorgement, can destroy many species and have serious consequences on the animal.

Fermentation is supported by a rich and dense collection of microbes. Fermentative microbes interact and support one another in a complex food web, with the waste products of some species serving as nutrients for other species.

Fermentative bacteria representing many genera provide a comprehensive battery of digestive capabilities. These organisms are often classified by their substrate preferences or the end products they produce.

Although there is some specialization, many bacteria utilize multiple substrates.

Some of the major groups of bacteria, each of which contain multiple genera and species, are:

Cellulolytic (digest cellulose)

Hemicellulolytic (digest hemicellulose)

Amylolytic (digest starch)

Proteolytic (digest proteins)

Sugar utilizing (utilize monosaccharides and disaccharides)

Acid utilizing (utilize such substrates as lactic, succinic and malic acids)

Ammonia producers

Vitamin synthesizers

Methane producers

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Biochemistry of the rumen

Biochemistry is the study of the chemical processes in living organism. It deals with the structure and function of cellular components, such as proteins, carbohydrates, lipids, nucleic acids, and other biomolecules. *Or Biochemistry* is the study of the chemical substances and vital processes occurring in living organisms.

Use of carbohydrates as an energy source

Glucose is the major energy source in most life forms. For instance, polysaccharides are broken down into their monomers (glycogen phosphorylase removes glucose residues from glycogen). Disaccharides like lactose or sucrose are cleaved into their two component monosaccharide.

Glycolysis (anaerobic)

Glucose is mainly metabolized by a very important and ancient ten-step pathway called glycolysis, the net result of which is to break down one molecule of glucose into two molecules of pyruvate; this also produces a net two molecules of ATP, the energy currency of cells, along with two reducing equivalents in the form of converting NAD⁺ to NADH.

This does not require oxygen; if no oxygen is available (or the cell cannot use oxygen), the NAD is restored by converting the pyruvate to lactate/lactic acid (e. g. in humans) or to ethanol plus carbon dioxide (e. g. in yeast).

Other monosaccharides like galactose and fructose can be converted into intermediates of the glycolytic pathway.

IN SUMMARY :

1. Cellulose and starch are broken down to glucose monomers.
2. Fermentative bacteria produce organic acids from glucose.
3. The non-volatile acids (e.g. lactate, succinate) produced from fermentation are converted into volatile acids (e.g. acetate). These enter the bloodstream of the host mammal from the rumen.
4. Methanogens utilize formate ($\text{H}_2\text{C}=\text{O}$) or carbon dioxide (CO_2), together with molecular hydrogen (H_2), to produce methane (CH_4).
5. The eructate consists of methane (35%) and carbon dioxide (65%). Daily production of gas from a cow is about 100 to 150 L; a well-fed dairy cow can generate as much as 500 L of gas daily!

Summary of protein utilization

Sources of Rumen Nitrogen

Feed

Protein nitrogen: Protein supplements (SBM, CSM, grains, forages, silages etc)

Non protein nitrogen (NPN): Usually means urea. However, from 5% of N in grains to 50% of N in silage and immature forages can be NPN

Endogenous (recycled) N

Saliva

Rumen wall

Protein Leaving the Rumen

Microbial protein

Escape protein (also called “bypass” protein)

These enter abomasum & small intestine and are digested by proteolytic enzymes similar to non ruminants

Utilization of roughages in ruminant feeding

Roughages comprise over 50% of all feedstuffs fed to livestock animals especially ruminants. Roughages are plant-based feedstuffs. Technically, forage and herbage are defined as plant materials, with a higher fiber content, available for consumption by animals.

The National Research Council classifies roughage as a feedstuff with a minimum crude fiber content of 18% and a maximum content of total digestible nutrients (TDN) of 70%.

Roughages provide a range of nutrients to animals. They also function to maintain and optimize the efficiency of the GI tract for selected species.

Fibrous carbohydrates function to maintain structure, activity, and microbial population of the GI tract, essential for optimal function of the GI tract.

Roughages are a link to the efficient utilization of earth's resources.

Roughages alone are of minimal value to humans. However, roughages consumed by selected species provide a means for conversion of relatively low-quality raw materials to relatively high-quality products such as food and fiber that may be used to fulfill human needs.

Roughages may be fed either in a fresh, dried, or ensiled state.

Types of roughages used as feedstuffs include grazed roughages (e.g. pasture and range), preserved roughages (e.g. hay and silage), and crop residues and by-products (e.g. Straw, Stover, and Hulls).

Roughages are high in fibrous carbohydrates such as hemicelluloses and cellulose. Fibrous carbohydrates are primarily present in the cell wall of the plant cell. As fibrous carbohydrates are associated with the structural components of plants, fibrous carbohydrates are often referred to as structural carbohydrates. Roughages may also contain relatively high amounts of lignin. Lignin content increases with plant maturity.

In a nutrition analysis, the fiber components of roughages may be expressed as crude fiber, acid detergent fiber (ADF), and/or neutral detergent fiber (NDF). Crude fiber contains cellulose and a portion of the lignin.

ADF contains cellulose and lignin. NDF contains hemicellulose, cellulose, and lignin.

The plant cell contents also contribute to the roughage. The cell contents include such components as non fibrous carbohydrates, proteins, and lipids.

The non fibrous carbohydrate content is comprised of simple sugars (i.e. fructose, glucose, and sucrose), starches, and/or fructosans. The protein component in forages is comprised of both true protein and non protein nitrogen compounds. Protein content varies by roughage; from 2% up to 30% on a dry matter basis.

In general, the protein content of legumes is greater than the content of grasses.

The mineral content of roughages is influenced by roughage and mineral content of the soil. In general, compared to concentrates, roughages are higher in calcium, potassium, and microminerals and moderate to low in phosphorus. Legumes have a higher calcium and magnesium contents compared to grasses. Regarding vitamins, compared to concentrates, roughages are higher in fat-soluble vitamins. Roughages are also a good source of the B-complex vitamins.

Roughages may contain one or more antinutritional factors such as alkaloids, cyanogenic glycosides, toxic amino acids, and/or mycotoxins.

The nutritional value of roughages varies. In addition to other factors such as plant species, the nutritional value of roughages depends on the proportion of cell contents to cell wall components and on the extent of cell wall lignification.

Most roughages can be effectively incorporated into at least one type of ration.

Effective use of roughage requires matching nutrient requirements of an animal with the nutritional value of roughage. Effective use of roughage also requires appropriate processing and supplementation.

As the population of rumen microorganisms is dependent upon the feedstuffs consumed, the composition of the diet influences the extent and rate of digestion of roughages. Feeding of high-energy feedstuffs has a negative associative effect on the degree of utilization of roughage. A negative associative effect occurs when the addition of one feedstuff negatively influences the utilization of another feedstuff.

One of the primary species responsible for the digestion of roughages is cellulolytic bacteria.

The primary end-product of digestion of roughages is acetate. Acetate is a relatively weak acid.

The primary end-product of fermentation of high-energy feedstuffs is propionate.

Propionate is a relatively strong acid.

An additional end-product of microbial fermentation of high-energy feedstuffs is lactate. Lactate is also a strong acid.

Compared to roughages, the digestion rate and extent are higher and the resultant pH of the rumen is lower for high-energy feedstuffs.

The lower pH has a negative effect on the microorganisms responsible for digestion of roughages; the cellulolytic microbes are inhibited by a pH of 6.0 or lower.

Therefore, the incorporation of high-energy, high-nonfibrous carbohydrate feedstuffs decreases the utilization of roughages.

Management strategies to increase the utilization of roughages include:

- 1) addition of buffers, such as bicarbonate, to the diet;
- 2) increasing particle size of roughage to increase the production of bicarbonate in the animal; and/or
- 3) reducing the rate of fermentation of high-energy feedstuffs either by substitution with another feedstuff or applying an alternative method of processing.

As with other feedstuffs, addition of roughages to rations is dependent on the GI tract. As roughages are high in fibrous carbohydrates and microbial enzymes are required for digestion of fibrous carbohydrates,

Utilization efficiency of roughages is dependent on the site and extent of microbial fermentation in the GI tract. Roughages are primarily added to the rations of herbivores. The proportion of forage in the ration varies with species and class of animal and also cost of feedstuffs.

