Nutritional Deficiencies and their Role in Animal Health

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Abstract

Feeding and nutrition have a significant effect on animals and their subsequent performance phenotypic/ genotypic expression, low fertility rate, changes in immune response, and diseases. Protein, carbohydrates, fats, vitamins, minerals, and water are some of the nutrients which are important in carrying out certain roles within the physiological system and metabolic processes. This chapter concentrates on a nutrient as being compulsory for life and some of the consequences perceived from lack of it including, protein energy, vitamins (A; D; E; K; and B complex), and minerals (calcium; phosphorus; selenium; zinc and iodine) and water. Other preventions such as giving proper nutrients and vitamins are still included in the same frameworks together with traditional methods of assessments like clinical assessments and laboratory analyses. Hence reduction in nutrition deficiencies will benefit veterinarians and farmers in improving an animal's health for selling to consumers while also improving sustainable farming methods to meet economic and food security needs.

Keywords: Nutrition, Fertility rate, Immune response, Physiological system, Vitamins, Nutrition deficiencies, Veterinarians

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Introduction

Nutrition is best described as the weakest chain in building an animal's performance and health, growth, reproduction, disease immunity, and vigor. The other factor that has also played some significant role in increasing the risk of nutritional imbalances in animals is animal husbandry which includes intensive farming, and genetic improvement for better performance among other deficiency diseases following low intake of nutrients, low-quality feed or maldigestion/ malabsorption and has a severe effect on animal's health and productivity in the farm (Council et al., 2001; McDowell, 2003).

The nutrients as discussed below have many roles in the body's vital processes. Protein is required for the generation of tissues as well as for enzymatic actions and carbohydrates and fats are the main energy supplies. The vitamins are coenzymes and antioxidants and, on the other hand, minerals are in the skeleton frame and in enzymatic actions as cofactors (Organization, 2004; Suttle, 2022). Despite its being overlooked, water works magic in regulating the body's heat and transporting nutrients into the cells or waste out of the cells. The absence of any of these nutrients influences balance and all diseases under this class impact the efficiency of the animal and its health.(Meehan et al., 2015).

It uniquely posts and argues that nutritional deficiencies can affect all the species. In livestock, protein and energy work symbiotically in the body influencing growth rate and reproduction, and vitamin A hampers vision and immune health. Lack of calcium and phosphorus leads to rickets and osteomalacia affections, whereas lack of copper gives anemia and the disease of lambs called swayback. Such disorders are not only unhealthy for the individual meat-generating animals but also for the animals within the herd, including the ability of the animals to grow and generate income (Radostits et al., 2006).

This chapter focuses on understanding the causes, signs, and management of nutritional deficiencies in animals as well as the underlying types of nutrition. In this series of elaborations, the important aspects related to the identification of these deficiencies and their prevention and reduction have been highlighted along with the scientific evidence of scientific management in each case. Nutrient strategies cannot only be adopted for scientific and economic reasons but also for moral reasons to improve animal welfare and agricultural practices (Smith & Sherman, 2009; Suttle, 2022)

The diseases arising from nutrient deficiencies are a major area of concern in the field of veterinary medicine and animal production since they influence growth, reproductive performance, immune status, and health. It is important to know about the essential nutrients, particularly the effect of their deficiencies on effective animal production and economic profitability of the animals (Arthington & Ranches, 2021; Suttle, 2022).

Essential Nutrients in Animal Nutrition

Macronutrients needed by animals include proteins, carbohydrates, and fats while micronutrients include vitamins A, D, E, K (fat-soluble), B-complex, C (water-soluble), and minerals (Calcium, phosphorus, magnesium, selenium, zinc, iodine, and iron), and water. Protein and its constituent component the amino acids being used in the building and repair of body tissues in addition to being a part of body enzymes. Protein is particularly essential for growth, reproduction as well as immune efficiency and effectiveness (Sciences et al., 2016) While carbohydrates are used for energy in metabolic work. It is further useful for their roles as a compact source of energy, for the assembly of cell membranes, and for the synthesis of hormones (Council et al., 2012).

Vitamins are organic compounds, required in small amounts for the normal growth and maintenance of animal life (Rasikh, 2019). Vitamins act as co-factors and antioxidants; control metabolic pathways, and minerals are involved in bones and teeth formation and supporting enzymes (McDowell, 2003; Organization, 2004). Lack of any of these nutrients has certain health implications which results in specific use disorders and systemic effects hence the importance of balanced feeding for animals (Wu, 2017).

