Role of Vitamin D Supplements in Animal Diets and Their Effectiveness Along with Safety Considerations

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Abstract

Vitamin D supplements play in animal nutrition and the potential risks to safety. Numerous physiological functions, including the metabolism of calcium and phosphorus, bone formation, immune system function, muscle growth, and reproduction, depend on vitamin D. Supplementation is required since many animals, particularly those kept in enclosed spaces like industrial farms, do not get enough sun exposure to produce vitamin D naturally. Ergocalciferol (D_2) and cholecalciferol (D_3), the two primary forms of vitamin D used in animal feed. D_3 has a better bioavailability and a more physiological role. It emphasizes the necessity of a tailored supplementation approach to meet the unique needs of different species and production systems and the potential risks of toxicity and insufficiency. Progress in vitamin D supplementation, including the development of improved metabolites such as 25-hydroxyvitamin D_3, and the necessity of dietary intake monitoring to avoid excess. To improve animal health, productivity, and welfare while resolving safety concerns, this study aims to inform evidence-based decision-making in animal nutrition through a comprehensive evaluation of the body of existing literature and practical applications. It is recommended that future studies look at sustainable vitamin D sources and the best supplementation techniques in line with evolving farming methods.

Keywords: Ergocalciferol (D_2), Cholecalciferol (D_3), Supplementation, Animal diet, Vitamin D

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Introduction

Vitamins are the micronutrients that animals require in trace amounts to sustain their growth, development, health, and physiological processes (Benedik, 2021). Among these, vitamin D has a vital role, especially in controlling the metabolism of calcium and phosphorus, which are essential for bone health and several metabolic functions (Gáll & Székely, 2021). Similar to humans, animals cannot internally synthesize sufficient levels of several vitamins; in these cases, dietary intake is essential (Plebani et al., 2025). This is especially important for animals in regulated environments, such as commercial farms and indoor housing systems, where natural vitamin D production is inhibited by limited or nonexistent sunshine (Rondanelli et al., 2023).

Ergocalciferol, or vitamin D_2, is derived from plants, while cholecalciferol, or vitamin D_3, is made in the skin of animals exposed to ultraviolet B (UVB) radiation from sunshine (Babazadeh et al., 2022). While both forms can be used in animal diets, most animals respond better to vitamin D_3 due to their higher physiological activity and bioavailability (Aggarwal & Bains, 2022). The primary circulating metabolite used to assess vitamin D status, 25-hydroxyvitamin D (25(OH)D), is produced in the liver after vitamin D is absorbed from the diet or synthesized in the skin (Pludowski et al., 2024). The kidneys then transform this into 1,25-dihydroxyvitamin D (1,25$(OH)_2$D), a physiologically active metabolite that affects other tissues (Bargagli et al., 2021).

Vitamin D is an essential ingredient in the manufacture of animal diets because it plays a key role in bone building, immunological regulation, muscle growth, and reproduction (Steg et al., 2025). Serious illnesses such as rickets, osteomalacia, reduced productivity, and immunodeficiency can result from deficiencies, whereas toxicity, soft tissue calcification, and organ damage can result from excess intake (Xiang et al., 2024). Therefore, veterinarians, animal nutritionists, and livestock management must know exactly how much vitamin D is needed (Guerra López et al., 2024).

Several reasons support the addition of vitamin D to animal feed. First, animals raised in modern production systems are frequently deprived of direct sunshine, preventing them from producing vitamin D naturally (Mavar et al., 2024). Second, vitamin D levels in natural feed ingredients are often inconsistent and insufficient, making it impossible to meet the physiological demands of animals, particularly during periods of rapid development, lactation, or reproduction (Chen et al., 2025). Thirdly, a one-size-fits-all approach will not work because species and breeds have different metabolic requirements and efficiency. As a result, particular supplementation is required to provide optimal animal welfare, improve performance, and prevent deficiencies (Dodd et al., 2024).

Recent scientific developments have produced improved vitamin D compounds, such as 25-hydroxyvitamin D_3, that bypass the liver conversion process and provide faster, more efficient usage. Despite these developments, vitamin D's importance in animal health care has grown due to growing interest in its non-bone effects, such as immunological function and reproduction success (Lilburn & McIntyre, 2024).