Based on the relatively high utilization efficiency of roughages in the GI tract and roughages are a source of fibrous carbohydrates to maintain optimal functioning of the GI tract,

Generally, roughages are added to ruminant rations. Although the utilization efficiency is less, roughages are also used in the rations of horses. In the horse, the caecum is the primary site of microbial fermentation. As the caecum is located posterior to the primary site of absorption, horses may practice coprophagy or consumption of feces to increase efficiency of utilization.

For monogastric such as swine and poultry, the low utilization efficiency limits the use of roughages in rations. Roughages can be added to the ration of swine with low nutrient requirements.

USE OF AGRO-INDUSTRIAL BY-PRODUCTS/CROP RESIDUES IN RUMINANT FEEDING

Why this alternative?

One of the principal limiting factors in ruminant production is **feed shortage**.

- ✚ Forages are known to form a greater proportion of the ruminant's diet but availability of these forages in quantity and quality all year round is limited. This is due mainly to seasonal fluctuations, overgrazing and increased land use by man.
- ✚ The high cost of conventional feed resources such as cereals and legume grains prohibit their wide-scale use, especially by small scale farmers.
- ✚ Furthermore, the competitive demand for these conventional feed resources as food between livestock and man on one hand and between monogastric animals and ruminants on the other hand limits the quantity of these conventional feeds available for ruminant feeding.
- ✚ Population pressure and urbanization, particularly in Africa, will further limit the quantity of grains available for animal feeding.
- ✚ In view of the limitations to the use of conventional feeds for livestock feeding, it is best to resort to the use of those feed resources, which are cheap, less competitive and which the ruminant animal can convert to useful products.

What definition do we then give to the term “*Alternative feed resources?*”

Alternative feed resources could be regarded as those materials arising from plant and animal origin which are cheap, not competitive and readily available which can be fed to livestock as to overcome problems of feed shortage and high production cost and at the same time ensuring the preservation of animal health, production yield and product quality. Alternative feed resources abound which can be used in the diet of ruminants. Most of the feeds available to both man and animals primarily come from plant sources.

It is rare that a crop plant can be completely used by man, most do yield some residues and by-products which if properly processed may be consumed by farm animals. *Crop residues* are the left-over that result from the **harvesting of crops** while *crop by-products* are the resultant materials that arise from the **processing of crops**. Crop residues and agro-industrial by-products have become an increasingly important way of feeding ruminants due to the scarcity of feeds particularly during the long dry season. The usefulness of these by-products often centres upon their being produced on or near to the farm and upon whether they are available at the right time of the year.

Agro-industrial by-products? Agro-industrial by-products are waste products arising from the processing of crops or animal product usually by an agricultural firm. The resultant products from these industries are considered as waste since they are of little or no nutritional importance to humans. Agro-industrial by-products in the tropics are abundant and varied and represent a substantial resource for increasing animal production. The use of these by-products for supplementary livestock feeding is justified when the forage supply is inadequate for the animals' needs, either in terms of quantity or quality. Agro-industrial by-products in Nigeria vary from primary processing of farm produce wastes to wastes from agro allied industries. Some of these wastes are left unutilized, often causing environmental pollution and hazard. Those that are utilized do not have their full potentials harnessed. Agro-industrial by products which can be of tremendous use in the livestock industry for feeding animals include brewers dried grain (BDG), palm kernel cake (PKC), maize offal (MO), wheat offal (WO) and cassava peels (CP). As grain production remains insufficient to meet human and animal feeding, the alternative is to employ feed ingredients which do not have direct human value. BDG, MO, and WO are by-products of sorghum, maize and wheat processing. They are of low protein and high crude fibre contents. These are two factors that limit their use in monogastric (poultry and pig) feeding. In contrast however, as due to their ability to digest low quality feeds and roughages, ruminants can utilize these products more effectively than monogastric livestock, and in doing so, they are not competing for human feed resources.

The supply of agro-industrial by-products is considerably high but their rate of utilization is dependent on the chemical composition and the species of livestock intended to be fed. Wheat bran/offals are considered the most common followed by fresh or wet brewers' grains.

Classification of Agro-industrial by-products

Agro-industrial by-products can be grouped according to the content of nutrients namely:

- i. **Energy sources:** these are rich in fermentable carbohydrates and low in protein (containing less than 20% crude protein). The best example is molasses traditionally used as a carrier for urea in ruminant feeding. Molasses is produced in the two sugar industries in Nigeria: Numan, in Gongola State, and Bacita and Jebba in Kwara State.
- ii. **Protein sources:** Protein supplements refer generally to those ingredients that contain more than 20% crude protein. Agro-industrial by-products that serve as protein sources are mostly the oilseed cakes. Palm oilseed cakes are produced in the southern part of Nigeria and form the most abundant and least expensive oilseed cake available. It is however notorious for being gritty and unpalatable. Cottonseed and groundnut cakes are also important although the latter had declined drastically about three decades ago and is only coming up again with this spirit of looking inwards.
- iii. **Miscellaneous by-products** supplying both energy and protein: by-products considered under this category are from cereal (wheat bran and other brans from traditional grains like sorghum, millet, rice and maize), brewery (brewers' grains), fruit and vegetable industries (citrus pulp, tomato pulp).
- iv. **Mineral sources:** these primarily supply minerals and are commonly from animal by-products example is bone meal, oyster shell.

Cereal by-products

By-products from the milling of grains find extensive use in the feeding of livestock. The dry milling products generally include brans and offals.

Cereal brans

This is the outer covering of grains separated during processing. They are obtained from the milling of wheat, maize or rice. Wheat bran was the most important cereal bran in the country. However brans from traditional grains (sorghum, millet, rice and maize) are growing rapidly in quantity. Brans will normally contain 9 - 18% crude protein and 10 - 14% crude fibre. They have a laxative action in the gut and because of their high fibre content can be used as nutrient diluents for monogastric animals. Usually, the amino-acid profile of bran protein is superior to that of the whole grain. They are high in phosphorus but low in calcium.

Cereal offals

This is made up of a mixture of small particles of the bran, germ and part of the aleurone layer. They usually have less than 7% crude fibre with a protein content varying from 10 - 20% depending on the grain.

By-products from brewery industries

Most cereal grains go into the production of alcoholic beverages. The production of alcohol from these grains involves grinding, cooking and addition of enzymes to hydrolyze starch to simple sugars and then yeast to cause fermentation. After fermentation, the alcohol is removed and the residue is available for livestock feeding. If the residue is used wet, it is referred to as *brewer's wet grain* (BWG) but if used dried, it is referred to as *brewer's dried grain* (BDG). Most of the breweries originally produced wet grains that were available on request. As the usefulness of the grains in livestock feeding became increasingly clear, some of these breweries started to dry some of their grains for sale. These dried grains constitute only 5% of the total produced. The composition of the brewer's dried grain varies depending on the grain used for brewing. The average BDG has about 18% crude protein and about 20% crude fibre.

By-products from roots and tubers

Roots and tubers are wide spread in Nigeria. These include yam, cassava, potato, beets and carrots. Most of the tubers are produced for human consumption. However, the processing of some of these crops produces substantial quantities of by-products which go into livestock feeding. The most common of these tubers is cassava. Cassava when dried contains less than 3% crude protein, 1.3% fat, 85% NFE, ME of about 3,500 - 3,700

kcal/kg. Cassava peels are richer in crude protein (5 - 6%) and fat (6%) than the tubers. The major problem with cassava is that the raw tubers contain linamarin, a cyanogenic glycoside and prussic acid. In the presence of enzyme linase, the glycoside is converted to β -glucose, acetone and hydrogen cyanide. This makes raw cassava poisonous. There is greater concentration of the glycoside in the peels than in the tuber. Processing methods such as soaking in water, fermentation, sun-drying or moist cooking destroys the glycoside in cassava.

By-products from sugar industry

Molasses is an important by-product of the sugar industry. The production of molasses is dependent on the production of cane or beet sugar. Molasses has been used for many years as a **cheap source of energy** in the ration of farm animals. Molasses contain about **3.25% crude protein**. Molasses has been used in animal **feeding at levels of 5- 10%**. These levels are mostly used as (i) **a carrier for urea** impregnation of poor quality roughages (ii) a **binder for commercial pelleted feeds** for the convenient and economic feeding of livestock and as (iii) **a sweetner for increasing the voluntary intake** of compounded feeds.

Bagasse is another by-product from sugar cane processing. Sugar cane is processed for its sugar which leaves two by-products, molasses and a fibrous residue termed *bagasse*. Bagasse is a high fibre, low protein product of very low digestibility which is sometimes mixed with the cane molasses for cattle feeding.

