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NUTRIENT REQUIREMENTS OF LIVESTOCK FOR SUSTAINABLE PRODUCTIVITY IN TROPICAL AFRICA: A REVIEW

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ABSTRACT: *The objective of this paper was to review nutrient requirements of farm animals in other to improve feed supply and utilization for healthy sustainable livestock productivity in tropical Africa. Farm animals require nutrients to support body maintenance, reproduction, lactation, and growth. The nutritional needs of livestock vary according to breed, age, sex, class, stage of production, performance level and weight. Physiological and environmental stressors, such as sickness and weather, can also influence nutritional requirements of farm animals. Most livestock need carbohydrates, protein, minerals, vitamins and water. Identification of nutritional need of farm animals throughout the production cycle is paramount. Feeding animals without consideration to their nutrient requirements is tantamount to wasting time and resources. Matching animal requirements to nutrient value of feeds and using body condition score to fine tune the nutritional program of farm animals is also economically advantageous. Feed, whether purchased or produced on the farm, make up a large part of the expenses incurred in livestock production. Therefore, for profitable and healthy production, proper feeding and year-round management are essential. Without proper nutrition, it is impossible to produce a high-quality livestock, wean healthy heavy animals, and develop satisfactory flock replacements. All livestock producers should have a basic understanding of animal nutrition and should be familiar with common nutrition terms. Producers must also know the nutritional requirements of the animals at different stages of life. The ideal nutrition program supports optimum production, is efficient and economical, and minimizes related problems. In order to understand the fundamentals of livestock nutrition, the farmer must first know the nutrients essential for growth, production, and reproduction.*

KEYWORDS: feed supply, utilization, farm animals, productivity, tropical Africa

INTRODUCTION

Livestock production, in Nigeria and elsewhere in the tropics, depends largely on feed availability and supply (NRC, 2000; 2001; Olawoye & Kubkomawa, 2018a). This, also, depends on the producer's intellectual capability to offer the required nutrients according to the classes of animals to be fed. Modern feeds are produced by carefully selecting and blending ingredients to provide highly nutritious diets that both maintain the health of the animals and increase the quality of animal end-products such as meat, milk and eggs. Animals, in general, require the same nutrients as humans but some feeds, such as pasture grasses, hay and silage crops and certain cereal grains, are grown specifically for animals. Other feeds such as cowpea husk, groundnut hauls, groundnut cake, cottonseed cake, rice bran, straws, maize bran, molasses, sugar beet pulp, brewers' grains, yam and cassava peels, orange peels and pineapple bran are crop residues and by-products that also serve as feed for livestock (Olawoye and Kubkomawa, 2018b). Similarly, surplus food crops such as maize, sorghum, rice, wheat, other cereals, fruits, vegetables, and roots, may also be fed to animals. Poor nutrients supply in required quantity and quality is the major causes of diseases and low livestock productivity in Nigeria and elsewhere in tropical Africa. The objective of this paper was to review nutrient requirements of farm animals in other to improve feed supply and utilization for healthy sustainable livestock productivity in tropical Africa.

NUTRIENT REQUIREMENTS OF CATTLE

Research has shown that, cattle are natural grazers and possess remarkable ability to digest plant carbohydrates that are generally indigestible to most other mammals. It is natural then to assume that, grazing is the best way to supply a nutrient-dense diet to growing cattle. Cattle require consistent supply of energy, protein, minerals, vitamins and water to maintain productivity and health (Cuesta *et al*., 1996). The nutrient requirements of cattle can be broken down into maintenance, lactation, growth, and reproduction requirements. From these components, requirements for energy, protein, minerals, and vitamins are calculated. By understanding the different factors that affect requirements, producers can make adjustments to changes such as a month of cold weather, moving to a hilly pasture, or the last stage of pregnancy (Cuesta *et al*., 1996).

Similarly, the maintenance component includes all the nutrients required for the animal to breath, move, digest food, keep warm, repair tissues, and maintain body weight. Weight, age, breed, physiological status, activity and environmental conditions are the primary variables impacting maintenance requirements. Even though, all nutrients are needed for maintenance, only energy requirements are divided into maintenance and non-maintenance portions. This is because energy is used more efficiently for maintenance than for other body processes such as growth (Cuesta *et al*., 1996).

Nutrient requirements for lactation are based on the amount of milk produced at peak lactation and the composition of the milk (NRC, 2000; 2001). Cows that produce more milk and milk with more fat and protein will have higher nutrient requirements. Requirements for growth are determined by actual weight, average daily gain (growth rate), and weight at maturity and composition of gain (NRC, 2001). Adjustments to requirements for reproduction are based on expected calf birth weight and stage of gestation. Usually, pregnancy does not significantly affect requirements until the last three months of pregnancy when the fetus is growing rapidly (Olawoye & Kubkomawa, 2018a).

Protein is one of the main animal body building blocks (NRC, 2001). It is usually measured as percentage of Crude Protein (CP). It is a major component of muscles, the nervous system and connective tissue. Protein is composed of chains of amino acids. Cattle, generally, require crude protein in the range of 7 - 14% of daily dry matter intake. Requirement is less for dry cows, while pregnant and lactating cows, especially dairy cattle, require more. Growing cattle, such as replacement heifers and steers, require 10.5 - 14% of their dry matter intake to be protein (NRC, 2000; 2001).

Olawoye and Kubkomawa (2018a) stated that, all cattle require mineral elements for cellular respiration, nervous system development, protein synthesis, and metabolism and reproduction purposes. Feed resources that contain minerals include; range or pasture plants, harvested forages, concentrates and mineral supplements. The minerals that often seemed deficient in beef cattle diets are sodium chloride (salt), calcium, phosphorus, magnesium, zinc, copper, selenium and sulfur. Attempts have been made to correct natural soil deficiencies for trace minerals by soil fertilization practices (NRC, 2001). Thus, it is implied that a beef producer needs to know the mineral and trace mineral content of the feed-stuffs used in cattle rations. A general approach to prevent deficiencies is to feed a commercial salt and mineral mixture manufactured for the geographic location of the herd (NRC, 2001.

The salt (NaCl) requirement for cattle is quite low (0.2% of the dry matter); however, there appears to be a satiety factor involved, since almost all animals appear to seek out salt, if it is not readily available (NRC, 2001). Range cattle may consume 1kg salt/head/day when forage is succulent but about half that amount when forage is mature and drier. Signs of salt deficiency include reduced feed intake, growth, and milk production (NRC, 2001).

Calcium is the most abundant mineral element in the body with about 98% functioning as a structural component of bones and teeth (NRC, 2000; 2001). The remaining 2% is distributed in extracellular fluids and soft tissues and is involved in such vital functions as blood clotting, membrane permeability, muscle contraction, transmission of nerve impulses, cardiac regulation, secretion of certain hormones, and activation and stabilization of certain enzymes (NRC, 2001). Most roughages are a relatively good sources of calcium. Cereal hays and silages and such crop residues are relatively low in calcium. Although leguminous roughages are excellent sources of calcium, even non- legume roughages may supply adequate calcium for cattle maintenance. Because lactating beef cows do not produce near the amount of milk that dairy cattle do, their calcium requirement is much less. Calcium requirement of growing cattle is 1.2 - 4.4 g/ head /day while lactating dairy cows is 1.6 - 4.2 g/head/day (NRC, 2000; 2001).

Phosphorus has been described as the most prevalently deficient mineral grazing cattle worldwide. Approximately 80% of phosphorus in the body is found in the bones and teeth, with the remainder distributed among the soft tissues. Phosphorus may be deficient in some beef cattle rations, because roughages often are low in phosphorus (NRC, 2001).

Good sources of supplemental phosphorus include steamed bone meal, mono and di-calcium phosphate, defluorinated rock phosphate, and phosphoric acid (NRC, 2001). Corn products like corn gluten and distillers' grains are also high in phosphorus. As most grains are relatively good sources of phosphorus, feed-lot cattle rarely suffer a phosphorus deficiency, although phytic acid chelation of phosphorus in grains may render up to one-half of it unavailable, especially for monogastric animals such as swine and poultry (NRC, 2001).

Magnesium maintains electrical potentials across nerve endings. Magnesium requirement for cattle is 2g/kg DM in the diet (NRC, 2001). Potassium is the major cation in intracellular fluid and is important in acid-base balance. It is involved in regulation of osmotic pressure, water balance, muscle contractions, nerve impulse transmission and several enzymatic reactions. It is good a practice to supplement rations for growing and finishing cattle such that, they will contain more than 0.6% potassium on a dry matter basis. Potassium (K) of 8g/kg DM is recommended for grazing cattle (NRC, 2001).

Cobalt functions as a component of vitamin B_{12}. Cattle do not depend on dietary vitamin B_{12}, because ruminal micro-organisms can synthesize it from dietary cobalt (NRC, 2001). Copper functions as an essential component of many enzyme systems, including those that involve the production of blood components. Recommended levels of cobalt and copper should be provided in the diet, either by supplementation of the total mixed ration or as part of the free-choice mineral mixture or supplemental mixture (NRC, 2001).

Iodine is an integral part of thyroxin and as such, is largely responsible for control of many metabolic functions. However, some soils do not have sufficient iodine to meet most livestock needs. Iodine requirements in cattle can be met adequately by feeding stabilized iodized salt (NRC, 2001).

Selenium is part of the enzyme glutathione peroxidase, which catalyzes the reduction of hydrogen peroxide and lipid hydroperoxides, thus preventing oxidative damage to the body tissues. Selenium can be included in mineral mixture at a level of up to 120 ppm so that, cattle intake is 3mg/head/day (NRC, 2001).

Vitamins are important for formation of catalysts and enzymes that support growth and body maintenance in animals (NRC, 2001). Although, cattle probably have metabolic requirements for all the known vitamins, dietary sources of vitamins C and K and the B- complex are not necessary in all, but the young. Vitamin K and the B vitamins are synthesized in sufficient amounts by the ruminal microflora and vitamin C is synthesized in the tissues of all cattle. Vitamin A can be synthesized from β-carotene contained in feed-stuffs such as green forages and yellow corn. Vitamin A supplementation should be included in the mineral mixture at about 1,200 to 1,700 IU's (International units) per pound of dry matter of feed intake per day. The daily requirements for beef cattle appear to be about 5mg of carotene or 2,000 IU of vitamin A/45 kg body weight; lactating cows may require twice this amount to maintain high vitamin levels in the milk (NRC, 2000; 2001).

Growing and finishing steers and heifers fed low-carotene diets for several months require 2,200 IU of vitamin A/kg of air dried ration (NRC, 2001). Commercial vitamin A supplements are not expensive, and should be used when such rations are fed and any danger of deficiency exists. An alternative way to supply supplemental vitamin A is by IM injection (NRC, 2001).

Vitamin D deficiency is comparatively rare in pastoral cattle, because they are usually outside in direct sunlight or are fed on sun-cured roughage (NRC, 2001). The ultraviolet rays of sunlight convert pro-vitamin D found in the skin of animals (7-dehydrocholesterol) or in harvested plants (ergosterol) to active vitamin D. Direct exposure to sunlight, consumption of sun-cured feed, or supplementary vitamin D (300 IU/45kg body weight) prevents deficiency. Green forage, high quality hay and cereal grains are typically high in Vitamin E (NRC, 2001).

According to the report of Olawoye and Kubkomawa (2018a), water is a fundamental constituent of all living cells. Its presence in adequate amounts in the body tissues is an essential pre-requisite for the normal maintenance of life (NRC, 2001). It is intimately connected with the transformation of nutrients and excretory matter from the digestive system, the cells of the different body tissues and the excretory organ. This also corroborate NRC (2001) who reported that, cattle require 3 - 30 gallons of water per day, at the rate of one gallon of water per 45kg body weight during wet season and two gallons of water per 45kg body weight during hot weather. Factors that affect water intake include age, physiological status, temperature, body size, sources of feeds, roughages, concentrates and succulence. Starving animals may lose nearly all their glycogen and fatty resources, half of their body protein and about 40% of their body weight and still remain alive, while the loss of only 10% of body water causes serious disorders and further losses may quickly lead to death. During the dry season, in the semi-arid/arid regions, feed and water can be so scarce that, animals do not have enough to eat and drink. This makes livestock owners/herdsmen to move to areas with pasture and water (NRC, 2000; 2001).

NUTRIENT REQUIREMENTS OF SHEEP

Sheep require an adequate diet for optimal growth and production which must include energy (carbohydrates and fats), proteins, minerals, vitamins and water as reported by Rayburn (2013). Under field conditions of particular stress, additional nutrients may be needed.

As high percentage of livestock feed comprises of grass and forage that is either sparse or of poor quality, the provision of adequate energy, therefore, is important (NRC, 2001). The energy requirements of ewes are greatest during the first 8–10weeks of lactation, because milk production declines after this period and the lambs begin foraging, the requirements of the ewe is then reduced to pre-lambing level (NRC, 2001; Rayburn, 2013).

Good-quality forage and pasture, generally, provide adequate protein for mature sheep. However, sheep do not digest poor-quality protein as efficiently as do cattle, and there are instances when a protein supplement should be fed with mature grass and hay, especially during the dry season (NRC, 2001; Rayburn, 2013). Therefore, a minimum of 7% dietary crude protein is needed for maintenance in most sheep. Protein requirements depend on the stage of production (growth, gestation, lactation, etc) and the presence of certain diseases (internal nematode parasites, dental disease, etc). If available forage are unable to supply adequate dietary crude protein, protein supplements, such as oil-seed meals (cotton-seed, groundnut and soybean meals) or commercially blended supplements should be fed to meet nutrient requirements (NRC, 2001).