This chapter aims to provide a thorough analysis of the application of vitamin D supplements in animal feed. It will cover the physiology of vitamin D in various animals, the effectiveness of supplementation programs, and safety and toxicity concerns. This chapter aims to support evidence-based decision-making in animal feeding operations and nutritional care by combining the results of contemporary research with practical experience.

2. Animal Physiology of Vitamin D

Ergocalciferol (vitamin D_2) and cholecalciferol (vitamin D_3) are the two primary forms of vitamin D. In contrast to vitamin D_3, which comes from plants, vitamin D_3 is created in the skin of most animals when they are subjected to ultraviolet B (UVB) light (Barszcz et al., 2024). In several species, endogenous synthesis may be reduced by geographic location, indoor dwelling, and hair or feathers, necessitating food supplements.

The primary circulating form of vitamin D, 25-hydroxyvitamin D (25(OH)D), is produced in the liver following consumption or synthesis and is used to assess vitamin D status (Shastak & Pelletier, 2024). The physiologically active metabolite 1,25-dihydroxyvitamin D, which regulates intestinal calcium and phosphorus absorption, bone resorption, and renal reabsorption, is created when 25(OH)D is hydroxylated in the kidneys (Wei et al., 2024). The role of vitamin D extends beyond the metabolism of minerals. According to recent data, it influences immune response modulation, reduces inflammation, and promotes muscular growth. However, the specific processes and actions vary mainly depending on the species and developmental stage (Kalia et al., 2024).

3. Bioavailability and Sources of Vitamin D

Animals can obtain vitamin D through food, supplementation, or sun exposure. In the environment, UVB-induced synthesis is often how animals graze outside to obtain theirs. However, feed is the primary source of vitamin D for animals kept in houses and intensively farmed livestock (Kianfar et al., 2025). Although the amount of vitamin D in natural products like fish meal or sun-cured hay can vary and be insufficient, it does exist. As a result, vitamin D supplements are frequently added to prepared foods (Gao et al., 2024). Several variables affect their bioavailability, including the supplements' chemical type, dietary fat intake, gastrointestinal health, and interfering chemicals. In most animals, vitamin D_3 is often more potent and accessible than vitamin D_2 (Kölln et al., 2025).

For instance, pigs and poultry are more efficient in absorbing and using D_3 compared to D_2, resulting in superior bone mineralization and growth. An underappreciated and pervasive issue in animal nutrition is vitamin D insufficiency, particularly in intensive, high-input production systems where there is little exposure to natural sunlight and a significant reliance on artificial diets (Condoleo et al., 2021). The effects of inadequate vitamin D synthesis or ingestion are extensive, affecting multiple physiological systems and resulting in various health and productivity problems in different animal species (Figure 1) (Giustina et al., 2023).

4. Vitamin D Deficiency Causes

Lack of exposure to ultraviolet B (UVB) radiation from sunshine, which the skin needs to generate vitamin D_3, is the primary cause of vitamin D insufficiency in animals. Seasonal variations, geographic latitude, indoor life, and high-density production facilities significantly impact how much UVB an animal is exposed to (Asif & Farooq, 2023).

Pigs and poultry kept in indoor systems, for example, may have very little, if any, exposure to sunlight and, therefore, are entirely reliant on dietary vitamin D. Another contributing reason is the variation and frequently low vitamin D content of natural feedstuffs (Babazadeh et al., 2022). Most traditional feed ingredients, including grains and crop proteins, have little or no vitamin D, and sun-cured forages may not be constant in their levels (Eder & Grundmann, 2022). Additionally, by decreasing the vitamin's bioavailability, feed preparation, storage, and pelleting can lower the amount of vitamin D present (Webster et al., 2023).

There are also metabolic limitations particular to a species. Dogs and cats, as well as humans, are entirely dependent on dietary sources of vitamin D because their skins are unable to manufacture them. This is also true for young animals, animals that grow quickly, and animals with higher physiological needs (such as high-yielding chickens or lactating sows), which increase the likelihood of vitamin D insufficiency if diets are poorly designed (Giustina et al., 2023).

i. Deficiency-Related Health Conditions

Skeletal illness, caused by faulty calcium and phosphorus metabolism, is the well-documented consequence of vitamin D insufficiency. It manifests as rickets in young animals, which are characterized by stunted growth, lameness, and bone abnormalities. It softens bones, increases fracture risk, and reduces adult productivity (Rinninella et al., 2022).