Oil seed by-products (Cakes and meals)

Oil seeds cakes and meals are the residues remaining after removal of the greater part of the oil from oil seeds. The residues are rich in protein and most are valuable feeds for farm animals. They often serve as protein supplements. Most oil seeds are of tropical origin, they include groundnut, cottonseed, soyabeans and palm kernel. Others plant protein sources that are less frequently used include coconut meal, rapeseed meal, rubber seed meal, sesame (Beniseed) cake.

Soyabeans is by far the most widely used oil seed protein and as such is assigned the standard against which other plant proteins are compared. The commonest form in which soyabean is fed is as soyabean meal after oil extraction by solvent or hydraulic method.

Soyabean meal has about 40 - 48% protein depending on the efficiency of oil extraction and whether or not the beans were dehulled.

Groundnut cake (GNC) is the major plant protein supplement used in Nigeria. The availability of which depends on the production level of groundnut. The unextracted groundnut has about 26 - 30% protein and it mainly consumed by humans. The residue remaining from extraction of oil from groundnut either by solvent or hydraulic method is the groundnut cake. This has a protein content of about 38 - 47%. GNC is palatable. It is however, deficient in lysine, methionine and threonine.

Cotton seed cake (CSC) is obtained from cotton after the removal of the lint, followed by oil extraction from the seed. It has a protein content of 41- 45% depending on the efficiency of oil extraction. It is high in fibre containing about 10 - 13%. It is deficient in lysine, methionine, leucine and isoleucine. CSC also contains several anti-nutritional factors including gossypol. The nutritional value of CSC can be improved by (i) decorticating and dehulling, (ii) removal of gossypol by extracting the meal with a mixture of hexane, acetone and water, (iii) treatment of the cake with phytase enzyme produced by *Aspergillus ficcum*. In Nigeria, most of the CSC is used in the feeding of ruminants and ruminants can utilize the CSC without dehulling.

Palm kernel cake (PKC) is a product of oil palm processing. It is obtained after oil extraction from Palm kernel. Protein content is between 18 - 25%. PKC is deficient in lysine, methionine, histidine and threonine. PKC is gritty and high in fibre content (at least 9%).

Sunflower meal is produced from sunflower seed following oil extraction by either solvent or mechanical methods. The protein content ranges from 41- 47%. It is highly deficient in lysine, tyrosine, methionine and cystine. It is high in fibre (11 - 13%). While decorticated sunflower meal can be fed to all classes of livestock, the use of undecorticated meal should be restricted to ruminants. Sunflower meal is high in calcium and phosphorus.

By-products from Animal Origin

By-products from animal origin supply protein or minerals. Most mineral sources are from animal origin. Animal proteins are derived from the processing of meat, fish and

milk and products hatchery wastes. By-products from animals which supply minerals include; bone-meal, Oyster shells, Periwinkle shells, Snail shells and Egg shells.

Fishmeal is made of dried, ground whole fish or fish cuttings with or without oil extraction. Fishmeal varies in protein between 54 - 75% with about 10% fat, making it a high protein, high energy feedstuff. Fishmeal protein is high in biological value, supplying all the known essential amino acids. It is also an excellent source of minerals including calcium (3 - 6%), phosphorus (1.5 - 3%) and micro-minerals. It is rich in vit B₁₂. The main constraint to its use is its high cost. High dietary levels of high fat fishmeal may lead to problems of rancidity in the diet.

Blood meal accounts for 7 - 9 % of the animal live-weight and so it can be harvested. Blood meal is essentially boiled and dried blood. The drying could be done naturally or artificially. Blood meal contains 80 - 82% protein and very little ash. The protein is very high in lysine but deficient in isoleucine. The processing temperature may affect the quality of protein. The protein contained in blood meal has a low digestibility. There is also the fear of disease transmission through the use of blood meal. Well processed blood is however safe for use. Blood meal should not be used beyond 8% inclusion level. Meat meal is made up of trimmings that originate from the slaughter of animals. Meat meal should be devoid of hair, hoof, horn, manure and stomach content. The typical meat meal has 50 - 55% of high quality protein. The level of protein varies with the amount of bone contained in the meal. If the phosphorus content of the meal is more than 4.4%, it is regarded as meat and bone meal and contains 45 - 50% proteins. Meat meal is used at about 7 - 10% dietary inclusion. It is however, virtually not in use in Nigeria as all parts of the animal are virtually consumed.

Feather meals have protein contents ranging from 85 - 95%. Feather meals can not be utilized by animals unless it is treated. Hydrolyzed feather results from heat treatment of this by-product under pressure. It is deficient in lysine, methionine and tryptophan. The protein is about 75% digestible. It should be used at low dietary inclusion levels. Other by-products from animal origin supplying proteins include hatchery waste, insect meal, milk and milk by-products.

Bone meal is a source of mineral. It is obtained by burning off the organic content of bone. Bone meal is a good source of both calcium (30%) and phosphorus (13%). Other minerals found in bone are also found in bone meal. It has the advantage of being available and can be produced by the local farmer.

Oyster/Periwinkle/Snail/Egg shells are all made of calcium carbonate with about 38% calcium. Oyster shell is predominantly used in most feed mills in the country. However, snail shell and egg shell are also excellent sources of calcium and could be used as a substitute for oyster shell.

Constraints to the use of agro-industrial by-products.

Constraints to the use of by-products and crop residues in livestock feeding systems include;

- (i) bulkiness - high fibre content
- (ii) their location in areas far from where they are needed (accessibility),
- (iii) poor nutritive value and
- (iv) unsuitability for direct animal use.
- (v) Presence of some anti-nutritive/toxic materials that may be harmful to animals when used over a long period.

In Nigeria today, the issue of the bulkiness and location in areas far from those where the materials are needed has been partially solved by the development of a good network of roads and the opening up of the rural areas for development. As regards the poor nutritive value and non-suitability for immediate animal use, research results have shown that supplementation with molasses, non-protein nitrogen (urea and poultry excrete) and chemical (NaOH) and physical (grinding and pelleting) treatments improve the nutritive value and intake and hence the response of animals to some of these by-products. Physical treatment is considered more useful in improving the nutritive value of these products and it is also a cheaper way of treatment compared to chemical treatments.

Note as highlighted above, that the ways of improving the utilization of agro-industrial by products include:

- ✚ Use of **Chemical treatment** (e.g. NaOH). This is especially for cereal crop residues such as rice straws and maize stover
- ✚ **Physical treatment** (drying, grinding, pelleting)
- ✚ **Supplementation** with molasses, non-protein nitrogen (urea and poultry waste). Adequate supply of nutrients may improve the nutritive value of low quality feeds
- ✚ **Ensiling**: The process of conservation of forage under strict anaerobic conditions that would ensure fermentation process. In so doing the fibre in feeds would have been pre-digested thereby enhancing better utilization and release of nutrients.
- ✚ **Feed block technology**: this is mainly for those high in moisture content. Several agro-industrial by-products could be mixed together with urea, a binder such as cement and/or quick-lime, minerals and vitamins.

IMPORTANCE AND METHODS OF BY-PASS PROTEINS IN RUMINANT FEEDING

Protein in ruminant feed

The total protein content of feeds/forages (dietary proteins) is generally referred to as “crude protein”. Crude Protein (CP) is calculated from the nitrogen content of the forage. The CP value is important since protein contributes energy, and provides essential amino acids for rumen microbes as well as the animal itself. The more protein that comes from forage, the less supplementation needed. Protein in forages is most correlated with forage maturity, as more mature forages have a lower percentage of crude protein.

Ruminants require two types of protein in their diet. One type is degraded in the rumen and is used to meet the needs of the microbial population, and the other bypasses the rumen and is used primarily to meet the productive needs of the animal.

Degradable proteins

When feeds/forages are ingested by ruminants, they are being transported to the rumen which is the first and largest compartment of the ruminant digestive tract. The dietary proteins entering the rumen are being attached by large population of microbes which

degrade the proteins into simple compounds such as ammonia which the microbes utilize to build up their own cell walls.

When protein is degraded in the rumen it is called *rumen degradable protein*. Rumen degradable protein is essentially the food for rumen bacteria. When the microbes die they are passed through to the stomach and small intestines where they are digested by the animal. The resulting *microbial protein* is then absorbed into the animal's bloodstream.

Un-degradable proteins

Some of the protein in the diet does not undergo degradation in the rumen, but passes straight to the abomasum or stomach for digestion. When protein escapes rumen breakdown and passes to the stomach it is referred to as *rumen un-degradable protein* or *bypass protein* or *rumen escape proteins*.