Sheep require the major minerals such as sodium, chlorine, calcium, phosphorus, magnesium, sulfur, potassium, and trace minerals including cobalt, copper, iodine, iron, manganese, molybdenum, zinc, and selenium (NRC, 2001; Rayburn, 2013). Trace mineralized salt provides an economical way to prevent deficiencies of sodium, chlorine, iodine, manganese, cobalt, copper, iron, and zinc. Selenium should be included in rations, mineral mixtures, or other supplements in deficient areas. Sheep diets usually contain sufficient potassium, iron, magnesium, sulfur, and manganese (NRC, 2001). Of the trace minerals, iodine, cobalt, and copper status in ewes are best assessed via analysis of liver biopsy tissue. Zinc adequacy can be assessed from the careful collection of non-hemolyzed blood placed in trace element–free collection tubes. Selenium status is easily assessed by collection of whole, preferably heparinized, blood. Range operators commonly provide 225–350g of salt/ewe/month. Salt as low 0.2–0.5% of the dietary dry matter is usually adequate. For pregnant ewes, the diet should contain equal to or greater than 0.18% and, for lactating ewes, equal to or greater than 0.27%. A content of 0.2–0.4% calcium is considered adequate, as long as the ratio is maintained between 1:1 and 2:1 (NRC, 2001; Rayburn, 2013). Diets containing iodine at 0.2–0.8% ppm are usually sufficient, depending on the animal's level of production (maintenance/growth, lactation, etc).

Sheep require 0.1 ppm of cobalt in their diet. Cobalt-deficient soils are found in North America and some tropical regions of Africa (NRC, 2001; Rayburn, 2013). Normally, legumes have higher content than grasses. Since cobalt levels of the feed-stuffs are seldom known, a good practice is to feed trace mineralized salt that contains cobalt to sheep. Pregnant ewes require 5mg of copper (Cu) daily, which is the amount provided when the forage contains equal to or greater than 5 ppm (NRC, 2001).

Selenium is effective in at least partially controlling nutritional muscular dystrophy. The dietary requirement is 0.3ppm (NRC, 2001). Providing selenium-containing mineral mixture may prevent selenium deficiency if animals are allowed free access. Levels of 7–10 ppm or higher may be toxic. Growing lambs require 30ppm of zinc in the diet on a dry-matter basis. The requirement for normal testicular development is somewhat higher. Classic zinc deficiency (parakeratosis) is more common in other small ruminants (goats), but is occasionally encountered in sheep, particularly if fed excessive quantities of dietary calcium (legumes).

Sheep diets usually contain an ample supply of vitamins A (provitamin A), D, and E. Under certain circumstances, however, supplements may be needed. The B vitamins and vitamin K are synthesized by the rumen microorganisms and, under practical conditions, supplements are unnecessary. Sheep on diets rich in carotene, such as high-quality pasture or green hays can store large quantities of vitamin A in the liver, often sufficient to meet their requirements for as long as 6 months (NRC, 2001).

Vitamin D2 is derived from sun-cured forage, and vitamin D3 from exposure of the skin to ultraviolet light. When exposure of the skin to sunshine is reduced by prolonged cloudy weather or confinement rearing, and when the vitamin D2 content of the diet is low, the amount supplied may be inadequate (NRC, 2001; Rayburn, 2013). The requirement for vitamin D is increased when the amounts of either calcium or phosphorus in the diet are low or when the ratio between them is wide. But such dietary modification should be done cautiously, because vitamin D toxicity is a severe syndrome. Fast-growing lambs kept in sheds away from direct sunlight or maintained on green feeds (high carotene) during the winter months (low irradiation) may have impaired bone formation and show other signs of vitamin D deficiency. Normally, sheep on pasture seldom need vitamin D supplements (NRC, 2001).

The major sources of vitamin E in the natural diet of sheep are green feeds and the germ of seeds. Because vitamin E is poorly stored in the body, a daily intake is needed. When ewes are being fed poor-quality hay or forage, supplemental vitamin E may result in improved production, lamb weaning weights, and colostrum quality. Vitamin E deficiency in young lambs may contribute to nutritional muscular dystrophy, if selenium intake is low (NRC, 2001).

Water participates in nearly all body functions and is the most important "nutrient," though often times the most neglected aspect of feeding sheep. A sheep can drink from ½ to 4 gallons of water per day, depending on its physiological state and the environmental conditions. Voluntary water intake is usually 2 or 3 times dry matter intake and increases with high-protein and high-salt diets. Decreased water intake may reduce milk production in ewes and growth rates of lambs. Animals that consume adequate water have fewer digestive upsets and a lower incidence of urinary calculi (NRC, 2001).

A clean, fresh, easily accessible source of water should be available at all times. As a minimum requirement in tropical environments, the usual recommendations are 2gallons (8L) of water/day for ewes on dry feed in winter, 3gallons/day for ewes nursing lambs, and 1gallon/day for finishing lambs (NRC, 2001; Rayburn, 2013). However, under temperate conditions, sheep require just a half of what is required in the tropics. In many range areas, water is the limiting nutrient; even when present; it may be un-potable because of filth or high mineral content. For best production, all sheep should have their water availability monitored daily during all weather conditions. However, the cost of supplying water often makes it economical to water range sheep every other day. When soft snow is available, range sheep do not need additional water except when dry feeds such as alfalfa hay and pellets are fed. If the snow is crusted with ice, the crust should be broken to allow access. Still, when possible, sheep should have unlimited access to fresh, clean water (NRC, 2001).

NUTRIENT REQUIREMENTS OF GOATS

Goats are efficient browsers and prefer eating bushy plants along with some other woody shrubs found on the ranges (NRC, 2001). Goats are able to digest a large variety of fibre and roughage. The nutrient requirements of goats are determined by age, sex, breed, production system (dairy or meat), body size, climate and physiological stage. Feeding strategies should be able to meet energy, protein, mineral, vitamin and water needs depending on the condition of the goats.

The daily feed intake of goats range from 3-4% of body weight as expressed in kg of dry matter/head/day (NRC, 2001). The daily feed intake is influenced by body weight, percentage of dry matter in the feeds eaten (12-35% in forages, 86-92% in hays and concentrates), palatability, and physiological stage of the goats (growth, pregnancy, and lactation).

Sugars, starches (found in grains) and fibre (cellulose) are the carbohydrates that convert into volatile fatty acids (energy) by rumen flora (beneficial bacteria). Normal goat diet (browse, forage, and grasses) is high in cellulose and requires digestion by rumen flora to be converted into energy (NRC, 2001). Fresh pastures and young plants may have highly digestible fibre and provide high energy compared to older plants. Higher energy levels come from lower fibre feeds. Maintenance of at least 12% crude fibre in the diet of goats is recommended. The Energy required for maintaining different physiological stages such as pregnancy, lactation and growth vary. The maintenance requirement for energy remains the same for most goats except dairy kids; they require 21% energy, higher than the average. It is important to feed high energy rations at the time of breeding, late gestation and lactation. Lactating does have the highest energy demand (NRC, 2001).

Fats can also be a source of energy for goats. Goats do consume some amount of fats while browsing. Excess energy produced by carbohydrates is stored in the form of fat, especially around internal organs. The stored fat in the body is used during high energy needs, especially the lactation period. Supplying fats may not be a cost-effective idea for goat production (NRC, 2001).

Proteins are digested and broken down into amino acids and are eventually absorbed in the small intestine (NRC, 2001). The amino acids are building blocks for body proteins (muscles). The rumen plays a major role in breaking down consumed protein into bacterial protein through bacterial fermentation. Feeds like forages, hays, pellets, barley, peas, corn, oats, distilled grains and meals (soybean, groundnut, canola, cotton-seed meals) are common sources of protein for goat rationing. The protein requirements are higher during growth (kids), milk synthesis (lactation), and mohair growth. Producers may need to supplement protein sometimes during the year, especially in late fall or dry season. It is very important for a commercial goat operation to do cost-effective rationing as proteins can be an expensive feed ingredient. Good quality hay does not need much protein supplement for goats. If the hay has about 12-13% protein content, then provide ½ lb of protein source in the form of ground nut cake, soyabean and cotton seed meals (with 20% protein in total). In case the hay is of average quality, add one pound of protein as supplement (NRC, 2001).

Requirements for minerals have not been established definitively for goats at either maintenance or production levels. Feeding to meet the goat's needs will maximize its production, reproduction, and immune system (NRC, 2001). The addition of specific minerals (phosphorus for dry season forages, selenium in deficient areas, etc) to salt (NaCl), preferably in granular form and offered free-choice, helps prevent most mineral deficiencies and improves performance. Minerals can be classified as macro-and micro-minerals. Calcium, phosphorus, magnesium, sodium, potassium, sulfur and chlorides are a few of the macro-minerals needed in a goat’s diet. Micro-minerals usually supplemented in goat rations are iron, copper, cobalt, manganese, zinc, iodine, selenium, molybdenum, and others (NRC, 2001).

Calcium requirements are generally met under grazing conditions, but calcium levels should be checked for high producing dairy goats because deficiency can lead to reduced milk production (NRC, 2001). Adequate level of calcium for lactating goats is necessary to prevent parturient paresis (milk fever). In browsing or grain-fed goats, the addition of calcium supplements (di-calcium phosphate, limestone, etc) to the feed or to a salt or trace mineral salt mixture usually meets calcium requirements. Legumes (eg, clover, alfalfa, kudzu) are also good sources of calcium (NRC, 2001).

Phosphorus deficiency results in slowed growth, unthrifty appearance, and occasionally a depraved appetite (NRC, 2001). Goats can maintain milk production on phosphorus-deficient diets for several weeks by using phosphorus from body reserves, but during long periods of phosphorus deficiency, milk production was shown to decline by 60%. The calcium-phosphorus ratio should be maintained between 1:1 and 2:1, preferably 1.2–1.5:1 in goats because of their predisposition for urinary calculi. Phosphorus deficiency in grazing goats is more likely than a calcium deficiency. In cases of struvite calculi, the ratio should be maintained at 2:1 (NRC, 2001).

Magnesium deficiency is associated with hypomagnesemic tetany (grass tetany), but ordinarily this condition is less common in grazing goats than it is in cattle. Goats do have marginal ability to compensate for low magnesium by decreasing the amount of magnesium they excrete (NRC, 2001). Both urinary excretion and milk production are reduced in a magnesium deficiency (NRC, 2001).

Salt (NaCl) is usually recognized as a necessary dietary component but is often forgotten (NRC, 2001). Goats may consume more salt than is required when it is offered ad lib; this does not present a nutritional problem but may depress feed and water intakes in some arid areas where salt content of the drinking water is quite high. Salt formulations are used as carriers for trace minerals, because goats have a clear drive for sodium intake (NRC, 2001).

Potassium has an important role in metabolism. However, forages generally are quite rich in potassium, so a deficiency in grazing goats is extremely rare (NRC, 2001). Marginal potassium intake is seen only in heavily lactating does that its diets are composed predominantly of cereal grains. Excessive potassium intake (particularly in late gestation) may be associated with hypocalcemia in dairy goats. If hypocalcemia is a herd problem, attention should be paid to reducing or monitoring potassium-rich feed-stuffs (eg, alfalfa).

Iron deficiency is seldom seen in matured grazing goats. Such deficiency might be seen in young kids because of their minimal reserves at birth, plus the low iron content of the dam's milk (NRC, 2001). This is more commonly seen in kids fed in complete confinement and heavily parasitized animals. Iron deficiency can be prevented by access to pasture or a good quality trace mineral salt containing iron. In severe cases, and for kids reared in confinement, iron dextran injections at 2 to 3weeks intervals (150mg, IM) for the first few months may be curative. In the cases of mixed iron/selenium deficiencies, caution should be used when injecting iron dextrans until the selenium deficiency is also corrected. Conditional iodine deficiency may develop with normal to marginal iodine intake in goats consuming goitrogenous plants. Marked deficiency of iodine results in an enlarged thyroid, poor growth, small, weak kids at birth and poor reproductive ability (NRC, 2001).

Zinc deficiency results in parakeratosis, stiffness of joints, smaller testicles, and lowered libido. A minimal level of 10ppm of zinc in the diet, or a trace mineral salt mixture of 0.5–2% zinc, prevents deficiencies. Excessive dietary calcium (alfalfa) may increase the likelihood of zinc deficiency in goats (NRC, 2001).

Copper deficiency may result in microcytic anemia, poor production, lighter or faded hair color, poor fiber quality, infertility, poor health and slowed growth, some forms of metabolic bone disease, diarrhea, and possibly a greater susceptibility to internal parasites (NRC, 2001). Copper deficiency in a diet may be caused by inadequate copper intake, a lowered copper-molybdenum ratio, or excessive dietary sulfur. Goats appear to be much more resistant to copper toxicity than sheep (NRC, 2001).

Selenium deficiency in the diet is usually associated with nutritional muscular dystrophy, retained placentas and metritis, poor growth, weak or premature kids, and mastitis (NRC, 2001).

Goats need certain vitamins for their maintenance as well as proper functioning of their physiological systems. Feeding of fat-soluble vitamins (A, D, E, K) must be ensured in a goat's diet due to its inability to make these vitamins. Rumen flora can make vitamin B in enough quantities needed for goat metabolism. Vitamin C is essential for the immune system to work efficiently (NRC, 2001).

Goats should be provided with unlimited access to fresh, clean, non-stagnant sources of freely accessible water (NRC, 2001). Goats are among the most efficient domestic animals in their use of water; however, only 10% of body water loss may prove fatal. They appear to be less subject to high temperature stress than other species of domestic livestock. In addition to a lesser need for body water evaporation to maintain comfort in hot climates, goats can conserve body losses of water by decreasing losses in urine and feaces. Factors affecting water intake in goats include lactation, environmental temperature, water content of forage consumed, amount of exercise, stage of production (growth, maintenance, lactation, etc), and salt and mineral content of the diet. Goats grazing lush pastures may consume much lower volume of water than those feeding on dry hay. Still, it is imperative to allow free access to water for all goats regardless of age, breed, purpose, stage of life cycle, or environment (NRC, 2001).

