

## **Improving Milk Production, Milk Quality, and Plant Productivity Through Zeolite: A Review**

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### **ABSTRACT**

*Zeolite is a natural mineral with wide-ranging applications in scientific and industrial fields such as animal husbandry, agriculture, water purification, the food industry, and pharmaceuticals. In animal husbandry, its inclusion in the diet of dairy cows leads to higher milk yield, improved milk quality, better calcium balance, and stronger immunity in calves. The mineral can also bind heavy metals and toxins, thereby increasing the safety of production in both livestock and crop farming.*

*In agriculture, zeolite improves the structure and composition of the soil, supports the retention of water and nutrients, and facilitates the uptake of macro- and micronutrients by plants, which enhances their resilience to various stress factors.*

*Milk monitoring is essential for tracking animal health and limiting the spread of diseases. In recent years, traditional and often costly monitoring methods have been increasingly replaced by modern sensor-based technologies that provide faster, more accessible, and equally accurate results.*

*Keywords: zeolites, livestock production, sustainable agriculture, milk production, milk quality.*

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### **INTRODUCTION**

According to various studies, the addition of zeolite to the diet of dairy cows significantly increases milk yield, primarily due to improved metabolic processes and enhanced energy status in the animals [1 - 3]. It has been established that the effect depends on the daily intake of zeolite, and its beneficial impact on metabolism explains the observed increase in productivity [1, 2].

In addition to stimulating milk production, zeolite also supports the mineral balance in the

body by facilitating the absorption of calcium, phosphorus, and magnesium. This is particularly important for the prevention of hypocalcemia (milk fever), which often results from unbalanced feeding practices [3, 4].

Zeolite is also successfully applied in agriculture. It improves water retention and the cation exchange capacity of soils, while simultaneously enhancing soil structure and microbiological activity. As a result, nutrient uptake is improved and crop yields are increased [5 - 7].

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The incorporation of zeolite into the soil environment leads to an improvement in soil structure, enhanced water retention capacity, and a reduction in nutrient losses. These effects create optimal conditions for plant growth and development. Due to its high ion-exchange capacity, zeolite facilitates the uptake of essential nutrient ions such as potassium, calcium, and magnesium, which positively influences the physiological processes in plants. As a result, an increase in the biological value of the crop is observed, including higher contents of antioxidants and minerals, thereby improving its nutritional quality [6, 8 - 11].

Furthermore, zeolite helps reduce the harmful effects of heavy metals, increases plant resistance to drought and salinity, and enriches fruits and seeds with essential nutrients [12 - 14].

Ferguson and Pepper state that zeolite works differently in different soils. It is most beneficial in coarse-textured soils that hold fewer nutrients [15, 16].

## EXPERIMENTAL

Research on zeolite is conducted both in controlled laboratory environments (*in vitro*) and on live animals (*in vivo*) to observe its effects on the organism. In addition, field experiments are carried out on soils and plants, allowing for a more comprehensive evaluation of its impact in agricultural practice [8, 17].

In animals, milk is analysed for parameters such as fat content, protein levels, fatty acid composition, and density. Chromatographic methods are used to examine both fatty acids and heavy metals in milk and feces. This provides data on compounds like myristic, lauric, and palmitic acids, which are important indicators of milk quality [18]. Spectrophotometry is employed to determine the concentrations of substances such as proteins, fatty acids, and immunoglobulins by measuring the interaction of light with the samples [19].

Feeds are also analysed to assess whether zeolite influences the content of minerals and trace elements [3, 6]. Fecal analysis serves as an indicator of nutrient absorption efficiency and the effect of zeolite on digestive processes [4]. For this purpose, both spectrophotometric and chromatographic methods are applied [9, 18 -20].