BYPASS PROTEIN

What is 'Bypass' protein?

Bypass protein is also called Rumen escape or Un-degradable Protein (UDP). It is the portion of the protein from a feedstuff (copra or cottonseed meal) that escapes from being broken down in the rumen by microbes. Bypass protein passes relatively intact into the small intestine where it is digested by enzymes of the animal and directly used as a source of protein.

Definition: In clear terms, bypass proteins are defined as the portion of the protein from a feedstuff that escapes from being broken down in the rumen by microbes and passes into the small intestine intact where it is then digested by enzymes and utilized by the animal as a source of protein.

Bypass protein meals such as cotton seed meal are a by product of extracting oil from the seed. The protein meal generated has passed through heat and physical treatments that modify its molecular structure and render it relatively unbreakable to microbes in the rumen. However, it is still digestible by the animal as a protein source in the small intestine. Hence the term "Bypass" protein as it bypasses the main site of protein digestion in the animal.

Why is it important to ‘bypass’ the rumen?

The microbes in the rumen take the protein from different feedstuffs and they break it down to make their own protein – microbial protein. Although microbial protein is a high quality protein, it isn't a very efficient form of protein synthesis and not all-essential amino acids are supplied in proper balance. Hence, anything we can do to provide the animals with a source of protein that escapes from being digested by the microbes in the rumen and make it to the small intestine for digestion, is beneficial to ruminant animal's nutrition.

Bypass protein is important because a large percentage of the rumen degraded protein is absorbed as ammonia and, if in high concentrations, can be lost through the urine as urea. In high-producing animals this represents an inefficient utilization of protein, so increasing the amount of protein that is by-passed to the intestines constitutes a more efficient utilization of protein for growing or lactating animals on high-quality pastures. In forages, roughly 20 to 30 percent of the protein taken in by the animal is bypassed to the intestines. Lactating or growing cattle generally require 32 to 38 percent of their total protein intake to be in the un-degradable form. High-quality pastures can meet almost all the needs of high-producing livestock. For those animals that require supplementation, corn, cottonseed and linseed meals, brewers dried grains, corn gluten meal, distillers dried grains, and fish meal are typically high in bypass protein.

The microbial degradation of protein is an energy-dependant process. Carbohydrates are the energy-yielding nutrients in animal nutrition and are supplied by the production of volatile fatty acids in the rumen. Generally more microbial protein is synthesized from green forage diets than from hay or mature forage diets. When a ruminant animal grazes fresh forage on high-quality pasture, about 70 percent of the protein is degraded in the rumen by microorganisms, and about 30 percent escapes to the small intestine for absorption. Ruminant animals need approximately 65 to 68 percent of the protein to be rumen degradable for adequate rumen function and the development of microbial protein. But if more protein is degraded in the rumen, less is available to the animal for absorption in the small intestine. This is important because researchers believe that rumen un-degradable or bypass protein consists of certain essential amino acids that are missing or deficient in rumen degradable protein. Much of the rumen degraded protein is absorbed

as ammonia and excreted out of the body via the urine, and is therefore a waste of protein. This is why bypass or undegradable protein is important, especially for high-producing livestock such as dairy animals, even in protein-rich-pasture diets.

Some animal nutritionists suggest that bypass protein has been overemphasized. This is because the total proportion of bypass protein in most forage is around 30 percent, which is very close to the requirements of the ruminant animal. In this case, they suggest, feeding the rumen microorganisms takes on particular importance, for if the rumen microorganisms are healthy, they will supply the ruminant with the nutrients they need to maintain body functions and remain productive. We must remember that ruminant animals evolved in symbiosis with rumen microorganisms in a grassland environment, and they are inherently adapted to this function.

What are the main benefits of ‘bypass’ protein?

The main benefit of ‘bypass’ protein is that the original amino acids in the protein meal are absorbed in the small intestine instead of converted to microbial protein in the rumen, thereby providing a different balance of essential amino acids for better animal nutrition hence, production. Another benefit of feeding meals with high ‘bypass’ protein is that the portion of the protein that is rumen degradable (RDP) breaks down in the rumen very slowly. This allows animals to source small amounts of protein over longer periods for microbial protein production, long after urea has been degraded and used in the rumen by the animals. Small quantities of ‘bypass’ protein fed at strategic times, have an enormously beneficial effect on production. ‘Bypass’ protein also provides an important protein source when the animal’s requirements for protein exceed those provided by microbial protein.

Factors Affecting Bypass Protein Variation in Forages

There are many factors that can influence the bypass protein content of forage. Listed below are common factors most often associated with creating variation in forage bypass protein content.

Maturity

Numerous research projects have demonstrated that **immature forage legumes and grasses contain more degradable and less un-degradable protein than mature forages. Immature forages contain more non-protein nitrogen primarily composed of ammonia, nitrate, amines, amides, and free amino acids which are rapidly degradable in the rumen. With advancing maturity, true plant protein synthesis advances and the cell wall matrix becomes more complex, rendering forage protein less accessible to rumen bacteria and less degradable.** These factors ultimately reduce degradation potential of forage proteins. Maturity therefore is considered as having a profound and large influence on bypass protein content of forages.

Species

Species is also known to affect bypass protein content of forages. **In general, legume protein is more degradable than grass protein. This is due in part to grasses containing more neutral detergent fiber which reduces rates of nutrient digestion. Variations also occur within grasses, and some grass species appear to have greater levels of bypass protein while others appear to be quite degradable.**

Fertilization

Grasses assimilate soil nitrate (NO_3) and ammonium (NH_4) into non-protein nitrogen and true protein fractions. Increasing soil N supply increases forage N (crude protein). The increase in forage N (crude protein) is, however, disproportionate with the non-protein nitrogen pool increased to a greater extent than the true protein pool. Because non-protein nitrogen is readily degradable in the rumen, nitrogen fertilization generally reduces the amount of bypass protein.

Ensiling (Proteolysis)

When forages are ensiled, bacteria ferment the forage and breaks forage protein down into smaller fractions which are more degradable by rumen bacteria. This process is called proteolysis. Some researchers estimated that only 9% of forage macro protein molecules remain after fermentation. The effect of proteolysis can have a dramatic effect on the bypass protein content of forages. The concept of proteolysis can be demonstrated from a study where Alfalfa silage was made at three different maturities and wilted for 0, 10, 24, 32, 48, and 54 hours before ensiling. Ruminant degradability of ensiled forages

was then compared to non-ensiled forage (NE). In all cases, the percent crude protein remaining (bypass) was less for the ensiled forages as compared to the non-ensiled forages.

Heat Damage

When forages are ensiled too dry and/or elimination of oxygen from the silage mass is not satisfactory, significant levels of heat can be produced during the fermentation process. Significant levels of heating can also occur when legume or grass hays are made too wet. In these situations when excessive heating occurs, forage protein may become bound (mallard reaction) to forage carbohydrate fractions, rendering the protein fraction less degradable.

Ways of protecting protein from degradation in the rumen

Protein requirements for high rates of growth in ruminants cannot be met solely from microbial protein synthesis in the rumen; therefore, supplementation with high quality rumen undegradable protein is necessary. Due to the high cost of protein supplements, ways and means of protecting the protein from degradation in the rumen whilst retaining the high digestibility is an urgent priority. Many experiments have demonstrated the beneficial effects of the technological processing of feeds, particularly heat treatment, in reducing the degradation of the crude protein in the rumen without decreasing digestibility in the small intestine. For highly producing ruminants, heat treatment of protein supplements has been used for increasing the amount of dietary protein escaping rumen degradation, and to increase the amino acid pool entering the small intestine.

There is no sure method that can be recommended for use on smallholder farms. Toasting and extrusion of the feed is appropriate for oilseed meals in the feed mill as may be dehydration of foliages. Reacting with formaldehyde has been used commercially in industrial countries but there are doubts as to the safety of the method for more widespread use.

None of these methods is feasible on smallholder farms. Sun-drying will have some positive effect in reducing protein solubility. There is also the possibility for mixing tannin-rich feeds with those rich in protein but low in tannins.