Insufficient water intake will depress a goat's performance earlier, and more severely, than any other dietary insufficiency. Adequate water (4 – 8litters/day) is the paramount management concern. Goats should be consuming more water with high protein ration feedings. Decent water quality, not just quantity, is a must (NRC, 2001).

NUTRIENT REQUIREMENTS OF PIGS

Pigs need energy, amino acids, minerals, vitamins, and water for body maintenance, growth, reproduction, and lactation (NRC, 1998; 2001; 2012). Synthesis of muscle and adipose tissue, bone, hair, skin, and other body components, resulting in accretion of water, protein, lipid, and ash, is dependent upon an adequate dietary supply of nutrients. Pigs must be provided these essential nutrients in adequate amounts and in forms that are palatable and efficiently utilized in order for optimal growth, reproduction, and lactation to occur (NRC, 2001).
The profitability of a piggery business is very sensitive to the price of feeds used, the efficiency of the pig to convert feed into meat and the high market price at any particular time is paramount. To maximize profits, a delicate compromise must be reached between minimizing feed costs and maximizing pig meat returns (NRC, 2001).

Feed costs can vary between 55 and 70% of a piggery's total operating costs. Reducing feed costs by using poor quality diets may not be very economical, as feed usage would be higher and pig meat returns lower because of poor carcass grading. Using very high quality diets or severely restricting feed intake does not improve carcass quality and returns (NRC, 2001).

Energy requirements of pigs are influenced by their weight (which influences the maintenance requirement), their genetic capacity for lean tissue growth or milk production, and the environmental temperature at which they are housed (NRC, 1998; 2001; 2012). The amount of feed consumed by growing pigs allowed to consume feed ad lib is controlled principally by the energy content of the diet. If the energy density of the diet is increased by including supplemental fat, voluntary feed consumption decreases. Pigs fed such a diet, generally, will gain faster, and efficiency of gain will improve, but carcass fat may increase. If the diet contains excessive amounts of fiber greater than 5–7% without commensurate increases in fat, the rate, and especially the efficiency, of gain are decreased (NRC, 2001).

Amino acids are the chemical building blocks of protein (meat) and at least 20 different types occur in nature. A pig needs only eight or nine of these in its diet, that is, essential amino acids. The pig's body can synthesize the remaining 'non-essential' amino acids. When pigs are fed grain-based diets, several essential amino acids are likely to be deficient: lysine, threonine, methionine, tryptophan and isoleucine. As all amino acids must be present in their correct balance for protein synthesis to occur, the essential amino acid is in least supply. The most limiting amino acid determines the rate at which protein synthesis occurs (NRC, 2001).

Amino acids, normally supplied by dietary protein, are required for maintenance, muscle growth, development of foetuses and supporting tissues in gestating sows, and milk production in lactating sows. Of the 22 amino acids, 12 are synthesized by the animal; the other 10 must be provided in the diet for normal growth (NRC, 1998; 2001; 2012). The 10 dietary essential amino acids for swine are arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Cystine and tyrosine can meet a portion of the requirement for methionine and phenylalanine, respectively. The dietary lysine requirement during the early starter phase is quite high (1.70%) but decreases to 1.53 and 1.40% during the middle and final starter phases, respectively. The requirement continues to decrease throughout the growing to finishing stage from 1.12% during the early growing phase to 0.71% during late finishing (NRC, 2001).

The amino acids of greatest practical importance in diet formulation (ie, those most likely to be at deficient levels) are lysine, tryptophan, threonine, and methionine. Corn, the basic grain in most swine diets, is markedly deficient in lysine and tryptophan (NRC, 2001). The other principal grains for pigs (grain sorghum, barley, and wheat) are low in lysine and threonine. The first limiting amino acid in soybean meal is methionine, but sufficient amounts are provided when soybean meal is combined with cereal grains into a complete diet that meets the lysine requirement (NRC, 1998; 2001; 2012). An exception might be in young pigs that consume diets with high levels of soybean meal or diets containing dried blood products low in the sulfur-amino acids (NRC, 2001).

Milk protein is well balanced in essential amino acids but usually is too expensive to be used in swine diets, except for very young pigs. Dried whey, commonly used in starter diets, contains protein with an excellent profile of amino acids, but the total protein content of whey is low. Diets based on corn and animal-protein by-products (eg, meat meal, meat and bone meal) are inferior to corn-soybean meal diets, but they can be improved significantly by adding tryptophan or supplements that are good sources of tryptophan. Animal proteins are also good sources of minerals and B-complex vitamins (NRC, 2001).

Diets formulated for early weaned pigs that contain high levels of dried animal plasma or dried blood cells may be deficient in methionine. However, high levels of methionine can depress growth, so methionine should not be added indiscriminately to diets. Supplemental valine may be of value in corn-soybean meal diets fed to lactating sows, but it is still too expensive to be considered as a dietary supplement (NRC, 2001).

Lysine is, generally, the first limiting amino acid in almost all practical diets, so if diets are formulated on a lysine basis, the other amino acid requirements should be met (NRC, 2001). However, caution must be exercised when a crystalline lysine supplement is included in the diet to meet a portion of the pig’s lysine requirement (NRC, 1998; 2001; 2012). A general rule of thumb is that, crude protein content can be reduced by 2% points and the diet supplemented with 0.15% lysine (0.19% lysine•HCl). However, greater reductions in dietary protein coupled with additional lysine may result in deficiencies of tryptophan, threonine, and/or methionine, unless they are also supplemented (NRC, 2001).

It is quite common today to formulate swine diets based on the concept of “ideal” protein; ie, to express essential amino acid requirements as a percent of the lysine requirement (NRC, 1998; 2001; 2012). Additionally, it is becoming more popular to formulate swine diets on the basis of standardized (or true) or apparent digestible amino acids. This method is particularly advantageous when substantial amounts of by-product feeds are included in the diet (NRC, 2001).

Minerals are essential compounds that provide the elements used to maintain the animal's bone structure and regulate many biochemical processes (NRC, 1998; 2001; 2012). The main mineral elements in diet formulation, considered individually, are sodium, calcium and phosphorus. Iron, zinc, copper and manganese are also required but only in trace amounts. Usually, these trace elements are added to the diet as a mineral premix (NRC, 2001).

Calcium and phosphorus, although used primarily in skeletal growth, they play important metabolic roles in the body and are essential for all stages of growth, gestation, and lactation. Growing pigs of 25–50kg body wt require 0.66% calcium and 0.56% total phosphorus (NRC, 2001). The requirements are higher for younger pigs and lower for finishing pigs, but the ratios of calcium: phosphorus is approximately the same for all weight groups (NRC, 1998; 2001; 2012). These levels are adequate for maximal growth (rate and efficiency of gain), but they do not allow for maximal bone mineralization. Generally, maximal bone ash and strength can be achieved by including 0.1–0.15% additional calcium and phosphorus in the diet (NRC, 2001).

For gestating and lactating sows, calcium and phosphorus requirements are influenced by stage of gestation (the first 90 days versus the final 25 days of gestation), parity, milk production, and other factors (NRC, 2001). The higher requirements during late gestation are attributed to rapid development of the fetuses. Swine producers may choose to feed slightly higher levels to sows to ensure adequacy of these minerals and to prevent posterior paralysis in heavy milking sows. If less feed is consumed per day, the percentages of calcium and phosphorus may need to be adjusted upward (NRC, 2001).

Most of the phosphorus in cereal grains and oil-seed meals is in the form of phytic acid (organically bound phosphorus) and is poorly available to pigs, whereas the phosphorus in protein sources of animal origin, such as meat meal, meat and bone meal, and fish meal, is in inorganic form and is highly available to pigs (NRC, 1998; 2001; 2012). Even in cereal grains, availability of phosphorus varies. For example, the phosphorus in corn is only 10–20% available, whereas the phosphorus in wheat is 50% available. Therefore, swine diets should be formulated on an "available phosphorus" basis to ensure that the phosphorus requirement is met (NRC, 2001).

Phosphorus supplements such as monocalcium or dicalcium phosphate, defluorinated phosphate, and steamed bone meal are excellent sources of highly available phosphorus (NRC, 2001). These supplements also are good sources of calcium. Ground limestone also is an excellent source of calcium. Phosphorus is considered a potential environmental pollutant, so many swine producers feed diets with less excess phosphorus than in the past to reduce phosphorus excretion (NRC, 1998; 2001; 2012). Supplemental phytase, an enzyme that degrades some of the phytic acid in feed-stuffs, is commonly added to diets to further reduce phosphorus excretion. The general recommendation is that, dietary calcium and phosphorus can both be reduced by 0.05–0.1% when ≥500 units of phytase per kg of diet are included (NRC, 2001).

These minerals are provided by common salt, which contains 40% sodium and 60% chloride. The recommended level of salt is 0.25% in growing and finishing diets, 0.5–0.75% in starter diets, and 0.5% in sow diets (NRC, 1998; 2001; 2012). These levels should provide ample sodium and chloride to meet the animal's requirements. Animal, fish, and milk by-products can contribute some of the sodium and chloride requirements (NRC, 2001).

Practical diets contain ample amounts of these minerals from the grain and protein sources, and there, supplemental sources are not needed. Magnesium oxide supplementation has been used to prevent cannibalism, but controlled studies do not support this practice (NRC, 2001).

Iron and Copper are involved in many enzyme systems. Both are necessary for formation of haemoglobin and, therefore, for prevention of nutritional anemia. Since the amount of iron in milk is very low, suckling pigs should receive supplemental iron; preferably by IM injection of 100–200 mg in the form of iron dextran, iron dextrin, or gleptoferron during the first 3 days of life (NRC, 1998; 2001; 2012). Giving oral or injectable iron and copper to sows will not increase piglet stores at birth nor will it increase the iron in colostrum and milk sufficiently enough to prevent anemia in neonatal pigs. High levels of iron in lactation feed results in iron-rich sow feces that pigs can obtain from the pen. Iron can also be supplied by mixing ferric ammonium citrate with water in a piglet waterer or by frequently placing a mixture of iron sulfate and a carrier, such as ground corn, on the floor of the farrowing stall (NRC, 2001).

The copper requirements for growing pigs is low (3–6 ppm) but higher for sows. Copper at pharmaceutical levels in the diet (100–250 mg/kg) is an effective growth stimulant for weaning and growing pigs (NRC, 1998; 2001; 2012). The action of copper at high levels appears to be independent of, and additive to, the growth-stimulating effect of antibiotics. Copper sulfate at high levels in the diet results in very dark-colored feces. Also, high copper diets result in marked increases in the copper content of excreted manure (NRC, 2001).

The thyroid gland uses iodine to produce thyroxine, which affects cell activity and metabolic rate. The iodine requirement of all classes of pigs is 0.14 mg/kg of diet. Stabilized iodized salt contains 0.007% iodine; when it is fed at sufficient levels to meet the salt requirement, it will also meet the iodine needs of pigs (NRC, 2001).

Manganese, although essential for normal reproduction and growth, the quantitative requirement for manganese is not well defined. Manganese at 2–4 mg/kg in the diet is adequate for growth, but a higher level (25 mg/kg) is needed by sows during gestation and lactation (NRC, 2001).

Zinc is an important trace mineral with many biologic functions. Grain-soybean meal diets must contain supplemental zinc to prevent parakeratosis. Higher levels of zinc may be needed when dietary calcium is excessive, especially in diets typically high in phytic acid, such as corn-soybean meal diets (NRC, 2001). Pharmacologic levels of zinc (1,500–3,000 mg/kg) as zinc oxide have consistently been found to increase pig performance during the post weaning period. In some instances, high levels of zinc oxide have been reported to reduce the incidence and severity of post weaning diarrhea (NRC, 1998; 2001; 2012). Responses to zinc oxide and antibiotics seem to be additive in nature, much like the responses to high copper and antibiotics; however, there is no advantage to including high copper and high zinc in the same diet. Similar to copper, high levels of dietary zinc causes increased zinc content in the excreted manure. For sows, zinc requirements should be from 50 ppm to 100 ppm (NRC, 2001).

The selenium content of soils, and ultimately crops, is quite variable. In the USA, areas west of the Mississippi River, generally contain higher amounts of selenium, whereas areas east of the river tend to yield crops deficient in selenium (NRC, 1998; 2001; 2012). Under most practical conditions, 0.2–0.3 mg of added selenium/kg of diet should meet the requirements. This trace mineral is regulated by the FDA, and the maximal amount of selenium that can be added to swine diets is 0.3 mg/kg (NRC, 2001).

Chromium is a co-factor with insulin, it is required by pigs, but the quantitative requirement has not been established. In some studies, chromium at a supplemental level of 200 mcg/kg (ppb) improved carcass leanness in finishing pigs and improved reproductive performance in gestating sows, but these effects have been somewhat inconsistent (NRC, 2001).

Cobalt is present in the vitamin B12 molecule and has no benefit when added to swine diets in the elemental form (NRC, 2001).

Vitamin A is a fat-soluble vitamin and essential for vision, reproduction, growth and maintenance of epithelial tissue, and mucous secretions. Vitamin A is found as carotenoid precursors in green plant material and yellow corn (NRC, 1998; 2001; 2012). β-Carotene is the most active form of the various carotenes. Unfortunately, only about one-fourth of the total carotene in yellow corn is in the form of β-carotene. It has been suggested that for pigs, 1mg of chemically determined carotene in corn or a corn-soybean mixture is equal to 267 IU of vitamin A (NRC, 2001).