Soil analyses focus on parameters such as organic matter content, water-holding capacity, pH, cation exchange capacity (CEC), and the presence of heavy metals [6, 21, 22]. Plants grown in zeolite-treated soils are evaluated for characteristics such as biomass, height, chlorophyll content, proteins, minerals, and trace elements [23, 24]. To determine their resistance to abiotic stress, levels of antioxidant enzymes and stress-related proteins are measured [11, 13, 25].

## RESULTS AND DISCUSSION

Fig. 1 presents an Ishikawa cause-and-effect diagram illustrating the impact of zeolite on cow's milk in a farm setting. The diagram also outlines various approaches to protect and improve milk quality. It demonstrates how multiple factors - such as nutrition, housing conditions, stress, and the use of additives like zeolite - interact and collectively influence animal health and milk quality.

The cause-and-effect diagram is structured around seven main categories:

- Milk quality;
- Animal health status;
- Feed;
- Colostrum and calf health;
- Housing conditions and care;
- Stress factors;
- Methods for analysis and monitoring.

### Milk quality

The addition of zeolite to cow feed has numerous positive effects on milk quality. It

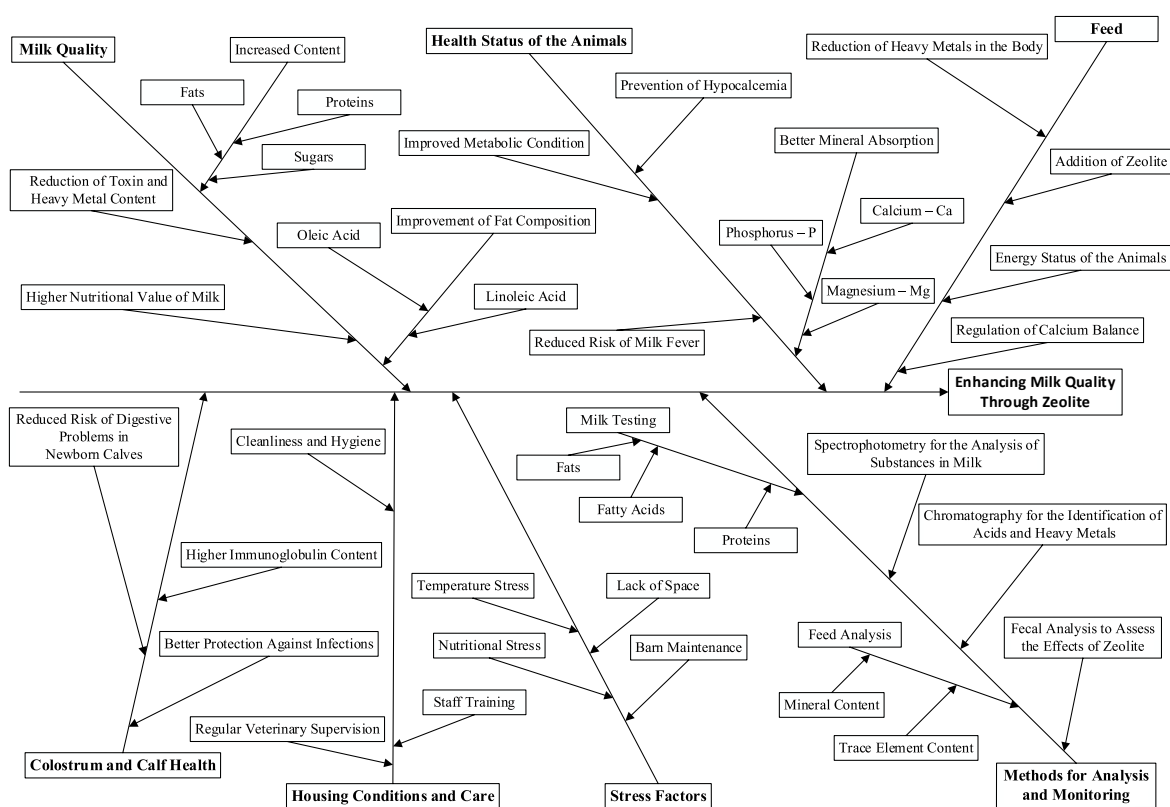


Fig. 1. Ishikawa Cause-and-Effect Diagram.

increases the levels of fats, proteins, and sugars, thereby enhancing the nutritional value and energy density of the milk - key factors for consumers seeking a healthier product. Moreover, zeolite aids in detoxifying the body by adsorbing heavy metals and toxins, which in turn improves the safety of the milk [1, 2, 18].