Role of Vitamins in Immunity and Disease Resistance

Vitamins have a considerable effect on animal immune systems and susceptibility to diseases. The effects of vitamin E used by animals depend on its immunomodulatory role attributed to the antioxidant nature of this vitamin. It has antioxidant properties, shields body cells and tissues from oxidation that emanates from free radicals. Also, the colostrum is rich in vitamins A, D & E all of which are very important in the immunities of the formation of newborn Calves. The calves that were fed with the vitamin E-enriched colostrum showed enhanced immunocompetent or defense mechanisms against diseases such as diarrhea and pneumonia and their incidence and mortality rates were lower. Similarly, an adequate amount of Vitamin A as a molecule also plays a role in disease immunity and immunological modulation with functional epithelium, stress, and glucocorticoid regulation. Certain nutrients including vitamin A and β-carotene, have been known to lower the risk of mastitis and enhance the health of the udder (Rasikh, 2019). B- complex vitamins, specifically vitamin B6 (pyridoxine), vitamin B9 (folate), and vitamin B12 (cyanocobalamin) are needed in the synthesis of nucleic acids and proteins that are required for Immunocyte proliferation and function. Vitamin C enhances the phagocytic action of leukocytes of the endothelial system, aids in the formation of antibodies, and possesses antiviral and anti-carcinogenic control. It was observed that Vitamin K affects the level of serum complement in the body (Kavitha et al., 2007).

Common Nutritional Deficiencies and their Impacts

Protein Deficiency

Proteins play a huge role in growth and muscle development and are involved in enzymatic actions. Animal protein malnutrition's effects include poor growth, reproductive inefficiency, poor feathers, and reduced milk or egg yield. The effects of protein deficiency include reduction in appetite muscular weakness, actual weight loss, poor hair coat condition etc. (Council et al., 2001; National Academies of Sciences and Medicine, 2021).

Energy Deficiency

The major sources of energy are carbohydrates and fats in a particular diet. Energy deficits are normally characterized by a failure of the animals to consume enough feed to meet their energy needs. This condition is more rectified during times when energy level demand is high like during lactation periods, and extreme weathering among others. Some of the signs include loss of weight, a low activity level, reduced fertility, and low immunity to illnesses (Herdt, 2000; Roche et al., 2009). Ketosis is a particular pathology familiar to dairy cows, which is associated with energy depletion (Council et al., 2001; Devi et al., 2024).

Vitamin Deficiencies

Another key problem, that concerns animal health, is vitamin deficiencies.

Vitamin A Chemically known as Retinol is important for perceiving the Rate, the maintenance of the epithelial of cells, and facilitating the immune system. There is a great positive relation between its deficiency and night blindness, xerophthalmia, and increased rate of infections (McDowell, 2003). The doses of both vitamin A and ß-carotene have a protective effect on periparturient diseases by causing a marked decrease in lymphocyte proliferation during parturition (Kumar et al., 2010). Common effects in cattle include reproductive failures in vitamin-A deficient animals, the same in poultry results in poor growth and poor egg production (McDonald, 2002).

Vitamin D helps the body to maintain low concentrations of calcium and phosphorus in the blood and many of the clinical manifestations of its deficiency can be recognized clinically and radiographically as rickets in young animals and osteomalacia in adults. This is a particular problem in grazing animals that do not have access to direct sunlight (Suttle, 2022).

Vitamin E (Tocopherol) and **Selenium** are used to combat oxidation of cells with deficiency leading to nutritional muscular dystrophy commonly known as white muscle disease, which affects lambs and calves mostly (Sciences et al., 2016). The lack of Se seriously affected productive efficiency and animal health, with high mortality in the offspring as a result of degenerative lesions in the myocardium (Tórtora-Pérez, 2010).

Vitamin B-Complex: The B-complex vitamins play major roles in energy production and the functioning of the nervous system. As with other vitamins, its deficiencies are attributed to certain gastrointestinal diseases or inadequate nutrient intake leading to signs like poor growth, anemia, and neurological disorders. For example, in ruminants, a deficiency of thiamine (B1) results in polio encephalomalacia (Krebs, 2000; Girard & Duplessis, 2022).

Mineral Deficiencies

Lack of minerals also has a huge effect on the health of animals. A brief overview about the importance of minerals in livestock is mentioned in the Figure 1.

