Natural Zeolite in Animal Nutrition

Mechanisms, Selected Animal Applications, Safety, and Regulatory Considerations

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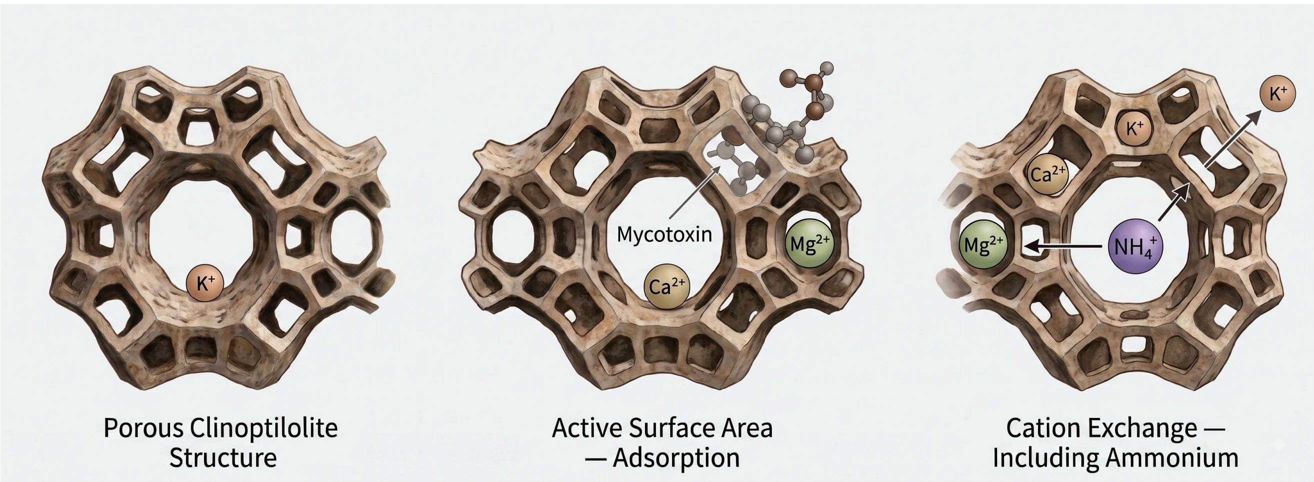

Introduction

Natural clinoptilolite has been used in animal feeding for many years, but the term "natural zeolite" by itself does not adequately describe a feed ingredient. Natural deposits differ in mineralogy, cation exchange capacity, surface area, exchangeable cations, particle size, and chemical purity.

The purpose of this paper is to explain why these differences matter. The emphasis is on the basic mechanisms of natural clinoptilolite and on applications in canine, dairy, and beef cattle, equine, and poultry nutrition. These are areas where the mineral's physical and chemical properties can be particularly important.

The central point is simple: natural clinoptilolite is not a conventional nutrient. Its value comes primarily from what the mineral can do while it passes through the digestive system—cation exchange, ammonium interaction, adsorption, and other surface reactions.

Mechanisms of Efficacy

Cation Exchange Capacity and Selectivity

The crystalline structure of clinoptilolite has a permanent negative charge. This charge is balanced by exchangeable cations, primarily potassium, calcium, sodium, and magnesium. These cations can be exchanged for other positively charged ions as the zeolite passes through the digestive tract [1–3].

Of particular importance is the affinity of clinoptilolite for ammonium ion (NH_4^+). Ammonia and ammonium are produced during the normal breakdown of protein and other nitrogen-containing compounds. Clinoptilolite can exchange cations within its structure for ammonium, which can then be held within the ion-exchange structure [1–3].

Both cation exchange capacity (CEC) and cation selectivity are important. Two natural zeolites with similar clinoptilolite content do not necessarily have the same ion-exchange performance.

Exchangeable Cations

CEC alone does not adequately characterize a natural zeolite. The type and amount of exchangeable cations are also important.

Natural clinoptilolites can vary considerably in potassium, calcium, sodium, and magnesium. A natural zeolite with a high-potassium and low-sodium exchangeable-cation profile can be attractive for animal feed applications. The cations associated with the zeolite participate in ion-exchange reactions as the mineral passes through the digestive system.

For this reason, evaluation of a natural zeolite for animal feed should include both its CEC and exchangeable-cation profile, together with mineral purity.