In summary, methods of decreasing protein and amino acid degradation in the rumen include:

1. Heat treatment
2. Chemical treatment
3. Encapsulation
4. Use of amino acid analogues
5. Selective manipulation of balances of rumen metabolic pathways
6. Oesophageal groove closure

PROTEIN DIGESTION

Proteins are chemical compounds of great complexity and high molecular mass containing about 16 % nitrogen (N). Nitrogen is the chief element which distinguishes proteins from carbohydrates and fats. Since there is a fairly constant proportion of about 16 % nitrogen in protein, nitrogen is used to estimate the protein content of feeds by determining the nitrogen content of the feed and then multiplying this value by 6.25 ($100/16 = 6.25$). The estimate of protein obtained from nitrogen determinations is called crude protein (CP).

The building blocks of protein are 20 naturally occurring amino-acids which are linked together by di-peptide bonds in a manner similar to beads strung on a necklace. The ruminant cannot synthesize these amino-acids in its body, but the micro-organisms in the reticulo-rumen can. This protein is known as microbial protein.

Amino-acids are the essential building blocks of all living tissues. Proteins are not absorbed as such, but enter the bloodstream as amino-acids which are released during digestion in the duodenum. To produce milk protein, the correct casein precursor amino-acids must be supplied to the udder.

In the ruminant, amino-acids are provided from two radically different sources. The first is the feed offered to the animal. Some of the protein in the feed will escape fermentation in the rumen and will arrive in the duodenum with its constituent amino-acids intact. This is called undegraded (UDP) or bypass protein and the constituent amino-acids can then be absorbed through the gut wall into the bloodstream.

The second source of amino-acids is from protein contained in the microbes' bodies. This microbial protein is derived from the nitrogenous feed material which is fermented in the rumen (called rumen degradable protein or RDP) by the same micro-organisms which transform the carbohydrate fraction of the feed into volatile fatty acids. The end products of the fermentation process are simple nitrogenous compounds, mostly ammonia, but also various other protein break-down products such as peptides and amides. Ammonia is also produced from any non-protein nitrogen in the foodstuff. The micro-organisms then proceed to use these simple materials as building blocks for their own body protein. These micro-organisms are constantly being swept down the gut with the rest of the digesta. The animal then digests these microbes in the duodenum and, during the digestion process, absorbs the amino-acids released from the microbes' body protein in the same way that it absorbs the amino-acids from the protein which has bypassed ruminal fermentation. The amount of protein which bypasses rumen fermentation varies between approximately 20 %, (in grazing) and approximately 40 to 60 % (for processed feeds, depending on the amount of heating, grinding, *etc.* employed in processing).

The unique ability of the ruminant to convert protein to ammonia, and subsequently into microbial protein is one of the most important aspects of ruminant nutrition, in that it allows the ruminant to convert non-protein nitrogen sources, such as urea, into ammonia through ruminal fermentation, and subsequently into microbial protein. This means that the ruminant can synthesize amino-acids from elemental nitrogen.

The rumen, however, has a limited capacity to convert ammonia to microbial protein. The maximum limit of conversion is considered to be 30 to 32 g N per kilogram digestible organic matter consumed by the animal. If more non-protein, or degradable nitrogen, is supplied than the microbes are able to convert into microbial protein, excessive ammonia may accumulate in the rumen. The excess ammonia produced has no nutritive value and is absorbed into the bloodstream across the rumen walls. The ammonia in the blood is converted to urea in the liver and excreted in the urine. It is possible to exceed the animal's ability to convert ammonia into urea in the liver, resulting in ammonia toxicity (urea poisoning). If non-protein nitrogen alone is provided as the only protein source in the diet of the cow, her milk yield will be restricted to a very low level of approximately 9 litres per day over the lactation. Therefore if a higher production level is required, the

amino-acids absorbed in the mid-gut must be derived from undegradable or bypass protein. The higher the production level, the greater the requirement for bypass protein.

Measures of expressing protein content

The present simple system of expressing the protein content of feeds, according to crude protein content (the CP system) does not take into account the degradability of protein. This system is therefore slowly giving way to other systems which take the role of undegradable protein into account. At present there are several major research efforts, in Europe and the United States of America, to develop and to perfect a new system of evaluating protein for ruminants. The modern trend is not to express the nitrogen content of feed as crude protein, but as the nitrogen from which it was derived.

This new system was recommended by the British Agricultural Research Council in 1980 and by the National Research Council (USA) in 1985. It takes into account the fact that the use of protein by the ruminant is dependant on the energy intake of the animal. This is because the ability of the microflora of the reticulo-rumen to synthesize microbial protein is directly dependant on the amount of energy supplied in the diet. The physical composition of the diet will also affect the natural degradability of the same protein source, such as by altering the rate of passage of the digesta through the reticulo-rumen.

Perhaps the best argument for adopting this new approach to determining the protein requirements of ruminants, is that ruminal digestion is an essential component of feed utilization in ruminants. The functioning of the rumen is dependant on a healthy microbial population which requires both energy and rumen degradable protein to survive. If insufficient degradable protein is available to the ruminal micro-organisms, the rate of fermentation in the rumen will be reduced, leading to a reduction in feed intake and consequently a decreased energy supply to the animal for production.

In conclusion, the advantage of the new system is that it describes animal protein requirements in terms of RDP (degradable) and UDP (bypass) protein. This allows for the formulation of rations with not only the correct quantity, but also the correct type of protein. Correctly formulated rations will lead to the most efficient possible use of protein by the animal in that a proper balance of RDP and UDP is required for optimal fibre digestion in the rumen. A surplus of RDP is wasteful in that the cow only benefits if

ammonia is converted to microbial protein. Excess ammonia has to be excreted from the bloodstream, at an energy cost of 22.8 kilo Joules per gram of N. The cost of excreting surplus RDP in the diet has been calculated to cost British dairy farmers between 1.3 to 2.6 litres fat-corrected milk (FCM) per cow per day on a typical grazing system. Surplus ammonia in the bloodstream has also been shown to adversely affect reproduction. Dry matter intakes have also been shown to be depressed by high non-protein nitrogen (NPN) levels in the herbage.

Bypass Protein

Other feed ingredients have special features with respect to protein degradability for use by ruminants. These are classified as bypass or undegradable protein sources, of plant or animal origin, and have crude protein content greater than 20%, with at least 50% of this protein escaping breakdown in the rumen. Most often, these ingredients have been specially heat treated or dried. They are most suitable for the diet of high-producing, early-lactation dairy cows or rapidly growing starter beef cattle. Bypass protein sources are often highly priced per unit of crude protein. The protein composition (amino acid profile) and levels of degradable, undegradable and soluble protein fractions are particularly important.

NUTRIENT PARTITIONING

PROTEIN PARTITIONING

The protein in the diet contains intake protein which is normally called crude protein. Immediately it is digested, it is divided into Digestible Crude Protein and Indigestible Crude Protein particularly in ruminant animals.

1. CRUDE PROTEIN (CP)

The common practice is for the nitrogen status of livestock feeds and food to be stated in terms of crude protein because most of the feed nitrogen is present as protein and most of the nitrogen required by the animal is used for protein synthesis. Chemically, the protein content of a feed is calculated from its nitrogen content determined by the modification of the classical Kjeldahl technique. This

gives a figure which improves most form of nitrogen except nitrite, nitrate and certain cyclic nitrogen compounds which require special techniques for their recovery. The assumption was that all the nitrogen of the feed is present as protein and that all feed protein contain 160g N/kg. Thus, the nitrogen content of feed is expressed in terms of crude protein.

$$CP \text{ (g/kg)} = gN/kg \times 6.25$$

$$Cp \text{ (g/kg)} = gN/kg \times \frac{1000}{160}$$

With time, these two assumptions were found to be unsound because;

- a) Different feed proteins have different N content and therefore different factors should be used in the conversion of N to protein for individual feeds. Factors for converting N to protein for some feeds are as follows:

Feed protein source	Nitrogen (g/kg)	Conversion factor
Maize, egg, meat	160.0	6.25
Barley, Wheat, Oats	171.5	5.83
Milk	156.8	6.38
Soyabean	175.1	5.71
Cotton Seed	188.7	5.30

Although, the use of an average conversion factor of 6.25 for all feed protein is globally in practice, because protein requirement of farm animals is normally expressed in terms of nitrogen x 6.25.

- b) Many nitrogenous compounds such as amides, amino acids, glycosides, alkaloids, ammonium salt and compound lipids occur along with feed nitrogen naturally. Only the amides and amino acids are important and these are present in large amount in only a few feeds such as young pasture, silage or immature root crops.