A lack of vitamin D in poultry results in soft-shelled eggs, decreased hatchability, and weak legs, particularly in broiler birds that grow quickly. Pigs may experience bowed legs, stunted growth, and difficulty standing or walking (Meza-Meza et al., 2022). Due to impaired calcium mobilization, vitamin D-deficient dairy cows may have lower milk production, infertility, and a higher incidence of metabolic diseases, including milk fever (Janoušek et al., 2022).

Vitamin D has a role in immunity that is becoming more widely recognized outside of bone health. Reduced resistance to infection, poor

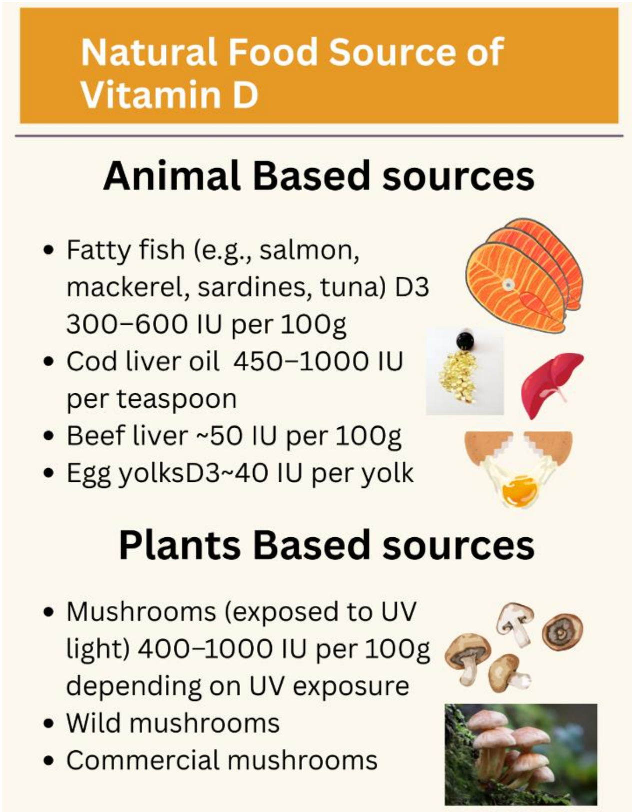

Fig. 1: Animals and plants based food source of vitamin D

wound healing, and a higher prevalence of respiratory or gastrointestinal disease are common symptoms of deficient animals (Neill et al., 2023). Vitamin D is an essential nutrient to guarantee disease resistance since it balances immune cell function and controls the expression of antimicrobial peptides. Additionally, reproductive function is compromised. Numerous studies have shown that vitamin D deficiency can impact fetal growth, delay sexual maturity, and reduce fertility in both male and female animals (Webster et al., 2023).

Generally speaking, vitamin D insufficiency impacts not only the health and welfare of animals but also the productivity and financial rewards of animal husbandry (Jiang et al., 2023). To solve the issue, close attention to diet composition, ongoing vitamin D status monitoring, and knowledge of the unique requirements of each species under various environmental conditions are all necessary (Fernandes & Bell, 2024).

ii. The Reasons for Supplementing Animal Diets with Vitamin D

Since many animals, particularly those kept indoors, receive little sunlight and cannot spontaneously synthesize adequate vitamin D, vitamin D is frequently added to animal diets (Saidi et al., 2023). Furthermore, most elements in standard feed do not contain enough vitamin D, so dietary supplements are required to meet the nutritional demands of animals. Supplementing with vitamin D keeps bones healthy, promotes healthy metabolism of calcium and phosphorus, speeds up growth, increases the quality of the eggshell in chickens, and guards against metabolic illnesses like milk fever in dairy animals (Rebelos et al., 2023).