Active Surface Area

Clinoptilolite has an open crystalline structure containing channels and cavities. This provides internal and external surfaces where adsorption and other surface interactions can occur [1,4].

The active surface is exposed to water, dissolved ions, organic compounds, microbial products, and other materials as the zeolite passes through the digestive tract. Surface area, pore structure, particle size, and surface chemistry can therefore affect performance.

Mycotoxin Adsorption

The active surface of natural zeolite is also important in understanding its potential interaction with mycotoxins. Mycotoxin adsorption is primarily a surface phenomenon rather than simply a cation-exchange reaction [4,5].

Mycotoxins differ greatly in molecular size, structure, polarity, and surface affinity. Adsorption therefore depends on both the toxin and the physical and chemical properties of the mineral surface. Natural clinoptilolite should not be considered a universal mycotoxin binder. Aflatoxins generally are more readily adsorbed by mineral adsorbents than some other important mycotoxins [4,5].

The important point is that the large and reactive surface of clinoptilolite provides sites where adsorption can occur.

Not All Natural Zeolites Are the Same

Important properties include clinoptilolite content and mineralogy, CEC and selectivity, exchangeable potassium, calcium, sodium and magnesium, active and accessible surface area, pore structure, particle size, and chemical purity.

Results obtained with one natural clinoptilolite cannot automatically be expected from every material sold as natural zeolite. The source and quality of the mineral matter.

Canine Nutrition

Aflatoxin Risk in Dogs

Aflatoxins are toxic metabolites produced primarily by certain Aspergillus molds. They can occur in corn and other agricultural ingredients used in animal feeds. The liver is the primary target of aflatoxin toxicity, and sufficiently high exposure can result in serious illness or death [6,7].

Dogs are particularly vulnerable because they may consume the same food every day for long periods. If that food is contaminated, exposure can continue day after day [6]. This makes mycotoxin control an important consideration in canine diets.

Active Surface and Mycotoxin Adsorption

Natural clinoptilolite has a large and chemically active mineral surface. Mycotoxin adsorption depends on the structure of the toxin and on the physical and chemical properties of that surface [4,5].

Aflatoxins are among the mycotoxins most effectively adsorbed by several mineral adsorbents. However, adsorption varies among minerals and among toxins. The appropriate claim is not that clinoptilolite binds every mycotoxin, but that a properly characterized material provides active adsorption sites capable of interacting with certain compounds in the gastrointestinal tract.

Gastrointestinal and Fecal Effects

A controlled study using extruded dog diets evaluated clinoptilolite inclusion rates from 0 to 50 g/kg and measured nutrient and energy digestibility, fecal characteristics, and palatability [8]. The study provides direct evidence that clinoptilolite can be incorporated into extruded canine diets.

The porous structure and adsorption properties of clinoptilolite can also influence water and other materials passing through the gastrointestinal tract. This is one reason zeolite has been studied for fecal characteristics in companion animals [8].

Why Material Quality Matters

For canine applications, important characteristics include high clinoptilolite content, high CEC, large active surface area, favorable exchangeable-cation balance, controlled particle size, consistent mineralogy, and low levels of undesirable trace elements.

Natural zeolite should not be treated as a commodity ingredient where all sources are assumed to perform equally.

Ruminant Nutrition

The rumen is a large fermentation system in which feed, water, minerals, microorganisms, fermentation products, and nitrogen compounds are continuously mixed. The CEC, ammonium affinity, and active surface area of natural clinoptilolite provide several mechanisms for interaction in this environment [1–3,9].

Dairy Cattle

Aflatoxin and Milk Quality

When a dairy cow consumes aflatoxin B1 (AFB1), a portion can be metabolized to aflatoxin M1 (AFM1) and transferred into milk. The active surface of clinoptilolite provides a mechanism for adsorption before absorption by the animal.

Katsoulos and coworkers studied 15 commercial dairy herds with elevated or near-limit AFM1 concentrations in bulk-tank milk. Natural clinoptilolite was added at 200 g/cow/day. After seven days, AFM1 concentrations in milk were reduced by an average of 56.2% [10]. Finer clinoptilolite produced a greater reduction than the coarser material, supporting the importance of accessible surface area and particle size.

Rumen Ammonium Exchange

Protein entering the rumen is partially degraded by microorganisms, producing ammonia and ammonium. Rumen microorganisms can use this nitrogen to make microbial protein. When production exceeds utilization, excess ammonia can be absorbed, converted to urea, recycled, or excreted.