- c) The assumption did not take into account the species of animal for which the feeds were intended. In the diets of pigs and poultry, cereals and oil seed predominate which contain little non- protein nitrogen (NPN), thus their nitrogen source may not need to be partitioned but in ruminant animals, variable amount of NPN are fed. Allowance therefore, need to be made for this in the evaluation of ruminant feeds.

2. DIGESTIBLE CRUDE PROTEIN (DCP).

The crude protein figure only provides a measure of the N present in feeds but gives little indication of its value to the animal. Before the feed becomes available to the animal, it must undergo digestion, during which it is broken down into simpler substances which are absorbed into the body system. Thus, the digestible protein in the feed is determined by digestibility trial in which nitrogen intake is measured along with the nitrogen voided in faeces. The assumption is that the difference between the quantities of N in the feed and faeces or digesta represents the quantity absorbed in the utilizable form by the body and that all N which appears in the faeces is of dietary origin. These assumptions are untenable in most cases particularly in ruminant animals because of the presence of nitrogen of metabolic origin in faeces and the production of ruminal ammonia gas. Thus, the figures obtained are called APPARENTLY DIGESTIBLE PROTEIN. This however, gives a measure of the protein status of a feed for livestock feeding.

3. TRUE PROTEIN (TP)

When crude protein is to be determined, it can be separated from NPN compounds by precipitation with cupric hydroxide or heat coagulation in some plant materials. The protein is then filtered off and the residue subjected to a kjeldahl analysis. Determination of the digestibility of true protein (true digestibility) always take account of the contribution of nitrogen of endogenous origin to take of the digesta. The endogenous N is derived from non – food substances entering the intestine such as saliva, bile, gastric and

pancreatic secretions, and cell sloughed off the mucous membrane of the gut. This measurement always present difficulties and the result may vary widely with the different techniques employed. Most figures in current use are apparent values minus the metabolic nitrogen which is taken principally as urine nitrogen. True digestibility = TP- (faecal N + MFN +UN) where MFN = Metabolic faecal Nitrogen and UN= Urinary Nitrogen. The concept of true protein and its attendant intricacies has given rise to many concepts which are now used more valuably to measure protein quality. These however, differ widely in application between monogastric and ruminant animals. In ruminant nutrition, certain proportion of the intake protein is degraded in the rumen by the microbes while some are lost in their complex compartments. This has made the evaluation of ruminant diets with CP or digestible CP later modified to Protein Efficiency Ratio (PER) unsatisfactory. Thus, estimation of protein quality and digestibility for ruminant animals which will take into account their microbial and endogenous losses is rather complex.

4. PROTEIN EFFICIENCY RATIO (PER)

Digestible protein figure as stated above are not entirely satisfactory measures of the value of a protein to an animal. This is because the efficiency with which the absorbed protein is used differs considerably from one source to another. PER always give the ratio of weight gain of animals to the amount of protein it consumed for each feed.

$$\text{PER} = \frac{\text{Weight gain of animals (g)}}{\text{Protein consumed (g)}}$$

5. NET PROTEIN RATIO (NPR)

This entails feeding of a group of animal with protein and compare with another group fed no protein as a ratio of protein consumed

$$\text{NPR} = \frac{\text{Wt gain of TPG} - \text{Wt loss of NPG}}{\text{Wt of protein consumed}}$$

TPG = Test Protein Group; NPG = Non – Protein Group.

6. BIOLOGICAL VALUE (BV).

Bv is defined as the proportion of the absorbed nitrogen which is retained by the body. It is a direct measure of the proportion of the feed protein which can be utilized by the animals for synthesizing body tissues and compounds.

$$\text{Biological value} = \frac{\text{N intake} - (\text{Faecal N} - \text{MFN}) - (\text{Urinary N} - \text{EUN})}{\text{N intake} - (\text{Faecal N} - \text{MFN})}$$

$$\text{N intake} - (\text{Faecal N} - \text{MFN}).$$

EUN = Endogenous Urinary N; MFN= Metabolic faecal N.

In determining BV, dietary protein should be provided by the feed under test. The protein intake must also be sufficient to allow adequate N retention but must not be in excess of that required for maximum retention.

7. NET PROTEIN UTILIZATION (NPU)

NPU is the product of biological value and digestibility. It is the proportion of feed N that is retained in the animal's body under specified condition. It entails doing a nitrogen balance study and carcass analysis. The higher the retention of a given dietary intake, the better the quality of the protein.

ENERGY PARTITIONING

1. GROSS ENERGY (GE)

When a feed is completely burnt to its ultimate oxidation product (CO₂, H₂ and gasses), the heat given off is known as Gross Energy or Heat of Combustion. Gross energy is determined with the aid of a bomb calorimeter and is just the starting point in determining the energy value of feeds because not all of it is utilized within the animal's body system. The fraction not utilized is wasted as faecal or urine energy.

2. FAECAL ENERGY.

This is the energy lost through the faeces i.e. heat of combustion of faeces. It includes energy of metabolic product of the body as well as that of undigested feed. Faecal energy is important because it is used to compute the apparent digestible energy. It can further be used to obtain the True Digestible Energy

(TDE) by subtracting the faecal energy of feed origin only from the gross energy.

3. DIGESTIBLE ENERGY

This is the difference between the gross energy intake from feed and energy voided in faeces. It is also determined by the use of bomb calorimeter to obtain gross energy of feed and faeces.

4. METABOLISABLE ENERGY

This is the proportion of energy ingested by the animal which is actually transformed and used for metabolic processes in the body. It is the apparent digestible energy minus energy lost in gaseous product of digestion and that lost in urine (UE). These gaseous losses (CH_4 , H_2) are particularly very important in ruminant animals and to a lesser extent in monogastric such as man, dog, swine and chicken. These gaseous losses are usually not accounted for when metabolisable energy is being calculated for monogastrics.

5. URINARY ENERGY

Urine which comes out of urinary tract of animals contains some energy which constitutes further loss to the animal's energy economy. The urine loss result from the excretion of incompletely oxidized nitrogenous products. The urinary loss is both from the blood and body cells. Therefore it is called Endogenous urinary Nitrogen (EUN).

6. HEAT ENERGY (HE)

This is energy lost as heat in the body. This heat is used by the body to maintain the thermo-neutral balance of body tissues. Sometimes, small amount of energy are lost in form of perspiration, epidermal loss (loss through epidermal scales) and shed hair. They could also be accounted for and subtracted from gross energy to obtain metabolizable energy. However, they are normally regarded as insignificant for specific dynamic action. As a result of continuous metabolic reaction in the body, which is a manifestation of life processes, heat is produced within the body in form of chemical energy and it is lost as heat energy. This heat increases with the amount and type of

food consumed and the increase is known as Heat Increment (HI). This consists of heat of fermentation and heat of nutrient metabolism.

The heat of fermentation is the heat produced in the GIT especially rumen of ruminant animals as a result of microbial action. Thus, it is more relevant in ruminant animals than any other species. The heat energy produced in an animal will therefore depend on:

- i) Nature of the diet/ration (whether soluble or insoluble carbohydrate or proteinous feed. Heat is more generated when carbohydrate is fed to ruminant than roughages).
- ii) The level at which it is fed (production or maintenance).
- iii) The purpose for which it is fed i.e the body functions the feed suppose to support (maintenance, growth, fattening, lactation etc.)
- iv) The environment under which it is fed. The ambient temperature will determine the amount of heat generated by the animal's body. For instance, the heat generated within the body of an animal in cold environment will be more than that of animal in hot environment. This is because of the demand of animal in cold environment to generate more heat to keep its body temperature up to normal within the thermo-neutral level. This will call for more chemical reaction and tissue breakdown in the animal.
- v) Physiological state of the animal. A sick animal may not have enough appetite to eat food. Consequently, its body metabolism may not be able to cope with environmental demand. The result of this is heat stress which could bring down the animal.

7. NET ENERGY

Net energy is the proportion of feed energy which is completely useful to the body and thereby appears as a product in form of energy for tissue maintenance, growth, milk, egg, wool and fur. It can be obtained by subtracting the heat increment expressed in terms of a given unit of intake from metabolisable energy of the same intake. In ruminants fed concentrate, this value must be added to a basal roughage ration to know the actual net

energy value. Energy partitioning has given rise to many concepts one of which is Total Digestible Nutrients (TDN) which represents values commonly used in ruminant animal feed

evaluation. It is calculated as:

$$\text{TDN} = \% \text{ DCP} + \% \text{ NFE} + \% \text{ CF} + \% \text{ EE} + 2.25$$

The 2.25 comes from the fact that fats are concentrated source of energy (1g of fat = 2.25g CHO).