Furthermore, vitamin D is essential for effective reproduction, strengthens the immune system, and promotes resistance to illness. Supplementing offers various animal species the best possible health, well-being, and productivity (Hoque et al., 2023).

iii. Types of Supplemental Vitamin D

There are various types of commercial vitamin D supplements, including vitamin D_3 (cholecalciferol), vitamin D_2 (ergocalciferol), and 25(OH)D_3. Vitamin D_3 is used in animal feed the most. 25(OH)D_3 is a recently created metabolically active form that bypasses the hepatic conversion phase, increasing efficacy and speeding up the physiological response (Steg et al., 2025). The supplements can be applied using enriched water systems, given by injection, or added to animal feeds as vitamin premixes (Xiang et al., 2024).

Delivery is frequently determined by the animal's age, species, health, and production system.

For instance, 25(OH)D_3 has been shown to more substantially stimulate bone growth and eggshell quality in chicken than regular D_3 (Mavar et al., 2024). Supplementing with vitamin D_3 during transitional periods improved immunological resilience and reduced metabolic problems in dairy cows (Starck et al., 2024).

5. Efficiency of Supplementation in All Species

i. Poultry: The development of the skeleton and the formation of eggshells depend on vitamin D. Numerous research attest to the fact that feeding diets supplemented with D_3 or 25(OH)D_3 increases shell thickness, reduces limb abnormalities and improves bone mineral content (Wei., 2024). Layers with adequate vitamin D produce eggs with superior hatchability and shell quality (Zhou et al., 2024).

ii. Swine: Vitamin D affects pigs' immune system, development rate, and bone strength, especially weaned piglets and sows (Phir et al., 2024). Increased weight gain and decreased lameness have been associated with 25(OH)D_3 supplementation. Additionally, vitamin D facilitates the absorption of calcium, which is necessary for both fetal and milk production, throughout late gestation and breastfeeding (Fernandes & Bell, 2024; Stein, 2024; Steg et al., 2025).

iii. Ruminants: As ruminants, sheep and cattle generate vitamin D when sunlight exposes them. However, in confined animals or throughout the winter, supplementing is crucial. In dairy cows, enough vitamin D reduces the risk of milk fever, improves reproductive efficiency, and aids calcium metabolism during lactation (Smołucha et al., 2024).

iv. Animal companions: Due to their inability to generate adequate amounts through exposure to sunshine, cats and dogs require vitamin D through their diets. Supplementation promotes healthy immune systems in mature animals and appropriate skeletal growth, especially in young pups and kittens (Figure 2) (García-Maldonado et al., 2024).

6. Toxicity and Safety Considerations

Supplementing with vitamin D is beneficial, but taking too much of it might be harmful (Abbas et al., 2025). Vitamin D poisoning or hypervitaminosis D can cause increased blood calcium levels (hypercalcemia). Symptoms include decreased feed intake, animal vomiting, soft tissue calcification, renal damage, and death (Shastak & Pelletier, 2024). Each species has a different amount of toxicity (Shodiqulovich et al., 2024). For example, dogs are extremely sensitive, and even little overdoses can have serious adverse health effects. L livestock will tolerate higher dosages, but long-term over-supplementation will impair organ function and performance (Starck et al., 2024).

Nutritionists follow species-specific guidelines from organizations such as the Association of American Feed Control Officials (AAFCO), the European Food Safety Authority (EFSA), and the National Research Council (NRC) for safety (Sivagurunathan et al., 2024). Thorough formulation processes, cautious application of high-potency preparations like 25(OH)D_3, and routine feed analysis are necessary. It is also crucial to consider how nutrients interact. Excessive dietary calcium or phosphorus may impact vitamin D metabolism and vice versa (Zhang et al., 2024). Therefore, a balanced formulation strategy is required to avoid imbalances that could affect animal productivity and health (Steg et al., 2025).