The use of stabilized vitamin A is common in manufactured feeds and in vitamin supplements or premixes. Concentrates containing natural vitamin A (fish oils most often) may be used to fortify diets (NRC, 2001). Green forage, dehydrated alfalfa meal, and high-quality legume hays are also good sources of β-carotene. Both natural vitamin A and β-carotene are easily destroyed by air, light, high temperatures, rancid fats, organic acids, and certain mineral elements (NRC, 1998; 2001; 2012). For these reasons, natural feed-stuffs probably should not be entirely relied upon as sources of vitamin A, especially because synthetic vitamin A is very inexpensive. An international unit of vitamin A is equivalent to 0.30 mcg of retinol or 0.344 mcg of retinyl acetate (NRC, 2001).

Vitamin D also antirachitic, fat-soluble vitamin is necessary for proper bone growth and ossification. Vitamin D occurs as the precursor sterols, ergocalciferol (vitamin D2) and cholecalciferol (vitamin D3), which are converted to active vitamin D by UV radiation. Although pigs can use vitamin D2 (irradiated plant sterol) or vitamin D3 (irradiated animal sterol), they seem to preferentially use D3 (NRC, 2001). Some of the vitamin D requirement can be met by exposing pigs to direct sunlight for a short period each day (NRC, 1998; 2001; 2012). Sources of vitamin D include irradiated yeast, sun-cured hays, activated plant or animal sterols, fish oils, and vitamin premixes. For this vitamin, 1 IU is equivalent to 0.025mg of cholecalciferol. The estimated vitamin D requirement of 200 IU/kg for gestating and lactating sows has recently been increased to 800 IU/kg (NRC, 2001).

Vitamin E, also a fat-soluble vitamin, serves as a natural antioxidant in feed-stuffs. There are eight naturally occurring forms of vitamin E, but d-α-tocopherol has the greatest biologic activity (NRC, 1998; 2001; 2012). Vitamin E is required by pigs of all ages and is closely interrelated with selenium. The vitamin E requirement is 11–16 IU/kg of diet for growing pigs and 44 IU/kg for sows. Some nutritionists recommend higher dietary levels for sows in the eastern corn belt of the USA, where selenium levels in feeds are likely to be low. Vitamin E supplementation can only partially obviate a selenium deficiency (NRC, 2001).

Green forage, legume hays and meals, cereal grains, and especially the germ of cereal grains contain appreciable amounts of vitamin E. Activity of vitamin E is reduced in feed-stuffs when exposed to heat, high moisture conditions, rancid fat, organic acids, and high levels of certain trace elements. One IU of vitamin E activity is equivalent to 0.67mg of d-α-tocopherol or 1mg of dl-α-tocopherol acetate (NRC, 2001).

Vitamin K, also a fat-soluble vitamin, is necessary to maintain normal blood clotting. The requirement for vitamin K is low, 0.5mg/kg of diet. Bacterial synthesis of the vitamin and subsequent absorption, directly or by coprophagy, will generally, meet the requirements for pigs (NRC, 1998; 2001; 2012). Although rare, hemorrhages have been reported in newborn as well as growing pigs, so supplemental vitamin K is recommended at 2mg/kg of diet as a preventive measure. Generally, hemorrhaging problems can be traced back to the feeding of diets with moldy grain or other ingredients that contain molds (NRC, 2001).

Riboflavin water-soluble vitamin is a constituent of two important enzyme systems involved with carbohydrate, protein, and fat metabolism. Swine diets are normally deficient in this vitamin, and the crystalline form is included in premixes. Natural sources include green forage, milk by-products, brewer's yeast, legume meals, and some fermentation and distillery by-products (NRC, 2001).

Niacin (Nicotinic acid) is a component of coenzymes involved with metabolism of carbohydrates, fats, and protein. Pigs can convert excess tryptophan to niacin, but the conversion is inefficient (NRC, 1998; 2001; 2012). The niacin in most cereal grains is completely unavailable to pigs. Swine diets are normally deficient in this vitamin, and the crystalline form is included in premixes. Natural sources of niacin include fish and animal by-products, brewer's yeast, and distiller's solubles. Niacin requirement of pigs has also been 30ppm during all phases of growth (NRC, 2001).

Pantothenic Acid is a component of coenzyme A, an important enzyme in energy metabolism. Swine diets are deficient in this vitamin, and the crystalline salt, d-calcium pantothenate, is included in vitamin premixes. Natural sources of pantothenic acid include green forage, legume meals, milk products, brewer's yeast, fish solubles, and certain other by-products (NRC, 2001).

Vitamin B12, also called cyanocobalamin, contains cobalt and has numerous important metabolic functions. Feed-stuffs of plant origin are devoid of this vitamin, but animal products are good sources. Although some intestinal synthesis of this vitamin occurs, vitamin B12 is generally included in vitamin premixes for swine (NRC, 2001).

Thiamine has important roles in the body, but it is of little practical significance for swine because grains and other feed ingredients supply ample amounts to meet the requirement in pigs (NRC, 2001).

Vitamin B6 group of compounds called the pyridoxines are important in amino acid metabolism. They are present in plentiful quantities in the natural feed ingredients usually fed to pigs. The requirement for vitamin B6 in young pigs (5–25 kg) has been increased by 3–4 folds (NRC, 2001).

Choline is essential for the normal functioning of all tissues. Pigs can synthesize some choline from methionine in the diet (NRC, 2001). Sufficient choline is found in the natural dietary ingredients to meet the requirements of growing pigs. However, in some studies, choline supplemented at 440–800mg/kg of diet increased litter size in gilts and sows. Natural sources of choline include fish solubles, fish meal, soybean meal, liver meal, brewer's yeast, and meat meal. Choline chloride, which is 75% choline, is the common form of supplemental choline used in feeds. If choline is added as a supplement to sow diets, it should not be combined with other vitamins in a premix, especially if trace minerals are present, because choline chloride is hygroscopic and destroys some of the activity of vitamin A and other less stable vitamins (NRC, 2001).

Biotin is present in a highly available form in corn and soybean meals, but the biotin in grain sorghum, oats, barley, and wheat is less available to pigs (NRC, 2001). There is evidence that, when these latter cereal grains are fed to swine, especially breeding animals, biotin may be marginal or deficient. Reproductive performance in sows has been found to improve with biotin additions (NRC, 1998; 2001; 2012). Although not as clear, there is evidence that, reproductive performance is also improved with addition of biotin to corn-soybean meal diets. In some instances, biotin supplementation decreases foot-pad lesions in adult pigs. For insurance, biotin supplementation is recommended, especially for sow diets. Raw eggs should not be fed to pigs because egg white contains avidin, a protein that complexes with biotin and renders it unavailable (NRC, 2001).

Sufficient folacin is present in natural feed-stuffs to meet the requirements for growth, but some studies have shown a benefit in litter size when folic acid was added to sow diets (NRC, 2001). Ascorbic Acids (Vitamin C) are thought to be synthesized at a rapid enough rate to meet their needs under normal conditions. However, a few studies have shown benefits in performance of early-weaned pigs under stressful conditions when this vitamin was added to their diet.

Linoleic acid, arachidonic acid, and probably other long-chain, polyunsaturated fatty acids are required by pigs. However, the longer chain fatty acids can be synthesized in-vivo from linoleic acid, so linoleic acid is considered the dietary essential fatty acid. The estimated linoleic acid requirement of growing and breeding swine is 0.1% (NRC, 2001). The requirement is generally met by the fats present in natural dietary ingredients. The oil in corn is a rich source of linoleic acid (NRC, 2001).

Pigs should have free and convenient access to water, beginning before weaning. The amount required varies with age, type of feed, environmental temperature, status of lactation, fever, high urinary output (as from high salt or protein intake), or diarrhea. Normally, growing pigs consume 2–3kg of water for every kg of dry feed. Lactating sows consume more water because of the high water content of the milk they produce. Water restriction reduces performance and milk production and may result in death, if the restriction is severe (NRC, 2001).

NUTRIENT REQUIREMENTS OF POULTRY

Poultry means any member of the domesticated and commercialized types of birds used for production of eggs and or meat for human food and also for other purposes. For example, breed of poultry include chickens, guinea fowls, turkeys, pigeons, peafowls, ducks, geese, upland game birds (quails, pheasants, partridges) and ratites (ostriches, emu), canaries, parrots and pea-cocks. Chickens, turkeys and laying hens have been commercially produced in confinement system for more than 70 years (NRC, 1994).

Poultry convert feed into food products quickly, efficiently, and with relatively low environmental impact compared with other livestock. The high rate of productivity of poultry results in relatively high nutrient needs. Poultry require the presence of at least 38 dietary nutrients in appropriate concentrations and balance. Criteria used to determine the requirement for a given nutrient include growth, feed efficiency, egg production, prevention of deficiency symptoms, and quality of poultry products. These requirements assume the nutrients are in a highly bio-available form, and they do not include a margin of safety (NRC, 1994). Consequently, adjustments should be made based on bio-availability of nutrients in various feed-stuffs. A margin of safety should be added based on the length of time the diet will be stored before feeding, changes in rates of feed intake due to environmental temperature or dietary energy content, genetic strain, husbandry conditions (especially the level of sanitation), and the presence of stressors (such as diseases or mycotoxins).

Feed cost is the largest single item in poultry production and accounts for 60 to75% of the total production cost from hatching eggs to processing plant. Much emphasis has been placed on least-cost feed formulation and getting the lowest feed cost per unit of salable product. All these efforts led to steady improvements in growth rate, feed conversion, and survival under intensive commercial conditions (NRC, 1994).Poultry can adjust their feed intake over a considerable range of feed energy levels to meet their daily energy needs. Energy needs and, consequently, feed intake also vary considerably with environmental temperature and amount of physical activity. A bird's daily need for amino acids, vitamins, and minerals are mostly independent of these factors (NRC, 1994). If a bird consumes a diet that has a higher energy content, it will decrease its feed intake; consequently, that diet must contain a proportionally higher amount of amino acids, vitamins, and minerals. Thus, nutrient density in the ration should be adjusted to provide appropriate nutrient intake based on requirements and the actual feed intake. It is impossible to set the energy requirements in terms of unit/kg diet because birds adjust their feed intake to achieve their daily energy intake (NRC, 2001).

Applegate and Angel (2014) also stated that, poultry, like all animals, synthesize proteins that contain 20 amino acids. Birds are unable to synthesize 9 of these amino acids because of the lack of specific enzymes: arginine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Histidine, glycine, and proline can be synthesized by birds, but the rate is usually insufficient to meet metabolic needs, hence a dietary source is required. These 12 amino acids are referred to as the essential amino acids. Tyrosine and cysteine can be synthesized from phenylalanine and methionine, respectively, and are referred to as being conditionally essential because they must be in the diet if phenylalanine or methionine levels are inadequate. The diet must also supply sufficient amounts of nitrogen to allow the synthesis of non-essential amino acids (NRC, 1994). Essential amino acids are often added to the diet in purified form (eg, methionine and lysine) to minimize the total protein level as well as the cost of the diet. This has the added advantage of minimizing nitrogen excretion (NRC, 2001).

Dietary energy content must be specified to maintain the proper ratio of protein to energy so that birds can consume an adequate amount of protein (NRC, 1994). The protein requirement or amino acid requirements can be defined accurately only in relation to the energy density. Also, the degree of fat deposition in meat producing birds can be affected by this relationship (Applegate & Angel, 2014).

Methionine would be the first limiting amino acid in grain and soybean meal diets, but lysine is likely to become the first limiting amino acid if soybean meal is replaced by another plant protein supplement such as cotton-seed meal (Applegate & Angel, 2014).Much of the phosphorus in feed-stuffs of plant origin is complexes by phytate which is not absorbed efficiently by poultry. Consequently, it is critical that only the available phosphorus and not the total phosphorus levels that are considered in poultry feed formulation. Appropriate calcium nutrition depends on both the level of calcium and its ratio to that of available phosphorus. For growing poultry, this ratio should not deviate substantially from 2:1. The calcium requirement of laying hens is very high and increases with the rate of egg production and age of the hen (NRC, 2001; Olawoye & Kubkomawa, 2018a).

Although it is not easy to ascertain the exact calcium requirements for poultry, care should be taken to avoid adding a generous amount because excess calcium interferes with utilization of potassium, magnesium, manganese and zinc which can reduce palatability of the diet. The use of phytase in poultry diets has been increasing in recent years (NRC, 2001).
Requirements for vitamins A, D, and E are expressed in IU (Applegate & Angel, 2014). For chickens, 1 IU of vitamin A activity is equivalent to 0.3mcg of pure retinol, 0.344mcg of retinyl acetate, or 0.6mcg of β-carotene. However, young chicks use β-carotene less efficiently. One IU of vitamin D is equal to 0.025mcg of cholecalciferol (vitamin D3). Ergocalciferol (vitamin D2) is used with an efficiency of <10% of vitamin D3 in poultry (NRC, 2001).

One IU of vitamin E is equivalent to 1mg of synthetic dl-α-tocopherol acetate. Vitamin E requirements vary with type and level of fat in the diet, the levels of selenium and trace minerals, and the presence or absence of other antioxidants. When diets high in long-chain highly polyunsaturated fatty acids are fed, vitamin E levels should be increased considerably (Applegate & Angel, 2014).

Choline is required as an integral part of the body phospholipid, as a part of acetylcholine, and as a source of methyl groups (NRC, 1994). Growing chickens can also use betaine as a methylating agent. Betaine is widely distributed in practical feed-stuffs and can spare the requirement for choline but cannot completely replace it in the diet (Applegate & Angel, 2014). All vitamins are subject to degradation over time, and this process is accelerated by moisture, oxygen, trace minerals, heat, and light. Stabilized vitamin preparations and generous margins of safety are often applied to account for these losses. This is especially true if diets are pelleted, extruded, or stored for long periods (NRC, 2001).