NON-PROTEIN NITROGEN (NPN) MATERIALS

The NPN part of the feed includes amides, nitrates, nitrites, Urea (feed and fertilizer grades), uric acid and a number of other ammonia compounds. Thus, NPN could be defined as nitrogenous feed nutrient that are not bound together by peptide bonds and are found within or outside the animal's body system. They may be found in forage plant especially when immature pasture is fed to the animals. In developing countries, crop residues are fed as supplements to ruminant animals with traces of urea and ammonium sulphate. All NPN's generate ammonia in the rumen which enters the liver and finally converted to urea.

RUMEN AMMONIA POOL

Ammonia is derived from most of the NPN feedstuffs and also when the proteins in feed stuffs are metabolized by ruminants. The level of nitrogen in the rumen builds up progressively and it is determined by the solubility of the nitrogen source. In most cases, it reaches a peak at about 3 hrs post-feeding. Experiments have also shown that nucleic acids are converted to ammonia in the rumen. This ammonia which all together now form a pool inside the rumen is usually lost through the following channels:

1. By incorporation into microbial cells to generate microbial protein which will pass out of the rumen
2. By absorption through the rumen wall
3. Some are freely lost into the rumen fluid.

The rumen ammonia pool under normal condition is very small but it turns over rapidly. The quantity of ammonia entering the rumen is dependent on the following:

1. The degradability of the protein source.
2. The solubility of the protein source
3. The method and extent of supplementation of the feed.

It has been established over the years that very small amount of ammonia flows out of the rumen. By implication therefore, most of the ammonia will normally be absorbed by the reticulo-rumen wall while the excess will be incorporated into the microbial protein. Thus, to sustain the ruminant animal, there will be the need to ensure that urea is continually made available in the rumen. The various forms of urea supplementation for animals on low quality diet include:

1. By spraying urea solution on the feed
2. By using urea blocks
3. By oral administration - this could be in liquid form put in a bowl and allow the animals to drink over a period of time (maximum 3 days).

Some of the ammonia produced in the rumen may also be absorbed in the abdomen/small intestine but ultimately, ammonia is sent to the liver where it is converted to urea. Excess of its post-metabolism would be sent out of the system as urine. In maintaining the ammonia level in the rumen, saliva plays a key role because;

1. It receives urea from the liver and
2. Such urea is recycled back into the mouth and back to the rumen.

It should be noted however, that urea derived from saliva may not be enough to sustain the animals hence the need for supplementation from time to time. Urea is also recycled into the blood and when quantified, it is called Blood – Urea level and this is normally used in assessing the quality of a feedstuff. Studies have shown that when animals are on low quality straw-based diet, it becomes meaningful to supplement with urea. In supplementing with urea, possible benefits include:

1. Increasing level of feed intake
2. Improved nitrogen balance value

3. Availability of protein or nitrogen in the rumen
4. Improved nutrient digestibility.
5. Improved general productivity of the animals.

The urea in the rumen is mostly recycled via the blood and saliva. The blood for instance, passes back an equivalent of about 0.5 – 2.3g of N per day while saliva recycles only about 0 – 0.5g/day. In the case of long time feed deprivation and consistent intake of low quality diet, the urea recycled from the saliva becomes unimportant because it is unable to sustain the animal. This therefore, calls for urea supplementation.

UREA UTILIZATION IN LIVESTOCK FEEDING

It has been known for quite a long time that urea can be recycled and used as a source of nitrogen for the rumen microorganisms.

- (1) Urea is used in ruminant feeding both as fertilizer grade as well as feed grade. It can be administered through feed along with other feed ingredients in a compounded ration
- (2) Urea can also be given as liquid nitrogen i.e. it could be dissolved in H₂O and offered as drinking water to the animals.
- (3) It could also be constituted as urea-molasses multi-nutrient feed block held together by a binder. The animal by abreaction licks off urea from the block. Experiment over the years have shown that urea could be utilized as whole ingredient to feed at levels between 1% - 5% which defines a safe utilization level. Although, some other studies recommended higher levels. For instance, Onwuka and Akinsoyinu (1989) recommended 10% level of urea while Leng and Preston (1980) recommended 10 – 15% level. When urea is used as a component of feed block, the level of urea may be as high as 40%.

UREA TOXICITY

The use of urea as a nitrogen source is not without its adverse effects. Abuse of urea leads to production of excess ammonia which usually elicit neurological symptoms

which result in the derangement of brain metabolism. Excess consumption of urea can be caused by:

1. Insufficient mixing of urea in compounded feed
2. Licking of urea in feed trough which lead to high concentration at the base.
3. Excessive consumption of urea from feed lots already exposed to rain water because the urea block is soften and dissolves in water. The inability of ruminant animals to handle urea can be trace to animal dysfunctional liver. Animal which have been fasted for long time also manifest urea toxicity. Note that urea on its own is not toxic. Its metabolic product (NH_3) is responsible for the observed toxicity. Additionally, at pH of rumen, urea diffuses very quickly via the rumen wall from where it is sent to the liver and excess of it excreted as urine. When the level of NH_3 that goes to the blood is high, it passes from there to the brain and therefore, various symptoms of ammonia toxicity manifest. The recent explanation for this is that when ammonia concentration is high in the rumen, some proportion diffuses into the abdominal cavity and from there via the lymph drainage goes to the jugular vein. In effect, the liver is by-passed and the brain is affected resulting in brain derangement. Urea toxicity is reflected as:

1. Reduced growth
2. Reduced lactation- although, this does not usually produce clinical symptoms
3. Reduced feed intake.

Despite these adverse effect, the reasons why urea utilization is still being encouraged in ruminant feeding system include :

1. The reduced cost of urea as nitrogen source. This is mainly because little quantity of it is required unlike the conventional feed ingredient.
2. The readily soluble nitrogen it produces.
3. It results in increased feed intake, nutrient degradation as well as increased productivity of the animal.
4. The ease with which urea can be used and administered to the animal.
5. The ease with which rumen microbes are able to degrade urea.

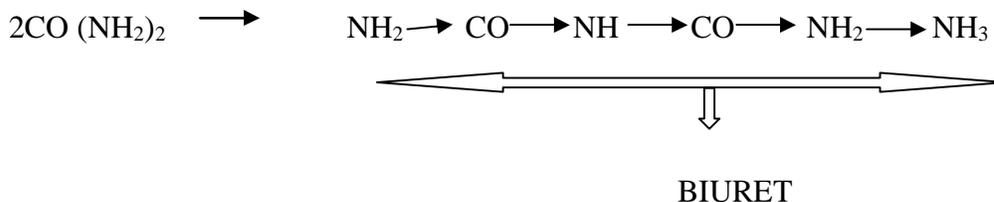
ANTIDOTES TO UREA TOXICITY

When the negative effect of urea toxicity sets in, the different curative and preventive measure to use are:

1. Infusion of dilute acid into the rumen which helps to reduce the rumen pH.
2. Inclusion of sulphur in urea based diets/ feed stuffs.
3. Ensure that urea is properly mixed in urea containing feed.
4. Ensure that urea is intermittently supplied as urea solution
5. Adhere to the use of low levels of urea always (1-5% level)

BIURET

Another form of NPN which has some merit in ruminant feeding is biuret. It is a compound derives from the condensation of two urea molecules. It has some merit over most other source of NPN because of its solubility and slow rate of degradation. It is an ammonium salt source which readily releases ammonia for microbial action in the lumen.



Since, it is slowly degraded in the rumen; it is able to bring about a slow but continuous source of ammonia. It is non-toxic. So, large amount of it can be safely consumed by animal without complication. Degradation of biuret in the animal's body system is brought about by an enzyme **biuretase**. However, when soluble carbohydrates are mixed and fed along with biuret, the energy is inefficiently utilized. Some disadvantages of biuret as nitrogen source are,

1. Biuret is quite expensive costing as much as 8 times equivalent quantity of urea.

2. The biuretase enzyme needed for biuret degradation is not automatically built up in animals system. Sometimes, it may require up to 6 months for a young ruminant to build up biuretase.
- 3 When the young animal grows up, the biuretase so built up still requires about 6 months to stabilize.