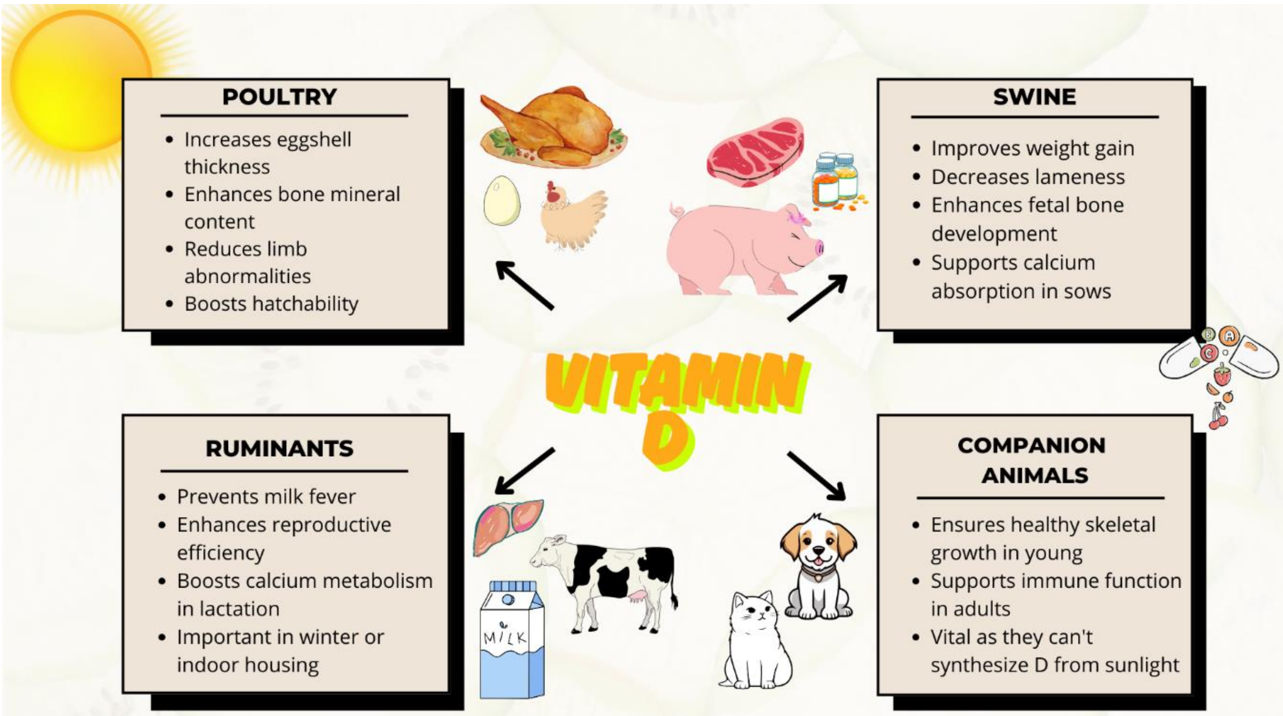

Fig. 2: Efficiency of Supplementation in poultry, swine, ruminants and companion animals

7. New Developments and Research Deficits

Recent developments in animal nutrition have made precision feeding techniques possible. Vitamin D supplementation is tailored to each animal's requirements based on factors such as age, stage of production, health, and genetics (Xiang et al., 2024). One technology that has been shown to increase the stability and bioavailability of vitamin D in feed is nanoencapsulation. The non-skeletal effects of vitamin D, such as immunological regulation, reproductive function, and even stress reduction, are currently being studied (Chen et al., 2025).

More controlled studies are necessary to guarantee causation and the best dosage, as many of these actions are poorly understood (Dodd et al., 2024). Natural and sustainable sources of vitamin D, such as algae-based D_3 and UV-treated fodder, are gaining popularity because they may lessen reliance on artificial pills. More research should be done on these options' economic and environmental aspects (Lilburn & McIntyre, 2024).

Conclusion

Vitamin D is essential for animals to be healthy, productive, and happy. Adding it to animal diets has shown beneficial for the majority of species, particularly when natural synthesis is compromised. However, utilizing the appropriate form, dosage, and delivery method—while accounting for species-specific needs and safety margins—is essential for the greatest outcomes. Evidence-based, balanced supplementation improves performance and infection resistance while guarding against deficient conditions. However, over-supplementation can be detrimental, and strict adherence to recommended criteria requires rigorous consumption monitoring. Given the ongoing developments in animal nutrition, future research is needed to address the sensitive roles of vitamin D, novel delivery systems, and the incorporation of supplements into larger sustainability contexts.

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