Vitamin and trace mineral supplementation do not contribute much to the overall feed cost, but play major roles in the metabolic functions of poultry (Applegate & Angel, 2014). Due to variations in the content, availability and stability, premixes are formulated to assure adequacy, rather than just satisfying the NRC recommendations. Vitamin D is expressed in ICU, which are based on the activity of vitamin D3 because birds do not use vitamin D2. (Turkeys are especially sensitive). Vitamin E requirements vary greatly depending on dietary lipids and antioxidants (NRC, 2001).

Folacin and biotin are now added to some turkey diets to prevent deficiency. Niacin may be required for laying and breeding hens but, the requirement is so low that, it will always be exceeded by natural feed ingredients (NRC, 2001). Water is an essential nutrient (NRC, 1994). Many factors influence water intake, including environmental temperature, relative humidity, salt and protein levels of the diet, birds' productivity (rate of growth or egg production), and the individual bird's ability to re-absorb water in the kidney (Applegate & Angel, 2014). As a result, precise water requirements are highly variable. Water deprivation for ≥12 hours has an adverse effect on growth of young poultry and egg production of layers; water deprivation for ≥36 hours results in a marked increase in mortality of both young and mature poultry. Cool, clean water, uncontaminated by high levels of minerals or other potential toxic substances, must be available at all times (NRC, 2001). Non-nutrient antioxidants, such as ethoxyquin, are usually added to poultry diets to protect vitamins and unsaturated fatty acids from oxidation. Antibiotics at low levels (5–25 mg/kg of feed, depending on the antibiotic) and surfeit copper (150 ppm) are sometimes included to improve growth rate and feed efficiency (Applegate & Angel, 2014). Enzymes that increase the bio-availability of dietary phosphorus, energy, and protein are often used in poultry diets when their costs are not prohibitive. In some cases, phytase enzymes are used to decrease the amount of phosphorus in the excreta to meet environmental regulations. Since 1950 or so, several antibiotics have become important additives in broiler and turkey feeds, to improve growth rate and feed efficiency. Also, egg production may be improved with dietary supplementation (NRC, 2001).

NUTRIENT REQUIREMENTS OF RABBITS

According to NRC (2001) and Amy (2010), rabbits are small herbivores with specialized feeding needs and digestive systems. They are selective eaters and choose feed rich in leaves and new plant shoots over mature plant materials that are higher in fiber. Rabbits are, therefore, considered concentrate selectors, because they, naturally, pick and choose foods higher in energy density, which predisposes them to obesity. Anatomically, rabbits are non-ruminant herbivores with an enlarged hind-gut. The large caecum supports a population of micro-organisms that use nutrients not digested in the small intestine. Most of the bacterial population in the caecum is made up of the gram-positive Bacteroides sp. This makes the rabbit very sensitive to oral antibiotics; as administration of oral antibiotics can disturb the bacteroides population and lead to fatal gastro intestinal (GI) upsets (Amy, 2010).

Separation of digesta on the basis of particle size occurs in the hindgut. Peristaltic action rapidly moves large particles (>0.5mm), primarily lignocellulose, through the colon and excretes them as hard fecal pellets (Amy, 2010). This is the "indigestible fiber" component of the diet. The clinical importance of a diet high in long particle length is to maintain the motility of the caecum and colon (NRC, 2001; Olawoye & Kubkomawa, 2018a). This is why these fibers are sometimes referred to as "scratch factor," because they mechanically stimulate GI motility. Anti-peristaltic action moves smaller particles (<0.3mm) and soluble materials into the caecum, where they undergo fermentation. This component of the diet is known as "digestible" or "fermentable" fiber (Amy, 2010). At intervals, the cecal contents are expelled as “soft faeces” or cecotrophs and again, consumed by the rabbit directly from the anus. Cecotroph ingestion is highest when rabbits are fed a diet high in non-digestible fiber. This re-ingested materials provide microbial protein, vitamins (including all the B vitamins needed), and small quantities of volatile fatty acids, which are essential in rabbit nutrition. However, because amino acids obtained in this manner make only a minor contribution to the rabbits’ protein needs (particularly young, growing rabbits), the diet must supply the additional amino acids, although the requirements for essential amino acids in rabbits have not yet been defined (NRC, 2001).

Rabbits digest fiber poorly because of the selective separation and rapid excretion of large particles in the hind-gut. A generous amount of dietary fiber (15% crude fiber) is needed to promote intestinal motility and minimize intestinal disease (NRC, 2001; Olawoye & Kubkomawa, 2018a). High-fiber intake can be provided by use of ad lib hay (30–35% fiber). Fiber may also absorb bacterial toxins and eliminate them via the hard feces. Diets low in fiber promotes an increased incidence of intestinal problems, eg, enterotoxemia. Carbohydrates will actually inhibit motilin release (Amy, 2010). Motilin is a polypeptide hormone secreted by cells of the duodenum and jejunum, which stimulates the GI smooth muscle. Excess starch can also be substrate for the proliferation of pathogenic bacteria, such as Clostridium spiroforme, which produce a potent toxin. Caecum fermentation produces volatile fatty acids, which are responsible for 40% of the rabbits' calorie requirements. Volatile fatty acids also aid in the control of pathogenic organisms by helping to maintain the normal pH (6–7) in the caecum (NRC, 2001).

All animals including rabbits require six classes of nutrients which are carbohydrates, proteins, minerals, vitamins and water. Often, energy is confused for a nutrient, but energy itself is not a nutrient. Energy (measured by calories) is provided in majority in the diet by carbohydrates and fats (NRC, 2001).

Carbohydrates are the major components of plant materials. The varied carbohydrates found in plant materials are categorized based on their structure and how they are utilized in the body. Carbohydrate types include sugars, starches and fiber (Amy, 2010). Some carbohydrates, such as simple sugars, are easily digested in the mammal's gastro-intestinal tract. Starches make up a large proportion of seeds, grains, and tubers. Starches are used for energy storage in plants and provide an energy source to animals. Some starches are digested by mammalian enzymes (NRC, 2001).

Fiber is composed of carbohydrates found in plant material that are not digestible by mammalian enzymes. Fiber is broken down only in the gastro-intestinal tract. Bacteria found in high concentrations in certain organs in the tract, such as the caecum of the rabbit, break down fiber. Bacteria are able to digest or ferment the soluble fiber fraction and are not capable of fermenting the insoluble fiber fraction (NRC, 2001). Soluble fiber serves as a key energy source to the bacteria and results in increased bacterial cell growth. The breakdown of soluble fiber by the bacteria results in the release of short chain fatty acids (SCFA). These SCFAs are then used by intestinal cells for energy, providing health benefits that can lower the risks or symptoms of some diseases, such as colon cancers or gastro-intestinal disease (Amy, 2010). Insoluble fiber, on the other hand, is not able to be fermented and is passed in the stool. Insoluble fiber plays an important role in facilitating feed movement through the gastrointestinal tract, improves satiety (feeling full after a meal), and prevents constipation (NRC, 2001).

Rabbits require high amounts of fiber in their diet to prevent gastro-intestinal disease and to provide a substrate for fermentation in the cecum to produce bacterial cells which serve as a source of protein and B vitamins (Amy, 2010). Rabbit diets should, therefore, contain a minimum of 14% fiber, the percentage may be higher in the diet of adult rabbits (NRC, 2001).

Fats are organic compounds that are insoluble in water and serve several important functions in the body. Fats supply energy, provide essential fatty acids, carry fat-soluble vitamins, and are an important part of cell membranes. Rabbits have relatively low fat requirements. Rabbit diets should contain around 3% fat, but can have slightly higher fat levels during lactation (Amy, 2010). Vegetable oils in the diet provide fatty acids that can improve the sheen (glossiness) of the rabbit's coat. For show rabbits, supplementing the diet with small amounts of vegetable oil (a teaspoon or less) can improve their appearance for show. Fats also increase the energy content of the diet without adding simple carbohydrates that can have negative effects in the gastro-intestinal tract. However, it is good to limit the amount of fat in rabbit's diet to prevent obesity. Obesity can cause health problems and decrease reproductive performance of rabbits (NRC, 2001).

Proteins are compounds comprised of amino acids. They make up an animal's DNA and enzymes. Proteins play a role in most cellular functions (Amy, 2010). In addition, proteins have an important structural role in the body. They make up muscle, hair, toe-nails, and skin. Animals require proteins in the diet for both essential and non-essential amino acids. Examples of essential amino acids for rabbits are lysine, methionine, valine, leucine, and isoleucine (NRC, 2001).

Rabbits use lower quality proteins than humans. Bacteria in a rabbit's colon produce protein (in the form of more bacterial cells), which the rabbit can use to meet its nutrient needs by practicing cecotrophy (consumption of selected stools rich in protein and bacterial cells). A rabbit's protein requirements increase during times of growth, pregnancy, or lactation (milk production). Protein needs are lowest for adults at maintenance. During this time, excess protein can cause a rabbit's kidneys to overwork to filter out waste products caused by protein breakdown in the body (NRC, 2001).

Rabbits require about 22 different inorganic elements, known as minerals, in the diet. These may be required in relatively large amounts (macro-minerals) or relatively small amounts (micro-minerals or trace minerals). The macro-minerals include calcium, phosphorus, sodium, chlorine, potassium, magnesium, and sulfur. Minerals have different functions in the body. Calcium and phosphorus are particularly important for their role in skeletal structure (NRC, 2001).

Calcium and phosphorus are important minerals to consider in the rabbit's diet. Consider both the amount of each of these minerals in the diet and the ratio of calcium to phosphorus in the diet (Amy, 2010). During growth and reproduction, the ideal ratio is 2:1; while at maintenance, rabbits can utilize a lower calcium-to-phosphorus ratio. The ideal levels of these minerals are affected by the life stage of rabbits (NRC, 2001). During growth, development and pregnancy, rabbits need higher levels of calcium and phosphorus to allow for bone development. Adult rabbits at maintenance, require lower levels of calcium and phosphorus than at other life stages. They are able to absorb adequate amounts from the diet, and any excess consumed is filtered out by the kidneys and excreted in the urine. You may notice a white substance in the rabbit's urine; this is excess calcium. If calcium levels are too high for too long, rabbits may develop kidney damage and urinary stones (NRC, 2001).

The ingredients used in commercial rabbit feeds should provide ample amounts of these minerals. Calcium is provided from alfalfa and alfalfa meal in the pelleted diet. Phosphorus is generally provided by grain by-products, such as wheat bran or wheat middlings. Provide no additional calcium or phosphorus in the diet. Grass hay is lower in calcium than alfalfa, making it more ideal for a companion rabbit diet. In addition, a high-quality diet provides all the needed minerals, so that, a salt or trace mineral lick is not required (NRC, 2001).

Rabbits, like humans, require a number of different vitamins (Amy, 2010). These vitamins can be divided into the fat-soluble vitamins (A, D, E, and K) and the water-soluble vitamins (B complex and C). Vitamins are required in small amounts by the body, and each one has its own function in the body. Lack of any one vitamin in the diet can cause deficiency symptoms or illness, while excesses of some vitamins can also be toxic (NRC, 2001).

Meeting the rabbit's vitamin needs is relatively easy with a good quality diet. Rabbits meet their B complex vitamin and vitamin K needs through cecotrophy. These vitamins are produced by the bacterial populations in the ceacum of the rabbit. By selectively eating the ceacal pellet produced by the bacteria, the rabbit is provided all the vitamins it needs. Often, these vitamins may also be found in commercial diets for rabbits (NRC, 2001).

Vitamins A, D, and E should be provided in the diet (Amy, 2010). The rabbit's requirements for vitamin D and E appear to be low and are met with a good quality diet. The appropriate vitamin A content of a diet depends on the life stage of the rabbit. Both deficiency and an excess of vitamin A result in similar signs causing poor reproductive performance (Amy, 2010). These symptoms in breeding rabbits include low conception rate, low survival rate of offspring, and fluid on the brain of the offspring (hydrocephalus). Toxicity may occur if vitamin A is supplemented to a high alfalfa diet because alfalfa contains large amounts of beta-carotene which is a vitamin A precursor. If multiple cases of hydrocephalus is noticed in breeding herd, carry out a veterinarian test of liver and diet vitamin A levels, to determine whether there is an excess or a deficiency. Choosing the appropriate diet for the life stage of rabbits will prevent vitamin imbalances. Consult a veterinarian before adding any supplemental vitamins to the diet (NRC, 2001).

Water is a critical nutrient that many people overlook. Water makes up more than half of the body mass of a rabbit (NRC, 2001). An animal's water requirements change depending on environmental temperature, humidity, and activity level, among other factors. A typical rabbit may consume approximately 10ml of water per 100g of body weight (8 teaspoons of water per pound of body weight). This means that a 2kg rabbit consumes at least 40 teaspoons of water a day. This is a very high water intake for an animal of this size. Water must be available at all times for the rabbit to reach this intake level. Nursing rabbits require an even higher water intake to meet with the needs for milk production (NRC, 2001).

Insufficient water intake can lead to dehydration in rabbits. Rabbits may pull water from their gastro-intestinal tract to prevent cellular dehydration (Amy, 2010). This result in drier than normal gastro-intestinal tract contents, which can cause blockages or gastro-intestinal stasis, conditions that can be fatal to rabbits. In addition, rabbits with lowered water intakes may be more likely to develop urinary stones or crystals (NRC, 2001).