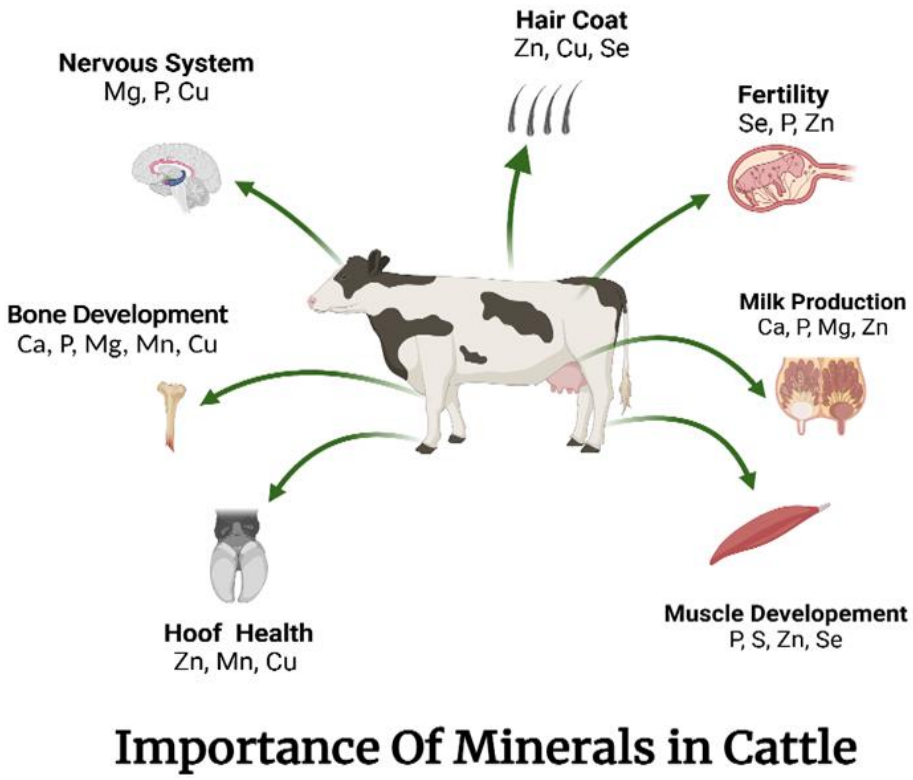

Fig. 1: Overview about the importance of minerals in animals

Calcium is affected by parathyroid hormone and plays a role in skeletal metabolism as well as phosphorus. Lack of these minerals may result to poor bone formation, limping, and slower growth. Milk fever is a hypo-calcemic disorder experienced by many fresh cows during the first few days postpartum (Council et al., 2001; Stenhouse et al., 2022).

Iron is a major component of hemoglobin, and its deficiency leads to anemia, which is demonstrably true in young pigs, such as piglets reared indoors (Council et al., 2012).

Zinc plays a part in metalloproteins and enzymes and participates in synthesis of protein, nucleic acid, and carbohydrate (Patil & Patil 2024). Zinc is helpful for the skin, and the immune system, and for reproduction its lack leads to skin problems called parakeratosis, growth problems, and reproduction problems (McDowell, 2003).

Apart from being involved in making new red blood cells and proper immune function, copper is essential. Lambs suffering from copper deficiency during fetal development can develop a condition called swayback; other effects include anemia, depigmented hair, and poor growth (Suttle, 2022). Some of the symptoms associated with copper deficiency are, slower weight gain, muscle atrophy, dull hair coats, and low fertility (Beighle, 2000; Pathak et al., 2025).

Phosphorus is required for the overhauling, building, and growth of tissue in the body. Phosphorus is important in skeletal muscle growth and breaking down fats, carbohydrates, and protein (McDonald, 2002). Cattle transport important minerals Phosphorus and Calcium from the skeleton for lactation, pregnancy, and weight gain purposes. Mobilization of minerals results in softening of the bone, and fractures of bone. Phosphorus deficiency signs include pica, where one eats non-nutritive items such as bones, stones, polythene pipes, and horns (Jackson et al., 2023).

Another factor that one would not readily think of is scarcity of water and that is also as important as any other necessity. The constraints in water availability, water quality, excessive water losses because of disease may lead to poor vehicle water availability, poor feed intake, and bad thermo regulation (Organization, 2004). This compound is all but indispensable for all physiological functions and its deficit varies from one animal species to the other and drastically affects their health and production.