The higher protein and fat content not only boosts the nutritional profile but also strengthens the immune protection of calves [4, 26]. These nutrients are essential for cellular growth and repair, making them highly important for both animal development and human health.

### Animal health status

Animal health has a direct impact on milk quality. Improving metabolism and mineral balance-particularly calcium-enhances the absorption of nutrients, which leads to higher milk quality and better fat composition. Proper

calcium regulation helps prevent the onset of milk fever, thereby maintaining the health of dairy cows and increasing milk production.

Additionally, zeolite reduces metabolic disorders and strengthens the immune system, improving the overall condition and fertility of the animals [3, 4, 27].

### Feed

Nutrition is one of the most critical factors influencing milk quality. The addition of zeolite to animal feed improves digestion and reduces the accumulation of toxins in the body. Furthermore, zeolite facilitates the absorption of essential minerals such as calcium, phosphorus, and magnesium, which are vital for muscle function and reproductive health in animals.

These effects contribute to increased milk yield and improved colostrum quality [1, 3 - 5, 26].

### **Colostrum and calf health**

The health status of newborn calves is closely linked to the quality of the milk, which reduces the likelihood of digestive disorders. High levels of immunoglobulins in colostrum enhance immune protection and safeguard calves against infections, while low toxin content contributes to better overall health [4, 26].

### **Housing conditions and care**

A well-maintained and hygienic barn improves animal health and milk quality. Zeolite contributes by absorbing moisture and reducing unpleasant odors, creating a healthier environment.

Regular veterinary supervision and staff training also play important roles, ensuring the proper use of zeolite and effective monitoring of its effects on the cows [4].

### **Stress factors**

Stress from various sources such as high temperatures, unbalanced nutrition, or lack of space negatively affects the health and milk productivity of cows. To reduce heat stress, good ventilation and cooling systems are implemented, while a balanced diet helps prevent nutritional stress. Zeolite supports animals in coping with these types of stress, leading to increased milk production [1, 3, 28].

### **Methods for analysis and monitoring**

To ensure high milk quality, regular monitoring and analysis are essential.

- *Spectrophotometry* - used to analyse substances in the milk.
- *Chromatography* - employed to identify toxins and heavy metals.
- *Feed analysis* - conducted to determine the content of minerals and trace elements.
- *Fecal examination* - performed to evaluate the effectiveness of zeolite.

The addition of zeolite to the feed of dairy cows leads to significant improvements in

both productivity and milk quality, while simultaneously strengthening animal health and enhancing the immune protection of calves. Zeolite reduces contaminants in the milk, making it safer for consumption. The Ishikawa diagram demonstrates that milk quality depends on the interaction of various factors such as nutrition, health, housing conditions, and stress, with zeolite exerting a positive influence on all these aspects.

Regular analysis and monitoring of key indicators are essential for optimizing processes and ensuring high standards of dairy products. The incorporation of zeolite in dairy farms represents a promising strategy to enhance both productivity and milk safety.

The intake of zeolite does not alter the composition of the milk but increases its quantity [1, 3]. Cows receiving zeolite produce more milk with slightly elevated levels of fats, proteins, and sugars [2]. Additionally, zeolite helps maintain calcium balance in the body, which is crucial for preventing health issues such as milk fever after calving [3]. Studies show that cows supplemented with zeolite have higher blood calcium levels and a reduced risk of metabolic disorders [4].

