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Amino Acid Chelated Minerals

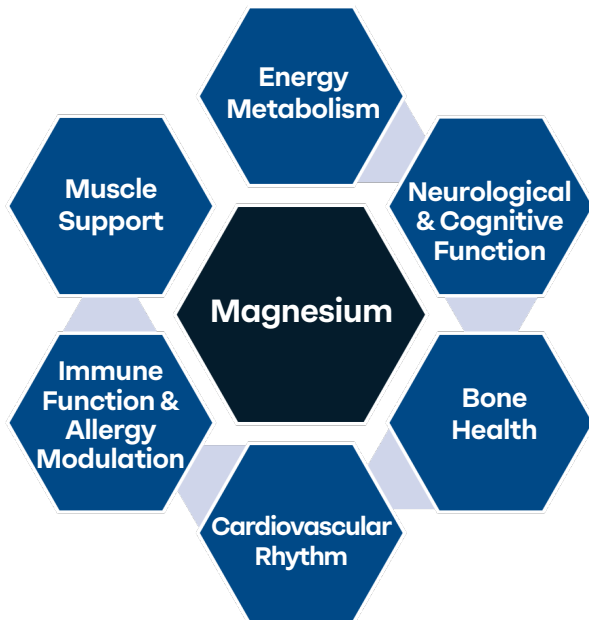
# **Magnesium** – An Indispensable Mineral in Canine & Feline Nutrition: Physiological Roles, Requirements, Sources & Formulation

This manuscript synthesizes current evidence on Magnesium (Mg) physiology, dietary requirements, bioavailability (inorganic vs. chelated), clinical implications (deficiency/excess), and special considerations in CKD and cardiac health. We integrate authoritative standards (AAFCO, NRC, FEDIAF) and recent peer-reviewed studies, and provide practical guidance for formulation and quality assurance.

## Magnesium: Universal Principles Relevant to Companion Animals

Magnesium (Mg) is an essential macro mineral acting as a cofactor for hundreds of enzymes—likely  $\geq 600$ —with additional roles as an activator for many others. It supports nearly all major cellular processes, including energy metabolism, protein and nucleic acid synthesis, and ion transport.

Across species,  $\sim 99\%$  of total body Mg resides in bone and soft tissues, while  $\sim 1\%$  is found in extracellular fluid; therefore, serum Mg alone can under-reflect total body status. These cross-species fundamentals underpin Mg's clinical relevance to neuromuscular, cardiovascular, skeletal, and immune function in dogs and cats.



### Physiological Roles of Magnesium

#### 1. Energy metabolism & enzymatic cofactor:

Mg acts as a cofactor in hundreds of enzymes, including those for ATP generation (glycolysis, oxidative phosphorylation and intracellular signaling) and other metabolic pathways. Magnesium's presence stabilizes the ATP molecule and drives enzymatic reactions for carbohydrate, fat, and protein metabolism.

**2. Muscle support:** Crucial for muscle contraction and relaxation and for normal nerve impulse transmission. Magnesium regulates the flow of calcium ions in muscle cells (acting as a natural calcium antagonist) to allow fibers to relax after contraction, which ensures smooth, coordinated movement. Inadequate Mg impairs relaxation, leading to stiffness, cramps, spasms, and potential atrophy or weakness. In young, growing dogs, deficiency can inhibit growth; active dogs may experience reduced performance and slower recovery. Mg also supports endurance and fatigue reduction and may aid gastrointestinal motility (constipation relief) via smooth muscle function.

**3. Cardiovascular rhythm:** Magnesium plays a key role in maintaining healthy cardiac electrophysiology, supporting efficient, rhythmic pumping. In synergy with potassium and calcium, Mg helps strengthen myocardium and may lower age-related cardiac risks.

Magnesium is required for the proper function of ion pumps (like  $\text{Na}^+/\text{K}^+$ -ATPase) and calcium channels that govern myocardial contraction and vascular tone.

Research insight (puppies): Diet-induced Mg deficiency in male puppies produced lowered weight gain, hyperirritability, convulsions, arterial and myocardial calcification, fibrous plaques in coronary arteries, significant decreases in serum potassium, and electrocardiographic changes, underscoring Mg's importance in cardiovascular development and function (Circulation Research 9(2):387).

#### 4. Neurological development & cognitive function:

Important for brain development, neuron signaling, and synaptic plasticity. Magnesium participates in neurotransmitter release and serves as a gatekeeper for NMDA receptors in the brain, which are involved in learning and memory formation. Adequate Mg can help calm the nervous system, reducing hyperactivity, twitching, and anxiety; it may help dogs respond more calmly to stressors such as loud noises or veterinary visits.