Factors Contributing to Nutritional Deficiencies

Poor-Quality Feed: Nutritive value in feeds declines following improper handling or storage, mold or pests therefore causing deficiencies. For example, vitamin A was found to be highly sensitive to storage and it is known that its value reduces greatly after some time of storage (McDowell, 2000; Sciences et al., 2016).

Unbalanced Diets: Specific feeding practices particularly focusing on the type of feed rather than the nutrient balance of the feed are likely to result in deficiency. This imbalance is well observed in countries or areas where the major foods consumed are mainly cereals which may lack vitamin or mineral components (Suttle, 2022).

High Nutrient Demands: The animals in the high physiological demand classes like the lactating and growing animals will need to take more nutrients. If these high requirements are not met there will always be a shortfall in some of the minerals such as calcium and phosphorus (Council et al., 2001; Lean et al., 2013).

Feed Contaminants: Tannins, phytates, and mycotoxins for instance are well documented as factors that interfere with absorption of nutrients.

For example, mycotoxins generated by fungi reduced protein digestibility and also affected the integrity of gut health thereby worsening nutrient deportation (Radostits et al., 2006).

Geographical Variability: Soil composition in different regions affects forage mineral concentration. Selenium is a typical example: Selenium-deficient soils result in low selenium forage production (Suttle, 2022).

Inadequate Feeding Practices: Some of the possible causes of nutrient imbalance include incorrect feed formulation and feeding system and excessive feeding of single feed types. This situation may lead more often to underfeeding or improper mix of feed in smallholder systems due to constraints in the economic aspect (Suttle, 2022).

Seasonal Variations: During dry periods, or in dry years, seasonal effects on pasture growth and development considerably reduce the overall quality of the available forage, and hence the energy and protein content that grazing animals can extract from the feed source (Herdt, 2000; Lavorel, 2019).

Health Conditions: Gastrointestinal diseases and parasites affect the body's ability to absorb nutrients. For instance, it is a well-known fact that the presence of intestinal parasites brings on iron deficiency anemia because of blood loss (Radostits et al., 2006).

Competition among Nutrients: Intake of large amounts of one mineral may reduce the absorption of others in the feed. Increased levels of calcium in the fluid may interfere with zinc and magnesium uptake and hence result in secondary deficiencies(Soetan et al., 2010).

Modern Farming Practices: Sustainable and efficient production is the major emphasis in extensive livestock farming practices and this may sometimes compromise the nutrient requirements in formulating feeds (McDowell, 2000; Sciences et al., 2016).

Diagnosing Nutritional Deficiencies

Nutritional deficiencies cannot be well diagnosed but must involve various steps. Symptoms like those related to physical and behavioral status are the first hints of concrete deficits. An important part of diet analysis is assessing the feed composition to determine the adequacy of nutrients. Blood chemistry or urea/Sulphur, chemical analysis gives evidence of the presence and severity of deficiencies that are essential for laboratory investigations (McDowell, 2003). Liver biopsies can also provide information about vitamin A reserves, and hair examination reveals the presence of such trace elements as zinc or selenium (Radostits et al., 2007). Autopsies are often likely to show structural or metabolic changes that are associated with deficiencies for instance the goiter that is characteristic of iodine deficiency or the white muscle disease that results from the deficiency of selenium and vitamin E (Smith, 2015). Therefore, these diagnostic methods complement one another and help determine and control cases of nutritional deficiencies.

Prevention and Management

Nutritional deficiencies can be prevented using an appropriate balanced diet that reflects the species' needs. Vitamin, minerals, or amino acid supplements are usually required to correct the shortage as a result of intensive farming practices. Feed and water quality, along with continual health checks are important factors that should be taken into exam consideration regarding nutrition. There is no doubt that veterinary advice is very crucial in preparing and implementing feeding strategies to cover the nutrient requirements of different animal species at different stages of their growth and reproduction and in the care and control of deficiencies (Epizooties, 2014; Suttle, 2022).

Advanced Insights into Nutritional Deficiencies

Role of Gut Health in Nutritional Absorption

The gastrointestinal health potential is a very noted element when it comes to diets and the consumption of nutrient foods. Some diseases which affect the digestive system, or parasitic infestations will impact on the availability of nutrients in the body even with a healthy balanced diet of the animal. Effective deworming, probiotics, and prebiotics are useful in preventing and addressing secondary deficiencies that occur due to poor absorption (Hill et al., 2014).