Clinoptilolite has a strong affinity for ammonium. Its ion-exchange sites can act as a temporary ammonium reservoir [1–3,9]. Because ion exchange is reversible, this provides a mechanism for modifying ammonium concentration and availability as rumen conditions change. Results in cattle have not been uniform, which again points to the importance of particle size and material properties [11,12].

Rumen Bypass and Milk Fat

Natural clinoptilolite can also modify interactions among feed components, microorganisms, and fermentation products in the rumen. This provides a possible rumen-protective or bypass mechanism, allowing a greater portion of some dietary components to pass through the rumen and become available farther down the digestive tract [9].

This is of interest in dairy cattle because changes in rumen fermentation and nutrient availability can affect milk composition, including butterfat. Some zeolite studies have reported changes in milk composition, while others have not [9,13]. Clinoptilolite should therefore not be promoted as an ingredient that will automatically increase butterfat. The more defensible point is that its active surface and ion-exchange properties can modify the rumen environment.

Natural Zeolite as an Alternative Rumen Buffer

Natural zeolite has also been evaluated as an alternative to sodium bicarbonate for rumen buffering.

In a 12-week Utah State University study, 30 lactating Holstein cows received a control ration, 1.4% sodium bicarbonate, or 1.4% magnesium-exchanged natural zeolite [14,15]. Ruminal pH increased with the zeolite treatment compared with the control and was similar to the response with sodium bicarbonate. Dry matter intake and milk production were not adversely affected. The researchers concluded that the zeolite product could cost-effectively replace sodium bicarbonate as a ruminal buffer under the conditions studied, while recommending additional evaluation under greater acidosis challenge [14,15].

Zeolite and sodium bicarbonate do not work in exactly the same way. Sodium bicarbonate directly neutralizes acidity. Zeolite provides a large active mineral surface and a reversible cation-exchange system. Magnesium can provide an additional buffering function.

Dolomitic minerals are also of interest because they contain calcium and magnesium carbonates. Utah State researchers separately investigated dolomitic limestone as a rumen buffer [16]. A clinoptilolite-dolomite combination therefore has a reasonable technical basis as a low-sodium mineral buffering system: the zeolite contributes cation exchange, ammonium affinity, and active surface area, while dolomite contributes calcium, magnesium, and carbonate. The performance of a specific blend should be established for that formulation.

Transition Dairy Cows and Calcium

Synthetic zeolite A has been studied for prevention of hypocalcemia around calving. Feeding Zeolite A before calving can reduce dietary calcium availability and stimulate calcium-regulating mechanisms before the large calcium demand at the start of lactation [17,18].

This work demonstrates how strongly zeolite ion exchange can influence mineral availability in the digestive system. Synthetic zeolite A and natural clinoptilolite are different materials, however, and results with zeolite A should not automatically be attributed to natural clinoptilolite.

Beef Cattle

Natural clinoptilolite entering the rumen provides a large active surface and ion-exchange sites that can interact with ammonium and other cations. Research in finishing and backgrounding cattle has examined nitrogen utilization, nutrient digestibility, animal performance, manure nitrogen, and ammonia emissions [11,12,19].

Results are mixed. Some studies report changes in nitrogen utilization, digestibility, manure characteristics, or ammonia emissions, while others show little or no improvement in animal performance. The scientific case should therefore not depend on the claim that zeolite will always increase gain or feed efficiency.

The stronger argument is that clinoptilolite introduces an active ion-exchange and adsorptive mineral into the rumen. Its performance depends on mineralogy, CEC, exchangeable-cation balance, active surface area, and particle size.

Equine Nutrition

The Equine Digestive System

The horse does not have a rumen, but it has an extensive microbial fermentation system in the cecum and colon. This creates an environment containing water, minerals, microorganisms, fermentation products, and nitrogen compounds that can interact with zeolite as it passes through the digestive tract.

The potential value of natural clinoptilolite again comes primarily from CEC, active surface area, and the type and balance of exchangeable cations [1–3].

Ammonium Exchange and Active Surface

Clinoptilolite's affinity for ammonium provides a mechanism for interaction with nitrogen compounds produced during microbial fermentation. Its large active surface provides sites for adsorption and other surface reactions. The same surface provides a potential mechanism for interaction with certain mycotoxins and other undesirable compounds [4,5].