POULTRY DROP LITTER

Poultry litter as NPN is very readily available in poultry producing areas where at times it may constitute a nuisance to the environment. In such areas, the ammonia given out is usually pungent and the odour is well recognized. The efficacy of poultry litter as NPN source depends on the quantity and quality of the bedding materials. Where the poultry litter is undiluted and collected directly, it tends to be supportive of the ammonia (NH_3) production, and is usually higher than when wood shaving or straws are used. Poultry litter mainly consists of URIC ACID which is degraded by rumen microbes to yield ammonia (NH_3) and it could be a very rich source of ammonia for both livestock and industrial utilization. There are however, health considerations as to why a product (faeces) of one species of livestock should be used to feed another livestock.

NUTRITIONAL DISORDERS IN RUMINANT ANIMALS

Ruminant animals have been noted to possess capability to utilize or convert waste resources into beneficial products such as meat, milk, hair among others. This is feasible as long as the animal is provided with good housing, feeding and hygiene. A number of nutrient related metabolic diseases have been studied under experimental conditions with ruminant animals. They include dysphagia, abortion, ketosis, enterotoxaemia, milk fever, urinary calculi, toxic plants etc. These diseases are always related to the absence of one or many nutrients from the feed given to the animals. It may be as a result of inadequate feeding of animals resulting in Marasmus otherwise known as malnutrition. This may eventually lead to more complex situation resulting

from generalized starvation of the animal. At times, the animal may be fed adequately but with the feed lacking a major nutrient as in Kwashiorkor otherwise known as prolonged insufficient intake of protein. In this case, there is a negative nitrogen balance because the nitrogen output exceeds that of input. The rate of tissue breakdown therefore, becomes accelerated. In some cases, a minor nutrient may be lacking as we have in the following diseases:

1. **DYSPHAGIA:** Ruminant animals during grazing are sometimes being observed to consume or lick materials which in nutritional terms are INERT materials. Such could be manifested as the licking of bones, stick, paper eating as well as soil eating. These behavioral symptoms are traceable to deficiencies of phosphorus in the diet of such animal. Such phosphorus deficiency could be aggravated by an imbalance in calcium: phosphorus ratio (Ca: P) or an excessive demand of the animal for calcium altering the Ca:P ratio from the normal of between 1.5:1. If the situation is not properly managed, the material which is consumed or licked could harm the animal. The disease dysphasia also results in metabolic symptoms similar to those of phosphorus deficiency which include.

- i. Muscular weakness
- ii. Low fertility and
- iii. Low productivity

The practical and effective solution to the menace of dysphagia on the farm is:

- Introduction or inclusion of adequate amount of phosphorus in the diet.
- The Ca:P ratio of ruminant ratio should always be kept between a range of 1.5:1 to 2:1

2. **ABORTION:** This is a condition which results in the expulsion of life or dead foetus by pregnant animals. Among several factors, nutrition stands out as a major cause. In pregnancy, the foetus develops over time and this calls for increase calcium, phosphorus and other nutrients. When the feed

is unable to supply required quantity of these nutrients, the foetus development is affected and may be expelled. The level of blood glucose is also very important in this condition. When an animal is under-fed, the glucose level in the blood becomes lowered and the animals become depressed. There is an elevated/increased production of estrogen. Arising from this, the foetus could be expelled. This is more frequent when the pregnancy is in second trimester, usually between 90 – 110 days in cows.

3. **ENTEROTOXEAMIA:** This is a metabolic disorder that is otherwise referred to as over-eating disease or toxic indigestion. It brings about diarrhoea, digestive in coordination (staggering or gait), coma and eventual death of the animal. Enterotoxaemia may result from a change in the feed of the animal resulting in consumption of more palatable and digestible feed by hungry animals. It can also be caused by Ca insufficiency in diet as well as acidosis. The disease can also be built up as a toxic reaction to the micro organism *Clostridium perfringens*. Enterotoxaemia condition can be prevented by frequent feeding of palatable feed such as milk, concentrate and succulent forages as well as hay in small bits at a time.
 - (a) In other words, offering of large quantity of milk or concentrates to animals at a time should always be avoided.
 - (b) When changes are to be made to concentrate feed to ruminant animals, a gradual introduction is recommended over a number of days. This is more relevant when urea is to be introduced to the animal at the first time and at high level. In this case, the animal may need a minimum of 3 weeks to adjust.

A situation referred to as Lactic acidosis could result when the PH level in the rumen drops to about 4.8 and this only favours a specific class of micro organisms.

4. **KETOSIS:** This is a nutritional condition in which there is an increase quantity of ketone bodies in the blood of animals. Such ketore bodies include acetone, aceto acetic acid, B-hydroxybutyric acid. When their

levels increase in the blood or milk, the metabolic disorder is referred to as Ketosis. Ketosis can also be associated with increase level of non-esterify fatty acids in the plasma since these are known to be the precursors of Ketone bodies. This condition is very common in dairy goats and cows that are high yielding, in which case it is referred to as LACTATION KETOSIS. Pregnancy ketosis also occurs in pregnant cattle, sheep and goat that are carrying multiple fetuses. Ketosis could be controlled and prevented by intravenous administration of glucose and adreno-corticotropic hormone or gluco-corticoid steroids.

5. **MILK FEVER:** This is otherwise referred to as *Parturient_paresis* because it manifests soon after parturition, as an increase in the blood flow to the mammary gland. In high yielding animals, milk fever could be caused by a drop in calcium level. Consequently, the disease could easily be treated by introduction of calcium into their diets. It could also be treated through vitamin D therapy i.e. administration of Vit. D Milk fever is not common where milk production is less intensive.
6. **URINARY CALCULI:** This disease is associated with stone formation along the urinary tract which endangers or brings about infection of the urinary tract. With the formation of stone there is the blockage of the urinary tract. It is more noticeable in confined animals than those which graze from time to time. This condition occurs more in males and can be associated with high feed phosphorus relative to Ca:P content of the feed. The ideal Ca:P is 1:5:1 for ruminant animals and when this is not conformed with the tendency is for the animals to start building up little stones progressively along the urinary tract. Thus, the best antidote against urinary calculi is a balanced Ca:P ratio particularly in zero-grazed animals.
7. **UREA TOXICITY:** This disease refers to in ability of ruminant animals to cope with excess level of urea in their feed supplements arising from which large quantities of ammonia is produced resulting in brain derangement. It could also occur or manifest when such a feed does not

possess sufficient quantity of readily available energy to cope with the rate of ammonia release. To prevent this disease, therefore

- (i) The urea level of feeds must be reduced or kept at minimum
- (ii) Acid infusion into the rumen has been used in many cases to counter the effect of urea toxicity.

8. TOXIC PLANTS: Much as it is being advocated that ruminant animals should always be grazed on forage for economic production, one needs to note that some plants are very toxic and can instantly result in death of animals. Such reaction is usually derived from the content of anti metabolite or toxins in the leaves of plants. Under normal condition, these toxic constituents are used as protective mechanisms by the plants themselves. The outstanding examples are:

- (i) Hydrocyanic acid (HCN) contained in the leaves of high cyanide variety of cassava.
- (ii) Tannins found in almond leaves
- (iii) Tannins found in sorghum
- (iv) Nitrate and Nitrite in some leaves as well as oxalate and phytate.

These toxicants influence the bio-availability of Ca, P, Mg, Cu, Zn, Mn, Co etc i.e. Minerals. Cases have been cited of goats that died within 3 hours after consuming cassava leaves. Such effects can however, be overcome through.

- (i) Wilting or partial drying
- (ii) Inclusion of sulphur to assist in detoxification
- (iii) When some of the effects are noticed which may include foaming in the mouth or prostration, palm oil could be administered to assist in reducing the surface tension of the rumen environment.

9. BLOAT

Bloat is the manifestation of accumulation of gas in the reticulo-rumen due to the rate of gas elimination falling behind the rate of gas production. In legume bloat for example, the primary abnormality responsible for inefficient gas elimination is excessive frothing of the gastric contents.

Some frothing of the reticulo-rumen contents always occurs when succulent legumes are ingested, but this foam is not always of the required consistency or sufficient in amount to cause bloat. Occasionally, however, the frothing is of such magnitude that there is a large increase in the volume of stomach contents and a change in their physical characteristics, and bloat results. Gas elimination is impeded by the trapping of gas in the foamy digesta, by interference with the access of free gas to the cardiac, and probably by reflex inhibition of oesophageal components in eructation. In the bloating animal, frothy digesta may enter the oesophagus only to be swallowed again; in effect, the foam is returned in the stomach until the former collapses.