Rabbits get some water from the food they consume. If commercial feed is used, this tends to be low in water, supply water in a bowl or bottle to meet rabbit's needs. Some studies have shown that, rabbits drink more water if it is provided in a bowl than in a sipper bottle. If water is provided in a bowl, ensure that the water is kept clean and does not get contaminated with stool or food. Change or provide water daily to ensure a clean, consistent water supply (NRC, 2001).

NUTRIENT REQUIREMENTS OF DONKEYS

Donkeys graze; eat forbs and shrubs and the bark of trees. Normally, they should be allowed to graze for six to seven hours a day on free range. A donkey is a monogastric herbivore, thus it eats roughages and utilizes cellulose and hemicellulose efficiently. A donkey that is not used all the time can find sufficient food on the range during the rainy season but may need to be offered supplementary feeds during the dry season or drought years. Donkeys graze successfully in most years when there is adequate rainfall and this keeps them in good body condition. When they are working regularly and do not have adequate grazing time, then supplemental feed will be required. In addition, dry matter intake of the donkey which is about 3.1% of its live weight is high compared to that of other large herbivores (Hagmann & Prasad, 1994). A general rule of thumb is that, a donkey should be provided daily with straw or hay equal to 5% of its bodyweight, even though it may only eat about half of this. For a 200-300kg donkey carrying 25-70kg load at 4 km/hour, 6 hours/day, the diet should consist of 500g grain (coarsely ground maize or sorghum) and 2.5kg chaff (by-product of dry cereal milling) or cowpea pods or peanut shells. Some chaff could be replaced with hay or straw (dry grass). The ration should be given to the donkey in the morning, and then the same amount again in the evening (NRC, 2001).

Donkeys need more fibre and less protein in their diets than horses. Donkeys are different from horses in many ways, therefore they should not be fed like horses and they are not ruminants, so they must not be fed like cattle, sheep or goats. For example, urea may be poisonous to donkeys when taken in large quantities (Aganga & Tsopito, 1998). Therefore, if donkeys have access to cattle lick with urea in the constituents, they must not consume too much to prevent urea poisoning (NRC, 2001).

Donkeys are grazers as well as browsers. The teeth and lips of donkeys permit them to graze close to the ground; thus they can graze short vegetation efficiently. Donkeys are non-selective grazers and can feed on a wide variety of feed-stuffs, including kitchen leftovers (NRC, 2001).

Feeding behaviour of donkeys is thought to be characterized by large intakes with low nutrient extraction. High rates of intake can be achieved by rapid chewing, large bites, effective chewing per bite, or sacrifice in particle size reduction (Aganga & Tsopito, 1998). The donkey differs, somewhat, from the horse because its narrow muzzle and mobile lips promote greater selectivity in feeding. This allows it to maximize feed quality rather than quantity. The donkey may use a selective feeding strategy, searching for high quality bites when foraging over a heterogeneous pasture or rangeland, but when provided with homogenous hay, employs an alternative strategy of maximizing intake. In practice, donkeys faced with some perceived need consume more food quickly, such as following an intentional or unintentional fast, or restricted time in which to eat due to insufficient feeder space, competition from herd mates or long hours spent working. Under these conditions the donkey may resort not to faster chewing but to incomplete chewing. This, could result in problems such as oesophageal obstruction (choke) and intestinal impaction. A donkey, which ate rapidly following a period of food restriction, was reported to suffer from oesophageal obstruction (NRC, 2001).

Chewing activity is an important aspect of feeding behaviour in donkeys. All herbivores, especially those that derive energy from microbial fermentation of fibre, must chew their food in order to prepare it for digestion (Hagmann & Prasad, 1994). The donkey chews fragments of plant cells to reduce the feed particle size, promote salivary secretion and allow wetting of feed. The donkey (a non-ruminant herbivore) has only one opportunity during mastication to complete the physical processing of feed, unlike the ruminants that chew upon initial ingestion (mastication) and again during rumination. The amount of time a donkey spends chewing a given amount of food is affected by a variety of factors, including the physiologic state, level of intake, amount of fibre in the diet, physical form of the feed, particle size of the feed and the health of the animal (NRC, 2001).

Physiological differences between the activities of the gastro-intestinal tract of donkeys and that of ruminants are not readily apparent in spite of the obvious anatomical differences. The dry matter consistency of fore-gut contents, the addition of fluids to the contents of the small intestines and the drying of the gut contents rearwards from the caecum to the rectum are all similar (Hagmann & Prasad, 1994). Organic acid concentration in the upper (cranial) part of the donkey's stomach appears similar to that found in the rumen of ruminants, although the volume of the gut fill is much smaller. In the donkey, the relative capacity of the stomach is 14 liters while that of caecum and colon is about 80 liters: in ruminants the stomach has a relative capacity of about 80 liters and the caecum and colon about 13 liters. In the donkey, microbial digestion occurs, principally, in the caecum and colon, while in ruminants it takes place in the rumen. The stomach of ruminants and the large intestine of the donkey are, therefore, functionally similar (NRC, 2001).

Coprophagy occurs in young donkeys which often eat the faeces of their dams within a few months of birth. This is viewed as a way for the young donkeys to obtain cellulose digesting bacteria and other microbes, which are abundant in the faeces. Well-fed adult donkeys on a balanced diet, do not normally practice coprophagy. It occurs occasionally in housed donkeys that are bored and due to lack of stimulatory activities start to eat their own faeces. This is regarded as a behavioural disorder or bad habit (NRC, 2001).

Donkeys require less energy per unit of weight than cattle for walking, which is due to skeletal differences, which make movement in equines more energy efficient. Energy requirement for work above maintenance is influenced by the size of the load, the slope of the land, the nature of the ground and the positioning and balancing of the load on the donkey (Hagmann & Prasad, 1994). Energy requirements can be estimated from the energy costs of the different activities associated with work and knowledge of the amount of work done and distance traveled. Donkeys are able to digest high fibre forage diets and utilize organic acids for energy. Therefore, virtually all donkeys in Botswana are grazed or fed on straw and hay. The donkeys require the fibre to keep their digestive systems fully functional and to ensure a steady rate of food passage through the gut (NRC, 2001).

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A donkey's protein requirement is influenced by the physiological status of the animal and what it is being required to do. Young growing donkeys and pregnant or lactating animals require more protein than mature, non-pregnant animals. Quality of protein fed to donkeys influences total daily protein requirements. Essential amino acids (EAA) are the amino acids which must be provided in the diets to the animal since it cannot synthesise the EAA by itself, or which cannot be synthesised by the bacteria in the digestive system in sufficient quantities to meet its requirements, for example methionine and lysine (NRC, 2001).

The donkey cannot store amino acids efficiently and, therefore, needs a constant supply in its diet. Legumes provide more of the essential amino acids than grasses and straws (Aganga & Tsopito, 1998). Good feeding of donkeys with adequate protein supply can enable the animals to better resist disease challenge and improve the growth rate of growing donkeys. The challenge to the nutritionists is to develop recommendations on crude protein requirements for donkeys that can allow farmers to make economic decisions on feeding practices of the donkeys (NRC, 2001).

Minerals are required for growth and development of the skeleton, especially in growing donkeys (Aganga & Tsopito, 1998). As skeleton is the load bearing structure for efficient working life, then it must be optimally developed and strong. Working donkeys need mineral supplements to replace the minerals lost in sweat. Donkeys should be provided with a mineral lick of a mixture of dicalcium phosphate and salt. The salt will replenish the sodium lost in sweat (NRC, 2001).

Vitamins play a variety of roles in the body of donkeys, and quite often they are catalysts for metabolism. While only a minute amount of each may be needed, a deficiency can cause severe side effects or illness once the reserves are depleted. Vitamins are classified into two groups. The fat-soluble vitamins, which can be stored in the body for future use, are A, D, E, and K (Hagmann & Prasad, 1994). As they are stored, toxicities can occur if fed in excess. The water-soluble vitamins, which are not stored and must be supplied continually, are the B-complex vitamins. Many vitamin supplements are available, but should only be used after determining that, the donkey's diet needs to be supplemented. Never supplement vitamins in amounts which greatly exceed the daily requirements. Be especially conscious of levels of the fat-soluble vitamins being fed. In general, a good, balanced diet of green hay, grain, and sunlight will provide adequate amounts of vitamins for the donkey unless under a large degree of stress (NRC, 2001).

Donkeys have lower water requirements per unit of weight than other domesticated animals, except the camel. Water intake of a donkey is influenced by the amount of work being done, the temperature and humidity of the environment, the dryness of the feed being consumed and the physiological status of the animal. Water requirements of a fully-grown adult donkey are in the range of 18 to 35 litres per day, according to the above circumstances (Hagmann & Prasad, 1994). Donkeys appear to feel less thirsty than other animals when exposed to water deprivation and may continue to eat when most animals, other than the camel, have stopped eating as a result of water shortage. Donkeys can withstand up to 20 - 25 percent weight loss due to dehydration and recover this loss when water becomes available. Dehydration in the thermo-neutral zone and at high ambient temperatures of 40ºC depresses food intake but apparently increases digestibility of ingested dry matter. Intermittent changes in temperature, such as diurnal variation in air temperature of deserts, do not depress appetite, provided water is not limited. Donkeys should be offered water at least once or preferably twice per day to ensure good functioning of their digestive system and provide opportunity for body water to evaporate, so maintaining body temperature (NRC, 2001).

Donkeys should not be offered very cold water when they are still hot from working. The water must be clean since donkeys may refuse to drink dirty water even when they need water. Donkeys can go without water for up to 3 days without harm to the animal when there is water shortage (NRC, 2001).

NUTRIENT REQUIREMENTS OF HORSES

The nutrient requirement for a horse depends on the activity or function the horse is expected to perform. Nutrient requirements are usually quoted for five specific physiological classes: maintenance, growth, lactation (nursing), gestation (pregnancy), and work. The weight of an animal influences its requirements regardless of the function (NRC, 2001). It is, of course, possible for a horse to be in more than one of these classes at the same time and in these cases, the ration must be altered to meet the requirements for both functions. The desired body condition also affects the requirements. Some horses have a slower metabolic rate and are called "easy keepers," while others always seem to need more than the average required energy and are called "hard keepers."

A maintenance ration is that on which a mature idle horse will maintain normal weight, or body condition score under average climate conditions while doing nothing. It should be remembered that, extreme cold climatic temperatures (less than 20 degree F) cause the horse to use energy to control body temperature. Work causes the energy requirements to increase. As the intensity or duration of the work increases from light to moderate to intense, the requirements for energy increases by 25, 50, and 100% above maintenance, respectively (NRC, 2001).

Lactation and growth increases demand for protein, minerals, and vitamin A as well as energy. With any sort of activity, especially lactation, the calcium and phosphorus needs are increased. There is a critical need for increases in protein, minerals, and vitamin A during the last three months of gestation. Energy requirements during the ninth, tenth, and eleventh months of gestation increase by 11, 13, and 20%, respectively. A young foal would require about 22% protein, 16% fat, and 58% carbohydrates. It is necessary to keep young foals on a high-protein and high-energy diet. As they get older, their need for high protein will decrease. A horse being maintained can meet its requirements on good pasture or hay only; however, as more is expected from a horse, its nutrient requirements increase (NRC, 2001).

Horse rations are usually made up of hay or pasture plus grain or concentrate. The idle horse has a low-energy requirement and can meet its needed level of nutrients on pasture and free access to water and mineralized salt. In order for the pasture to provide the majority of the nutrients for a horse for a year, owners must allow two to three acres per horse (NRC, 2001).

Most horses will eat about 2.5 pounds of air-dried feed per 100 pounds of body weight per day. This depends on the feed-stuff's quality and dry matter composition, but a 400lb horse eats about

10lbs. of feed per day, and a 2000lb horse eats about 50lbs of feed per day. To maintain normal digestive processes in the large intestine and to avoid boredom, all horses should receive at least 1pound of forage per day per 100 pounds of body weight. This can be supplied by pasture, long hay, or cubes with at least a three quarter-inch particle size. The pelleted products can cause digestive problems when fed alone. In addition, a diet consisting solely of pellets results in less time spent eating and can lead to boredom and increased wood chewing (NRC, 2001).

Horses can use hay and other roughages as nutrient sources much more efficiently than other non-ruminants such as poultry or pigs, although utilization is less efficient than in ruminants. Traditionally, it was stated that a good source of roughage should comprise of at least 50% of the total equine ration by weight. Current recommendations are that, horses receive at least 1.5–2% of their body weight in forage or forage substitutes, such as hay cubes or other high-fiber source daily. The average maximum daily dry matter intake is 2.5–3% body wt (although some breeds and age groups, notably ponies and weanlings, can exceed those maximums if on good pastures); therefore, forage or forage substitutes should be the major components of an equine ration. The main sites of fermentation in horses are in the ceacum and large colons, where products of microbial fermentation, such as volatile fatty acids, amino acids, and vitamins, are also absorbed. Microbial fermentation also occurs in the stomach and small intestine to lesser degrees, depending on the type of feed. Enzymatic digestion of carbohydrates, protein, and fats occurs only in the duodenum and jejunum. Any of these nutrient sources that escape small-intestinal digestion/absorption are passed on for microbial degradation in the large intestine, where their fermentation will alter pH and microbial activity, both acutely and long term (NRC, 2001).