In contrast, magnesium shortage can lead to neural hyperexcitability (irritability, tremors) and cognitive deficits. Animal studies show that a magnesium-deficient diet impairs learning ability, whereas restoring brain magnesium improves memory performance.

Clinically, hypomagnesemia in both humans and pets has been linked to nervous system problems – for example, young dogs with low magnesium become abnormally hyperactive or convulsive until magnesium is replenished.

**5. Bone health:** Contributes to bone mineralization and skeletal integrity across life stages. Approximately 50–60% of total body magnesium resides in bone, where it helps form the crystal lattice alongside calcium and phosphorus. Magnesium is also required for the secretion of parathyroid hormone and the activation of vitamin D, hormones that tightly regulate calcium balance and bone remodeling. Thus,  $\text{Mg}^{++}$  availability affects bone strength: adequate magnesium supports healthy bone density, while chronic deficiency can reduce bone mass or quality—benefiting growing puppies and active adult dogs; maintaining proper Mg helps reduce brittle bones and fractures in seniors.

## 6. Immune function & allergy modulation:

Supports a well-regulated immune response and helps modulate inflammation and allergic reactions. Magnesium is necessary for the function of many immune cells; for instance, T-lymphocytes require sufficient magnesium for effective activation and pathogen killing. It also influences the production of antibodies and complements proper immune cell signaling (e.g., magnesium is a cofactor for immunoglobulin synthesis and other immune processes). When magnesium is deficient, research in both humans and animal models shows disrupted immunity – including elevated pro-inflammatory cytokines (like IL-6, TNF- $\alpha$ ) and aberrant immune cell activity. Magnesium has a stabilizing effect on mast cells (the cells involved in allergic release of histamine); adequate Mg<sup>2+</sup> limits excessive histamine release and thereby can lessen allergic inflammation. In practice, low-magnesium status has been linked to higher propensity for inflammatory stress and allergic hypersensitivity.

### Sources and Bioavailability

Given the wide range of physiological functions that critically depend on magnesium—often exceeding minimum requirements, for example those established by NRC—nutritionists must ensure the inclusion of highly bioavailable and stable magnesium sources in diet formulations.

Inorganic sources such as magnesium oxide, chloride, and sulfate are cost-effective but exhibit variable solubility and bio accessibility. In contrast, organic or chelated forms—such as amino acid chelates (e.g., bisglycinate, proteinate) and magnesium citrate—tend to offer higher bioavailability. However, their efficacy should be validated based on species-specific outcomes.

### Special Populations

In cats with chronic kidney disease (CKD), carefully controlled magnesium enrichment—within phosphate-restricted dietary frameworks—may offer benefits when implemented under veterinary supervision. For dogs with cardiac conditions, magnesium is considered a supportive nutrient alongside omega-3 fatty acids, taurine, and antioxidants.

### Dietary Frameworks

#### Dietary Requirements and Regulatory Standards

AAFCO nutrient profiles (dogs/cats) provide minimum concentrations to prevent deficiency; NRC offers foundational life-stage recommendations; FEDIAF harmonizes EU guidance. Values should be interpreted on a DM and per 1,000 kcal ME basis, validated through product analytics and quality assurance (QA).

## Practical Formulation Guidance

- Ensure magnesium levels meet or exceed AAFCO minimums and remain within canine maximum limits; cross-reference FEDIAF guidelines for EU compliance.
- Prioritize ingredient sources based on bioavailability and stability during processing; validate efficacy of chelated forms through species-specific data.
- Maintain appropriate calcium-to-phosphorus ratios; manage dietary fiber and phytate levels; align acid-base balance with urinary health targets, particularly in feline diets.
- Implement robust quality assurance protocols, including routine analytical verification, in-process controls, and monitoring of urinary parameters when supporting urinary health claims.
- For therapeutic formulations, adjust magnesium levels within clinical monitoring frameworks (e.g., CKD in cats, cardiac conditions in dogs).

### Analytical & Quality Considerations

- Report magnesium content on a dry matter basis and adjust for metabolizable energy (ME) when comparing across diet formats.
- Combine total magnesium assays with mineral balance studies and clinical endpoints—such as urine pH, specific gravity (USG), and relative supersaturation (RSS)—to support nutritional adequacy and health claims.

### Conclusion

Magnesium is a non-negotiable element in canine and feline nutrition, underpinning critical physiological systems including neuromuscular function, cardiovascular stability, skeletal integrity, immune competence, and urinary health.

Optimal outcomes depend not only on meeting baseline requirements but on strategic source selection, matrix interactions, processing resilience, and hydration management.

As scientific understanding advances, the targeted use of highly bioavailable chelated magnesium forms will be pivotal in elevating the efficacy and differentiation of premium formulations.

## References

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