Impact of Environmental Stressors

Such conditions like; extreme temperatures, drought, and overcrowding also play a significant influence in the promotion of nutritional deficiencies. Some of the heat stress effects for example cause a decrease in feed intake thus allowing a poor supply of nutrients in the food. Electrolyte replacement and selected vitamins, such as vitamin C are useful in countering such adversities (West, 2003).

Lack of Nutrients in Today's Methods of Agriculture

With increased emphasis on animal concentration, feed formulation becomes more common although imbalances can lead to deficiencies or toxicities. Sometimes the supplements may cause antagonistic effects for example, excessive intake of calcium hinders magnesium absorption. An imbalance of diets can lead to such problems, therefore, feed analysis and consultation from experts are recommended (McDowell, 2000; Mehrabi et al., 2020).

Species-Specific Nutritional Requirements

Each species has its dietary requirements, and the general feeding regime is the worst thing that an animal can be exposed to. For example, ruminant animals depend on the microbes in the rumen to synthesize their feed therefore when feed imbalances occur, these animals are likely to be affected by deficiency problems affecting the microbes. On the other hand, monogastric animals including pigs and poultry need the vitamins and amino acids in their feed to already be performed (Council et al., 2001).

Long-Term Consequences of Subclinical Deficiencies

Low-level deficiencies, which do not manifest themselves through initial visible symptoms, bring about chronic productivity losses. For instance, marginal zinc deficiency which persists for many years in dairy cattle leads to udder health complications and reduced milk

production. These are some of the benefits as to why people should undergo constant health check-ups and metabolic rate checks to be able to detect any scarcity and remedy it on time (Radostits et al., 2006).

Trends in Nutritional Management

Precision Nutrition

Adopting precision nutrition programs in animal production has become possible due to enhanced technology to design feed rations that are specific and unique to each animal depending on their genetics, disease status, and productivity. Besides, enhancing the health of animals, precision feeding also reduces feed losses and minimizes the effects of feed on the environment (Patience et al., 2015).

Use of Functional Foods

Supplemented feed or functional feed is being employed in animals' diets including omega-3 fatty acids, antioxidants, and bioactive compounds. These foods improve the nutritional requirements of the human body, with improved immunities hence better disease-fighting ability (Surai, 2007).

Alternative Protein Sources

The increased awareness of sustainable animal feed solutions has resulted in to search for other protein sources for livestock including insect meal, algae, and single-cell proteins. Although these novel ingredients have shown potential however, their nutritional compositions, as well as anti-nutritional effects, need to be assessed (Huis et al., 2013).

The Role of Genomics in Nutritional Research

A significant area of interest with a focus on genomic tools is used in examining the nutrition genetics of animals. Knowledge about these interactions can help define the breeds/individuals with specific nutritional needs and set the stage for effective intervention (Hill et al., 2014).

Ethics and the Environment

Nutrition is not just an animal welfare issue, but humane and ecological too! An appropriate diet helps to avoid health problems and means enhanced readiness to help the animals. Thirdly, maximizing nutrient efficiency reduces the relative impact that livestock farming has on the environment, especially in terms of the emission of nitrogen and phosphorus (Steinfeld, 2006).

Conclusion

Indeed, lack of proper diet has been singled out as a very important factor that determines the health of animals, productivity, and general welfare. In this chapter, we have discussed how low intake of macronutrients vitamins and minerals affects normal body functions and impairs immunity and reproductive and productive potential. Nutritional adjustments are crucial instruments for meeting the health and productivity requirements of animals. Clinical assessment together with nutrition history investigation and environmental monitoring and biochemical testing compose a comprehensive method for nutrition diagnosis. The analysis stops disease development while improving the life quality of performance animals. Preventative measures such as adequate proportions feeding, nutritional status check-ups, and early interventions prevent negativities associated with deficient nutrition. With the development of diagnostic technologies, better feed composition and feeding regimes are available as proactive weapons against deficiencies. However, the application of these solutions is only possible through cooperation, and the use of knowledge from veterinary medicine, sciences related to nourishment, and agroecological farming systems. In this way, the stakeholders can go on developing innovation and education processes in this sphere, as well as enhancing the experience in animal health treatment and concerning the perspective for further creation of effective and sustainable agriculture.

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