Energy is derived from carbohydrates, fats, and even protein; but, because of their abundance in plant feeds, carbohydrates are the horse's major source of energy. The sugars and starches are easily digested and cellulose very poorly digested, but the ability to digest cellulose increases as the animal matures, when the bacterial population in the digestive tract increases. It is essential that, a horse should have an adequate source of energy in the form of carbohydrates and fats so that, the protein can be used for foal growth, the production of milk and body repair, rather than as a source of energy. Naturally occurring fats make up less than 5% of the horse's diet. Fats act as a source of linoleic acid (a fatty acid which affects growth, and condition of the skin). Fats are an excellent source of energy for the animal and can be added up to 10% of the diet to increase energy and make the feed more palatable. The body uses energy as fuel for all physical activity, growth, milk production, and repair. A deficiency of energy will cause slow growth, sluggish activity, and general weakness and unthrifty condition. Excess energy will become body fat, and a weight problem can follow. Energy is measured as Digestible Energy (DE). DE is expressed in calories (or mega calories-1000 cal) and represents the amount of energy that is actually available to the horse in a digestible form. In a good, well-balanced ration, carbohydrates and fats should be the only source of energy; they are expressed in requirement tables together as energy (NRC, 2001).

Minimum nutrient requirements of horses, provides a guideline as to how these requirements change among mature horses of four different sizes. The crude protein is expressed in pounds per day; calcium and phosphorus are expressed in grams per day; digestible energy needed per day is expressed in mega calories per day. Vitamin A is measured and expressed as 1000 International Units (I.U.). Exercise at a moderate level of some trotting and cantering for one hour each day was used (NRC, 2001).

Protein is needed by the horse for growth, muscle development, reproduction, lactation, repair of body tissues, skin and hair development. If energy in the diet is low, protein can also be converted to energy. It is necessary to consider the quality of the protein (the content of essential amino acids) as well as the total amount of protein fed. The lysine (an indispensable amino acid) requirement for weanlings is 0.6-0.7% of the diet and for yearlings 0.5% of the diet.

Although some amino acid synthesis and absorption occurs in the ceacum and large intestine, it is not sufficient to meet the amino acid needs of growing, working, or lactating horses; therefore, the protein quality of the feed provided to these classes of horses is important. Weanlings require 2.1g, and yearlings 1.9g, of lysine/Mcal DE/day. Requirements for other dietary amino acids have not been well established; however, the crude protein recommendations given in estimated daily nutrient requirements of growing horses and ponies and estimated average daily nutrient requirements of mature horses and ponies should be adequate, if good quality forages and concentrates are used in the ration. The amino acid balance in alfalfa and other legumes such as soybeans appears to be better than that found in cereal grains or some grass hays. This should be considered when formulating rations, especially for rapidly growing young horses (NRC, 2001).

Growing horses have a higher need for protein (14–16% of total ration) than mature horses (8–10% of total ration). Aged horses (>20 yrs old) may require protein intakes equivalent to those for young, growing horses to maintain body condition; however, hepatic and renal function should be assessed before increasing the protein intake of old horses. Fetal growth during the last stage of pregnancy increases protein requirements to about 10–11% of total ration, and lactation still increases requirements further to 12–14% of total ration. Work apparently does not significantly increase the protein requirements, provided that, the ratio of crude protein to DE in the diet remains constant and the increased energy requirements are met (NRC, 2001).

Horsemen must rely on legume hay or quality concentrate feeds to provide the balance of amino acids needed. Commercial feeds containing urea, a non-protein nitrogen source, should not be fed to horses because the horse does not have the ability to utilize non-protein nitrogen to the degree that cattle can. Feeding excessive protein to horses with the belief that, it will increase muscle development is not valid and is very expensive. Excess protein (that is fed above the requirements) is broken down into energy (calories) and a nitrogen by-product called urea, which is excreted in the urine causes the horse to urinate and drink more (NRC, 2001).

Mineral content of a horse's diet is determined by the soil and water in the area, the quality of feed, and the proportion of grain to hay in the diet. The main minerals are often classified as macro-minerals. These are Calcium (Ca), Phosphorus (P), Sodium (Na), and Chlorine (Cl). Depending on the area, trace minerals of concern are Iodine (I) Iron (Fe), Selenium (Se), Zinc (Zn), Manganese (Mn), and Copper (Cu). These trace or micro-minerals are also referred to as electrolytes (NRC, 2001).

Because the skeleton is of such fundamental importance to performance of the horse, calcium and phosphorus requirements deserve careful attention (Estimated Daily Nutrient Requirements of Growing Horses and Ponies and Estimated Average Daily Nutrient Requirements of Mature Horses and Ponies). Excessive intakes of certain minerals may be as harmful as deficiencies; therefore, mineral supplements should complement the composition of the basic ration. For example, if the horse is consuming mostly roughage with little or no grain, phosphorus is more likely to be in short supply, especially for growth, than calcium. However, if more grain than roughage is being consumed, a deficit of calcium is much more common. The total mineral contribution and availability from all parts of the ration (forages and roughages, concentrates, and all supplements) should be considered when evaluating the mineral intake. However, aside from actual feeding trials, no suitable test for availability of dietary minerals exists. Blood concentrations do not reflect dietary intake adequately for any of the macro minerals, especially calcium (NRC, 2001).

Requirements for calcium and phosphorus are much greater during growth than for maintenance of mature animals. The last stage of pregnancy and lactation also appreciably increase the requirements. Aged horses (>20 yrs old) may require more phosphorus than is needed for adult maintenance (0.3–0.4% of total ration). Excess calcium intake (>1% of total ration) should be avoided in aged horses, especially if renal function is reduced (NRC, 2001).

For all horses, the calcium:phosphorus ratio should be maintained at >1:1. A desirable ratio is 1.5:1, although, if adequate phosphorus is fed, foals can apparently tolerate a ratio of up to 3:1, and young adult horses a ratio even higher. Work does not appreciably increase calcium or phosphorus requirements as a portion of diet (NRC, 2001).

Salt (NaCl) requirements are markedly influenced by sweat losses. It is recommended that, horse rations contain 1.6–1.8 g salt/kg feed of dry matter, although there are limited data on the precise requirements. Sweat losses may cause NaCl loss >30 g (1 oz) in only 1–2 hrs of hard work, and feed concentrations of salt for working horses are recommended to be at least 3.6g NaCl/kg feed of dry matter (NRC, 2001). The upper limit for salt inclusion in the ration of even hard-working horses is recommended at 6% of the total ration. However, NaCl is the only mineral for which horses are known to have true "nutritional wisdom." Horses voluntarily seek out and consume salt in amounts to meet their daily needs if given the opportunity. Salt lick or salt blocks should be readily available. Supplemental salt may be provided by oral dosing or added to feed or water in addition to free-choice salt to replace acute losses during hard work, but prolonged, excessive, salt supplementation will enhance excretion, which will reduce the ability to adjust to acute losses in the future (NRC, 2001). Forced oral administration of concentrated salt pastes (electrolytes) to dehydrated horses can cause abdominal malaise. Some horses, usually those confined to stalls, will ingest excessive amounts of salt, possibly due to restricted feed intake and/or boredom. This will not cause health problems, as long as adequate water is available, although it will increase water intake and urination. Salt poisoning is unlikely unless a deprived horse is suddenly allowed free access to salt, or if water is not available to horses force-fed salt (eg, electrolyte mixtures given during competitions). Excessive salt content of feed or water will limit voluntary intakes, precluding toxicity but putting the horse at risk of energy deficits (NRC, 2001).

The most satisfactory method to provide supplemental calcium, phosphorus, and salt is to furnish a mixture of one-third trace mineral or plain salt and two-thirds dicalcium phosphate free choice. Trace mineral salt blocks do not contain additional calcium or phosphorus.

The daily magnesium requirements for maintenance have been estimated at 0.015 g/kg body wt based on limited studies. Working horses are estimated to require 0.019 to 0.03 g/kg body wt for light to strenuous exercise, respectively, due to sweat losses. The requirements for growth have not been well established but have been estimated to be 0.07% of the total ration. Most feeds used for horses contain 0.1–0.3% magnesium. Although deficiencies are unlikely, hypomagnesemic tetany has been reported in lactating mares and stressed horses. The upper limit of recommended intake is estimated to be 0.3% of ration dry matter, based on data from other species, but adult horses have been fed rations with higher magnesium content without apparent adverse effects. Anecdotally, high magnesium intake has a pharmacologic calming effect on horses, but large doses of magnesium sulphate (ie, Epsom salts) are also laxative (NRC, 2001).

The recommended potassium intake for maintenance in adult horses is 0.05 g/kg body wt. Most roughage contain >1% potassium, and a ration containing ≥50% roughage provides more than sufficient potassium for maintenance animals. Working horses, lactating mares, and horses receiving diuretics, need higher potassium intakes because of sweat, milk, and urinary losses. Hard work may increase intake needs by a factor of 1.8. It has been proposed that, rations fed to hard working horses should provide 4.5g potassium/Mcal DE. Potassium chloride is the most common salt used to supplement rations. However, upper safe limits have not been established, and although excesses are usually efficiently excreted by the kidneys in healthy horses, acute hyperkalemia caused by the rapid absorption of concentrated salt mixtures can induce potentially fatal cardiac arrhythmias. Forced oral supplementation with large doses of potassium salts should be avoided, even in hard working horses (NRC, 2001).

Iodized salts used in salt blocks or commercial feeds easily fulfill the dietary iodine requirements (estimated to be 0.35 mg/kg feed dry matter), as do forages grown in iodine replete soils. Late pregnant mares may require slightly higher intakes (0.4 mg/kg feed dry matter), but iodine toxicity has been noted in pregnant mares consuming as little as 40 mg of iodine/day. Goiter due to excess iodine intake has been well documented in both mares and their foals, and several cases were associated with large amounts of dried seaweed (kelp) in the diet. Except in regions where the soils are known to be severely iodine deficient, iodine supplementation is not necessary for horses (NRC, 2001).

The dietary copper requirement for horses is probably 8–10ppm, although many commercial concentrates formulated for horses contain >20ppm. The presence of 1–3ppm of molybdenum in forages, which interferes with copper utilization in ruminants, does not cause problems in horses. However, excessive iron supplementation (fairly common, especially in performance horses [see below]) may inhibit adequate absorption. Copper deficiency may cause osteochondritis dissecans in young, growing horses and is associated with a higher risk of aortic or uterine artery rupture in adults. Copper deficits may also cause hypochromic microcytic anemia and pigmentation loss. Horses are extremely tolerant of copper intakes that would be fatal to sheep. However, excessively high copper intakes, potentially reduce the absorption and utilization of selenium and iron, and should be avoided (NRC, 2001).

The dietary maintenance requirement for iron is estimated to be 40mg/kg feed dry matter. For rapidly growing foals, pregnant and lactating mares, the requirement is estimated to be 50mg/kg feed dry matter. Virtually all commercial concentrates formulated for horses and most forage contains iron well in excess of the recommended concentrations. Only horses with chronic blood loss (eg, parasitism) should be considered to be at risk of iron deficiency. Excess iron intake potentially interferes with copper utilization. The presence of anemia (low PCV or red cell volume) alone is not sufficient indication for iron supplementation in horses (NRC, 2001).

The zinc requirement is estimated to be 40mg/kg feed dry matter, although there is evidence that, this recommendation may be as much as twice the actual requirement to prevent signs of deficiency in most horses. This mineral is relatively safe when taken in required quantity, although intakes of >1,000 ppm have induced copper deficiency and developmental orthopedic disease in young horses (NRC, 2001).

The dietary requirement for selenium is estimated to be 0.1mg/kg feed dry matter in most regions. However, there are regions of the world (including the lower Great Lakes, the Pacific Northwest, the Atlantic coast, and Florida in the USA, as well as parts of New Zealand) where soils are profoundly deficient in this important but potentially very toxic trace mineral. In other areas (including parts of Colorado, Wyoming, and North and South Dakota), forages may contain 5–40ppm of selenium, which is sufficient to produce clinical signs of toxicity (see Selenium Toxicosis). Exercise increases glutathione peroxidase (selenium-containing enzyme) activity and may increase need for supplementation in heavily exercised horses. No more than 0.002 mg/kg body wt should be supplemented on a daily basis; toxicity has been seen with as little as 5 mg selenium/kg feed dry matter (NRC, 2001).

The requirement for sulfur in horses is not established. However, sulfur-containing amino acids (methionine) and vitamins (biotin) are essential for healthy hoof growth. If the protein requirement is met, the sulfur intake of horses is usually 0.15% feed dry-matter intake—a concentration apparently adequate for most individuals. Sulfur deficits may contribute to poor hoof quality (NRC, 2001).

The dietary requirement for cobalt is apparently <0.05 ppm. It is incorporated into vitamin B12 by micro-organisms in the ceacum and colon and, therefore, is an essential nutrient per se only if exogenous sources of B12 are not incorporated into the ration. The upper limit of intake is estimated to be 25mg/kg feed dry matter based on data from other species (NRC, 2001).

Manganese requirements for horses have not been well established; amounts found in the usual forages (40–140mg/kg dry matter) are considered sufficient (NRC, 2001).

Rock phosphates, when used as mineral supplements for horses, should contain <0.1% fluorine. Fluorine intake should not exceed 40mg/kg feed dry matter. Excessive ingestion can result in fluorosis, although horses are more resistant to fluorine excesses than ruminants (NRC, 2001).

Although molybdenum is an essential co-factor for xanthine oxidase activity, no quantitative requirements for horses has been demonstrated. Excessive levels (>15mg/kg feed dry matter) may interfere with copper utilization (NRC, 2001).

Vitamins play a variety of roles in the body, and quite often they are catalysts for metabolism. While only a minute amount of each may be needed, a deficiency can cause severe side effects or illness, once the reserves are depleted. Vitamins are classified into two groups. The fat-soluble vitamins, which can be stored in the body for future use, are A, D, E, and K. As they are stored, toxicities can occur if fed in excess. The water-soluble vitamins, which are not stored and must be supplied continually, are the B-complex vitamins (NRC, 2001).