Direct Equine Research

Direct research in horses is limited but encouraging. In a study involving sport horses, natural clinoptilolite was fed at 70 g/horse/day and a finer-particle material at 28 g/horse/day. The researchers reported favorable changes in several blood biochemical measurements [20].

The limited number of controlled equine studies means that clinoptilolite should not be promoted as treating a condition or automatically improving performance. The stronger case is based on established mineral chemistry together with the available direct feeding evidence.

Natural and Synthetic Zeolites

Synthetic zeolites provide additional evidence that zeolite ion-exchange reactions remain active in animal digestive systems and can produce measurable biological effects. The dairy calcium work with synthetic zeolite A is a good example [17,18].

Synthetic zeolites and natural clinoptilolite are not interchangeable. Their structures, exchange capacities, pore sizes, and exchangeable cations can differ substantially. Synthetic zeolite research is useful for understanding the mechanism, but claims for natural clinoptilolite should be based on natural clinoptilolite evidence.

Not All Zeolites Are Equal

For equine nutrition, important characteristics include high clinoptilolite content, high CEC, large active surface area, favorable exchangeable-cation composition including high potassium and low sodium, controlled particle size, low levels of undesirable trace elements, and consistent mineralogy.

A properly characterized clinoptilolite is not simply an inert filler. It provides an active mineral surface and ion-exchange system throughout passage through the equine digestive tract.

Poultry Nutrition

Natural and synthetic zeolites have been studied extensively in poultry nutrition. The research is particularly useful because it demonstrates several zeolite properties, including interactions with calcium and mineral metabolism, effects on feed utilization, and adsorption of certain mycotoxins through the active mineral surface.

Eggshell Quality and Calcium Metabolism

Eggshell formation places a substantial demand on calcium metabolism in laying hens. The ion-exchange properties of zeolites provide a mechanism by which the mineral can influence the availability and utilization of calcium and other minerals within the digestive system.

Research with natural clinoptilolite has reported improvements in eggshell quality. Olver found significant effects from feeding 5% clinoptilolite on the number of eggs produced, eggshell thickness, feed utilization, and droppings moisture [27]. Malecky and coworkers also evaluated natural clinoptilolite for its effects on eggshell quality and reviewed earlier work reporting increased serum calcium and improved eggshell thickness with dietary clinoptilolite [28].

Improved eggshell quality has a direct economic importance. Poor shell quality increases the number of cracked and broken eggs during collection, grading, packaging, and transportation [28]. Maintaining adequate shell strength becomes particularly important with larger eggs. Improved shell thickness and shell quality can therefore increase the number of saleable eggs and the marketable weight of eggs produced, even when zeolite does not increase individual egg weight.

Research with synthetic sodium zeolite A provides additional evidence that zeolite ion exchange can influence calcium metabolism and bone mineralization [29–31]. Natural clinoptilolite and synthetic zeolite A are different materials and should not be considered interchangeable. The response also depends upon the calcium and phosphorus balance of the complete ration.

Broiler Feed Efficiency and Bone Development

Feed efficiency is one of the most economically important measurements in broiler production. A relatively small reduction in the amount of feed required to produce a pound of meat can have a significant effect on production cost.

Elliot and Edwards directly compared natural and synthetic zeolites in broiler chickens. Supplementation with 1% natural zeolite significantly improved feed efficiency [32]. Other research has reported increased broiler body weight without a corresponding improvement in feed conversion [33]. Improved feed efficiency should therefore be considered a potential benefit under appropriate conditions rather than an effect that will occur with every zeolite or ration.

Zeolites have also been studied for their effects on bone development. Ballard and Edwards reported increased bone ash and reduced incidence and severity of tibial dyschondroplasia in broilers receiving dietary zeolite. Calcium absorption was also increased in one experiment [30]. Edwards subsequently demonstrated that the response was strongly influenced by the calcium and phosphorus composition of the ration [31].

These studies provide additional evidence that zeolite ion exchange can influence calcium utilization, bone mineralization, and mineral interactions within the digestive system.

Mycotoxin Adsorption

Mycotoxins represent another potential application of natural clinoptilolite in poultry diets.

As discussed earlier in this paper, the large active surface of clinoptilolite provides adsorption sites capable of interacting with certain mycotoxins [4,5]. This is a different mechanism from the ion-exchange reactions involved in calcium and mineral metabolism.