Zeolite also improves the quality of colostrum - the first milk vital for the health of newborn calves - by increasing the content of immunoglobulins, which strengthen their immune protection and reduce the risk of infections [4, 26]. Additionally, it raises the levels of beneficial fats in the milk, such as oleic and linoleic acids, making the milk more nutritious [18].

An additional advantage of zeolite is its ability to reduce the content of heavy metals such as lead and cadmium, which can enter cows' bodies through contaminated feed or water and pose a risk to human health. Zeolite acts as a natural filter, preventing these harmful substances from passing into the milk [18]. Calves whose mothers receive zeolite are healthier and less frequently suffer from digestive problems, likely due to the improved quality of the colostrum [26].

### **The impact of zeolite on soil properties and plant productivity**

Zeolite improves soil properties by enhancing the soil's ability to retain and exchange nutrients such as potassium and calcium, increasing water retention, boosting organic matter content, and stimulating microbiological activity [5, 6, 8, 29]. These improvements facilitate better uptake of essential macro- and micronutrients by plants, leading to healthier growth, increased biomass, and higher yields [7, 23, 24]. Additionally, zeolite reduces the toxic effects of heavy metals, enhances plants' resistance to drought and salinity, and increases the nutritional value of fruits and seeds [14, 20, 29].

Moreover, zeolite aids in the remediation of contaminated soils by adsorbing heavy metals such as cadmium, lead, and zinc, thereby reducing their uptake by plants and supporting sustainable and safe agricultural practices [11, 20, 25, 29].

### **Origin and properties of zeolite**

Alex F. Cronstedt, a Swedish mineralogist and chemist, discovered natural zeolite in 1756. This mineral has been known to humanity since ancient times, when it was used in construction. Today, zeolite finds wide applications in agriculture, animal husbandry, medicine, and even household uses. It is characterized by its unique crystalline structure [30].

In animal husbandry, zeolite is added to the feed of cows, where it binds and removes toxins and heavy metals, helping to improve their health. Additionally, this mineral reduces ammonia emissions, leading to a cleaner and more comfortable environment in the barn.

Zeolites are classified according to their origin: natural zeolites - minerals formed naturally; synthetic zeolites - produced through controlled industrial processes [27]. These minerals are mainly found in regions with a volcanic history or currently active volcanic zones [31].

### **Veterinary practice**

Clinoptilolite, a type of zeolite, is widely used in veterinary medicine as an effective detoxifying agent, especially in cases involving mycotoxins and heavy metals. Beyond its purifying properties, it exhibits a range of biologically active effects - it has antioxidant properties, supports blood clotting, reduces diarrhea, stimulates growth, and demonstrates antiviral, antibacterial, and immunostimulatory actions.

Zeolites, including clinoptilolite, are valued for their ability to bind and gradually release metal ions with antimicrobial effects such as  $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ , and  $\text{Ag}^+$ , which inhibit the growth of pathogenic microorganisms. In dairy cows, clinoptilolite is believed to support metabolic and hormonal regulation, enhance antioxidant defence, and thereby contribute to improved health, increased fertility, and higher milk yield [28].

### **CONCLUSIONS**

Zeolite is a natural mineral with numerous beneficial properties and finds wide application in both animal husbandry and agriculture. In dairy cows, its addition to feed leads to increased milk production, improved colostrum quality, and better mineral balance in the body. This helps reduce the risk of diseases such as milk fever and enhances the content of valuable substances like fats and immunoglobulins in the milk. Moreover, zeolite reduces the levels of harmful metals and toxins, making the milk safer for consumption.

In agriculture, zeolite improves soil properties by increasing water and nutrient retention, activating beneficial microflora, and enhancing the uptake of elements by plants. This results in healthier crops, higher yields, and greater resilience to adverse conditions.

Modern analytical methods confirm the benefits of using zeolite, establishing it as an effective, environmentally friendly, and economically viable means to boost productivity

and quality in farming. Beyond supporting the health of animals and plants, it also contributes to the safety of the food chain and environmental protection.

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