The vitamin A requirement of horses can be met by β-carotene, a naturally occurring precursor, or by active forms of the vitamin (eg, retinol). Fresh green forages and good-quality hays are excellent sources of carotene, as are corn and carrots. It is estimated that, 1mg of β-carotene is equivalent to 400 IU of active vitamin A. However, because of oxidation, the carotene content of forages decreases with storage, and hays stored for more than 1 year may not furnish sufficient vitamin A activity. Horses consuming fresh green forage for 3–4 months of the year usually have sufficient stores of active forms of vitamin A in the liver to maintain adequate plasma concentrations for an additional 3–6 months. Rations for all classes of horses should provide a minimum of 30 IU active vitamin A/kg body wt (whether as β-carotene or an active synthetic form, such as retinyl acetate). Prolonged feeding of excess retinyl or retinol compounds (>10 times recommended amounts) may cause bone fragility, bone exostoses, skin lesions, and birth defects such as cleft palate and micro-ophthalmia (based on data for both horses and other species). The proposed upper safe concentration limits for chronic administration is 16,000 IU of the active form of the vitamin per kg feed dry matter. There is no known toxicity associated with β-carotene in horses (NRC, 2001).

Horses exposed to ≥4 hrs of sunlight per day or that consume sun-cured hay do not have dietary requirements for vitamin D. For horses deprived of sunlight, suggested dietary vitamin D3 concentrations are 800–1,000 IU/kg feed dry matter for early growth and 500 IU/kg feed dry matter for later growth and other life stages. Vitamin D toxicity is characterized by general weakness; loss of body weight; calcification of the blood vessels, heart, and other soft tissues; and bone abnormalities. Any excessive feeding of diet as small as 10 times the recommended amounts may be toxic for horses and are aggravated by excessive calcium intake (NRC, 2001).

No minimal requirements for vitamin E have been established. However, it has been established that, selenium and vitamin E work together to prevent nutritional muscular dystrophy (white muscle disease, please refer to White Muscle Disease in Goats), equine degenerative myeloencephalopathy, and equine motor neuron disease. Evidence of vitamin E deficiency is most likely to appear in foal-nursing mares on dry winter pasture or horses fed only low-quality hay unsupplemented with commercial concentrates. Horses forced to exert great physical effort and/or fed high-fat (>5%) rations may have increased needs for vitamin E. However, if selenium intakes are adequate, it is likely that 50 IU vitamin E/kg feed dry matter is adequate for most stages of the life cycle and moderate activity. Supplementation with 500–1,000 IU vitamin E may be necessary for horses working hard and/or fed high-fat (>7%) rations. Excessive supplementation (>5,000

IU/day for an average adult horse) results in decreased vitamin A absorption and should be avoided (NRC, 2001; Olawoye & Kubkomawa, 2018a).

Vitamin K is synthesized by the micro-organisms of the ceacum and colon in sufficient quantities to meet the normal requirements of horses. However, consumption of moldy sweet clover hay may induce vitamin K–dependent coagulation deficits (please, see Sweet Clover Poisoning). The synthetic form of vitamin K (menadione) is nephrotoxic, if administered parenterally to dehydrated horses (NRC, 2001).

Mature horses synthesize adequate amounts of ascorbic acid for maintenance, from glucose in the liver. Some horses may need supplemental ascorbic acid (0.01 g/kg body wt/day) during periods of severe physical or psychological stress, eg, prolonged transportation or weaning. Oral availability is variable. Ascorbyl palmitate is reportedly more readily absorbed than ascorbic acid or ascorbyl stearate. Prolonged supplementation to non-stressed horses may reduce endogenous synthesis and/or enhance excretion, resulting in deficiencies if supplementation is abruptly discontinued (NRC, 2001).

Although thiamine is synthesized in the ceacum and colon by bacteria and 25% of this may be absorbed, thiamine deficiency has been reported in horses fed poor-quality hay and grain. Although, not necessarily a minimum value, 3mg thiamine/kg ration dry matter has maintained peak food consumption, normal gains, and normal blood thiamine concentrations in skeletal muscle in young horses. As much as 5mg/kg feed dry matter may be necessary for horses exercising strenuously, although verifiable deficits have not been recorded. Occasionally, horses are poisoned by consuming plants that contain thiaminases, which results in acute deficits (please, see Bracken Fern Poisoning).

Riboflavin deficits have not been documented in horses. Previous correlations with low riboflavin intake and recurrent uveitis in horses have not been substantiated. However, there is no evidence of toxic effects as a result of supplementing this water-soluble vitamin, and daily intakes of 0.04mg riboflavin/kg body wt is recommended (NRC, 2001).

Intestinal synthesis of vitamin B12 is probably adequate to meet ordinary needs, provided there is sufficient cobalt in the diet. Deficiencies of cobalt in horses have not been reported. Vitamin B12 is absorbed from the ceacum, and feeding a ration essentially devoid of vitamin B12 for 11 months had no effect on the normal hematology or apparent health of adult horses. Vitamin B12 injected parenterally into race-horses and foals is rapidly and nearly completely excreted via bile into the faeces (NRC, 2001).

Niacin is synthesized by the bacterial flora of the ceacum and colon as well as in the liver from tryptophan. There are no known dietary requirements for niacin in healthy horses.

Other Vitamins such as folacin, biotin, pantothenic acid, and vitamin B6 probably are synthesized in adequate quantities in the normal equine intestine. However, biotin supplementation (15–25 mg/day) has been documented to improve hoof quality in adult horses with soft, shelly hoofwalls (NRC, 2001).

Many vitamin supplements are available, but should only be used after determining that, the horse's diet needs to be supplemented. Never supplement vitamins in amounts which greatly exceed the daily requirements. Be, especially, conscious of levels of the fat-soluble vitamins being fed. In general, a good, balanced diet of green hay, grain, and sunlight will provide adequate amounts of vitamins for the horse, unless under a large degree of stress (NRC, 2001).

Water requirements depend largely on environmental conditions, amount of work or physical activity being performed, type and amount of feed and physiological status of the horse (NRC, 2001). The minimal maintenance daily water requirements of a sedentary adult horse in a thermoneutral environment is 5L/100kg body wt/day, assuming the horse is consuming at least 1.5% of its body wt in feed dry matter. However, a 500kg horse will usually drink 21–29L of water per day, when fed a mixed hay/grain ration or pasture. If fed only dry hay, water intake will almost double. Lactation or sweat losses also increase the needs by 50–200%. A 500kg horse exercising for 1hr in a hot environment will need to drink 72–92L of water to replace sweat and evaporative losses. Lactating mares need 12–14L per 100kg body wt to sustain good health and milk production (NRC, 2001).

Without water, an animal can live only a few days, while without other nutrients life can be prolonged much longer. Many horses are managed adequately with fresh, clean, water offered twice each day. Without adequate water, horses have increased chances of impaction colics and will decrease dry matter intake. It is, therefore, vital that a constant supply of clean water be available for the maintenance of a healthy horse. Unlimited free access to clean water is usually recommended, although horses can easily adapt to only periodic access throughout the day, if the amounts offered during the watering sessions are not limited. Inadequate water access will reduce feed intake and increase the incidence of impaction colic, anhidrosis, and other metabolic disorders (NRC, 2001).

NUTRIENT REQUIREMENTS OF CAMELS

Camel enjoys, globally, a unique ecological as well as socio-economic status. It’s unaccounted for service to the human being under harsh climatic conditions and within highly marginalized ecosystems dates back to ancient times. The versatility of camel to survive and perform in the hard arid and semi-arid regions and its unique physiological system motivated herders to keep it. Camel is predominantly a browser, although it also grazes on tall succulent young grass, shrubs, bushes and trees (up to 3.5m above ground level). Camels have long necks and legs that enable them to munch on leaves and fruits of trees beyond the reach of other livestock (Guerouali & Wardeh, 1998; Arshad & Bakht, 2001).

Camels are remarkable animals that have evolved with a ruminant-like digestive system to enable them to survive on low quality, fibrous feeds (Abdalla, Wasfi & Gadir, 1988). Being browsers, camels are able to select high quality diets, which they can efficiently digest. Camels have lower energy requirements than ruminants, and have evolved an efficient mechanism for nutrient recycling. Camels have the ability to perform muscular functions such as racing at a level of intensity that exceeds the ability of horses (Guerouali & Wardeh, 1998; Arshad & Bakht, 2001). This unique capacity reflects the lower energy requirements for locomotion, the higher glucose supply, the lower oxygen demand, and preferential dependence on slow twitch muscle fibres, which in turn rely on aerobic metabolic pathways. For short distance, high intensity races, camels need high energy feeds to meet the additional energy demand. Inclusion of high levels of grain in camel diets can cause metabolic disorders (NRC, 2001).

Camels have a continual energy demand for maintenance and muscular performance. The form of energy in the muscle cell is adenosine triphosphate (ATP), and is the only energy source that can be used for muscular contraction (Faye, Saint –Martin & Cherrier, 1992). ATP is stored only to a limited extent in cells, and so ATP must be produced from other sources by chemical reactions. These sources of ATP include creatinine phosphate (which is converted directly to ATP) or feed sources (glucose, fats and proteins). ATP is supplied from the feed sources either by aerobic or anaerobic chemical pathways. Camels typically consume only 1.7% of body weight feed as dry matter and can efficiently digest low quality roughage because of the wide range of ruminal microflora which can adapt to a range of forages, active rumination, and high levels of urea recycling (NRC, 2001).

A 450kg camel requires only 37 MJ ME for maintenance per day. Racing camels have an energy requirement of 2 MJ ME/ km travelled, ie an additional 20 MJ ME for an average 10km race. For feeds with an energy density of less than 10, this represents an additional feed intake of over 2 kg/day, which is a 25% increase in feed intake (NRC, 2001). The challenge, therefore, is to increase energy intake without increasing the amount of bulky feed, and without causing rumen dysfunction by feeding excess grain. Camels can store fats efficiently in their humps, and in an adequately fed camel, the hump can represent 20% of the camels total body weight. The oxidation of fat in adipose tissue yields more energy (1g fat=9.3 kcal) than the oxidation of carbohydrates (1g=4.2 kcal).

Basal protein requirements in camels (450 kg body weight) have been estimated at 300g DCP / day for adult working and racing camels (Abu, 1998). Nitrogen retention in camels is greater when fed on a diet of 4% crude protein. During a state of dehydration, the camel’s nitrogen retention is increased by 150%. Supplementation of urea has been found to have a variable effect on the VFA producing microbes in the camel. Camels recycle greater quantities of urea to the rumen, which in turn would support higher levels of digestion. It is reported that, young camels given low protein diets respond well to supplements of by-pass protein (NRC, 2001).

Macro and micro-minerals are essential elements for camel body functioning and health. Trace elements such as cobalt, selenium, copper, zinc and iron are integral components of some enzymes and are also involved in many physiological activities of camel (Faye, Saint –Martin & Cherrier, 1992). Deficiency of trace elements, therefore, leads to a wide variety of pathological consequences and metabolic defects. On the other hand, macro elements such as calcium, phosphorus, magnesium etc are important structural components and their deficiency weakens the body structures (NRC, 2001; Olawoye & Kubkomawa, 2018a).

Although vitamins are needed in a very small percentage as dietary nutrients, they are very important in camel nutritional programs for proper animal function, such as joint and ligament development, immune function, muscle contractions, and nervous system function, growth and reproductive performance (Guerouali & Wardeh, 1998; Arshad & Bakht, 2001). However, deficiency of vitamins in the diet of the camels or any disturbances in the absorption from the body tissues, leads to the appearance of different clinical symptoms. The important vitamins for survival and growth of grazing animals are either manufactured in the rumen by the rumen microbes, in the body by the action of sunlight, or are stored in sufficient quantity in the liver or contained in adequate amounts in available feed. Although, the body needs small quantities for the purpose of maintaining vital activities that occur in the body, requirements may be increased to meet the various immune and metabolic stresses imposed during hard exercise (NRC, 2001).

Proper attention to camel nutrition by following a systematic regular program and use of balanced food supplements containing all the vitamins is expected to prevent nutritional deficiencies. Provision of green or dry ration rich in beta carotene, especially in the latter stages of pregnancy is paramount. Dosaging of racing camels with Vitamin E supplement at least once per week is very necessary (NRC, 2001).

Environmental factors (thermal environment, level of dehydration, etc.) affect the water intake capacity of camel. The camel obtains most of its water requirements, for extended periods of time, from selected feed, more of which is succulent vegetation to drinking of large volumes of water at a time (Faye, Saint –Martin & Cherrier, 1992). For this reason, together with its peculiar physiological characteristics, the camel is able to maintain appetite under conditions of dehydration. A camel can take a drum of water (250-300 liters) at a time, having the ability to reserve that water for longer periods of time than any other animal. It can stay for two months (60 days) without drinking water and would not show any sign of dehydration. That is why it survives in the desert area compared to other livestock. When the basal feed resources are mostly straw and stovers and other low quality roughages, there is little opportunity for those capacities of selective browsing of succulent vegetation. And the camel may not tolerate restricted access to drinking water as may be the case under natural conditions (NRC, 2001; Olawoye & Kubkomawa, 2018a).

CONCLUSION AND RECOMMENDATIONS

The minimum amounts of nutrients (energy, protein, minerals, vitamins and water) necessary to meet an animal's needs for healthy maintenance, growth, reproduction, lactation or work is known as nutrient requirements. Animals are kept for specific production purposes and have to be fed according to the specifications for optimal productivity. Deficiencies of these nutrients at times result to severe ill-health with marked reduction in productivity and even loss of animals’ lives. Good animal products depend on good management which encompasses proper feeding of different classes of livestock with the required nutrients. For optimal production and quality product presentation, livestock feeds have to be analyzed.

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