Natural clinoptilolite should not be considered a universal mycotoxin binder. Adsorption depends upon the particular mycotoxin and the physical and chemical properties of the mineral surface [4,5]. The published tibial dyschondroplasia studies also should not be interpreted as demonstrating that mycotoxin adsorption was responsible for the observed reduction in tibial dyschondroplasia [30,31].

As with other animal applications, poultry performance depends upon the properties of the zeolite being fed, including clinoptilolite content, cation exchange capacity, active surface area, exchangeable-cation composition, particle size, mineral purity, and consistency.

Regulatory Status, Safety, and Organic Production

United States – FDA

Animal feed and pet food ingredients in the United States must have an appropriate regulatory basis for their intended use [21,22].

In 2018, a GRAS notice was submitted to FDA for clinoptilolite of sedimentary origin for use as an anticaking agent at levels up to 1% of the complete diet in cattle, swine, goats, sheep, broiler chickens, turkeys, cats, and dogs [23]. FDA responded that it had “no questions” regarding the notifier's GRAS conclusion under the stated conditions of use.

This does not mean that every natural zeolite or every possible use is FDA approved. The conclusion applies to the material, specifications, intended use, species, and conditions described in the notice.

European Food Safety Authority

EFSA evaluated clinoptilolite of sedimentary origin in 2013 and concluded that 10,000 mg/kg complete feed, equivalent to 1% of the diet, could be considered safe for all animal species under the conditions evaluated [2].

In 2025, EFSA reevaluated the additive and concluded that it remains safe for all animal species, consumers, and the environment under the authorized conditions of use [24]. These evaluations provide important independent support for the safety of properly characterized clinoptilolite.

Use in Organic Animal Production

Under the USDA National Organic Program, naturally occurring or nonsynthetic substances are generally permitted unless specifically prohibited [25,26]. Natural clinoptilolite is a mined mineral. Mining and physical processing such as crushing, drying, grinding, screening, and sizing do not by themselves make the material synthetic.

A mined natural zeolite does not become “certified organic” in the same manner as an agricultural crop. Separate third-party organic certification of the mineral itself is generally not required simply to establish that it is a natural mineral. The supplier should be able to document the mineral source, processing methods, and absence of prohibited additives or treatments.

The final determination for use by a certified organic operation remains with that operation's USDA-accredited organic certifying agent [25,26].

Material Quality and Claims

Regulatory evaluations reinforce a central point: not all natural zeolites are the same. Mineralogy, clinoptilolite content, chemical composition, CEC, exchangeable cations, active surface area, particle size, moisture, trace elements, and lot-to-lot consistency are important to both performance and safety.

Claims also matter. Explaining published research on adsorption, rumen effects, or animal feeding is different from claiming that a commercial product prevents or treats disease. The white paper should continue to distinguish scientific mechanisms from commercial product claims.

Conclusions

Natural clinoptilolite should not be evaluated simply as a mineral commodity. Its usefulness in animal nutrition comes from a combination of physical and chemical properties: cation exchange capacity, affinity for ammonium, active surface area, pore structure, exchangeable-cation composition, particle size, and purity.

The animal-feeding literature does not show that every zeolite produces the same result in every ration. That is not surprising. Natural deposits differ, diets differ, inclusion rates differ, and the biological conditions differ. The more useful question is whether the particular clinoptilolite has the properties needed for the intended application.

In canine nutrition, the active surface and mycotoxin literature are particularly relevant. In dairy cattle, the strongest areas include AFM1 reduction, rumen ammonium interaction, and rumen buffering. In beef cattle, nitrogen utilization and manure ammonia are important areas of study. In horses, the direct literature is smaller, but the hindgut fermentation environment and established ion-exchange chemistry provide a reasonable technical basis for continued use and study. In poultry, the literature provides evidence for effects on eggshell quality and calcium metabolism, bone mineralization, and, under some conditions, feed utilization.

The regulatory record also supports the use of properly characterized clinoptilolite under defined conditions. FDA GRAS documentation, EFSA safety evaluations, and USDA organic rules provide a useful framework for feed manufacturers.

The practical conclusion is that the question should not be simply, “Does the product contain natural zeolite?” The better question is, “What are the physical and chemical properties of the natural zeolite being used?”

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