Biosecurity in livestock farming: strategic use of lime by-products to prevent infectious diseases and improve animal health

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ABSTRACT
Objective: To provide an expanded understanding of lime and its strategic uses, promote best-use practices, and reduce problems associated with livestock diseases. These measures will strengthen biosecurity in the livestock sector and protect public health.
Design/Methodology/Approach: A systematic review was carried out to update essential knowledge for everyone interested in the livestock sector, strengthening biosecurity in livestock farms and safeguarding public health.
Results: Lime and its by-products are some of the most widely used disinfectants to prevent and control infectious livestock diseases. As one of their action mechanisms, lime-based disinfectants can affect vital components of bacterial cells, reducing the risk of antimicrobial resistance.
Study Limitations/Implications: Applying different disinfectants depends on environmental factors and animal and human safety considerations.
Findings/Conclusions: Applying biosecurity measures throughout the production chain reduces the risk of introducing and spreading new pathogens on livestock farms. Meanwhile, the affordability of lime and its by-products facilitates disinfection and carcass management in facilities. Lime slurry and lime water are useful as remarkable facilitators of carcass decomposition and space disinfection.

Keywords: Livestock biosecurity, infectious diseases, lime, disinfectants.

INTRODUCTION

Livestock farming is one of the primary activities of the agricultural sector, focusing on raising domesticated animals and producing by-products for human consumption. This activity plays a significant role worldwide, accounting for 40% of agricultural production (Herrero *et al.*, 2015). In Mexico, livestock farming is one of the most important economic activities (SIAP, 2017).

However, one of the most significant challenges to livestock farming lies in controlling infectious diseases. Not all of these diseases can be tackled through preventive medicine (vaccines, bacterins, dewormers), which adds a layer of complexity to animal health management in this sector. In this regard, effective biosecurity —whose implementation encompasses practices and measures aimed at preventing the entry, spread, and transmission of pathogens, such as viruses, bacteria, and parasites— not only helps to reduce mortality among livestock but can also increase productivity and decrease the use of antibiotics (Maye and Chan, 2020). Furthermore, various animal-source foods (*e.g.*, meat, eggs, and milk) have been linked to the transmission of pathogens responsible for zoonotic diseases that impact consumers (Libera *et al.*, 2022).

Overall, infected animals can excrete a high load of viruses, bacteria, and parasites through nasal discharge, saliva, urine, feces, and even their carcasses, facilitating the spread and contamination of farms, urban settlements, and the environment in general (Stephens *et al.*, 2019). An additional risk of cross-contamination is present in farms through surfaces such as shoe soles, work clothing, and various materials (plastic, wood, metal, or textiles) that can be sources of infection for up to four days after contamination (Alam *et al.*, 2018). Therefore, cleaning and applying disinfectants are essential for the control of these diseases.

Three key elements must be considered to ensure optimal biosecurity in the agricultural industry: preventive medicine, hygiene, and the application of disinfectants (Maye and Chan, 2020). In this context, lime is a highly relevant resource that substantially benefits the prevention and control of infectious diseases due to its antibacterial properties and economic accessibility. Furthermore, the direct use of lime is recommended for organic matter. Lime can be found in various standard forms —such as quicklime (calcium oxide), slaked lime (calcium hydroxide), lime slurry, and lime water (aqueous suspensions)— all of which have disinfectant capabilities. The appropriate choice will depend on the surface and specific purpose —whether it will disinfect facilities or handle contaminated carcasses and objects (Maillard and Pascoe, 2023).

Therefore, this review explores the importance of biosecurity in livestock farming. The appropriate selection and strategic application of disinfectants and lime products will contribute to the prevention and control of infectious diseases in livestock. Additionally, the review will provide general knowledge on best practices for applying disinfectants and lime products in the agricultural sector for anyone interested in the subject. The review aims to strengthen the biosecurity of livestock operations, reduce risks to animal health, and safeguard public health.

Uses and properties of lime in animal breeding

Lime is a mineral product widely used worldwide and is fundamental to animal husbandry (Matsuzaki *et al.*, 2021). Due to its antibacterial properties and low cost, it is used to combat infectious diseases in the livestock, poultry, and swine industries (Yamanaka *et al.*, 2020). The resistance of microorganisms to biocides is based on their type and unique physiological characteristics. Figure 1 shows the susceptibility of different types of microorganisms to disinfectants. The intrinsic mechanisms of vegetative bacteria, bacterial endospores, and biofilms (multicellular and sessile bacterial communities) can be considered separately (Maillard and Pascoe, 2023).

Considering critical properties is essential for the selection of lime. Such properties include its specific surface area —which influences its adsorption capacity and reactivity to trap gaseous pollutants— and particle size —which accelerates reactions (Rashad, 2022).

Quicklime (calcium oxide), a by-product of the calcination of limestone, is widely used in livestock farming as a prophylactic measure against infectious diseases, primarily due to its low cost. Its action mechanism is based on its capacity to saponify fats and coagulate microbial membranes and other cells. Additionally, quicklime dehydrates tissues to the point of destruction, preventing the spread of pathogens and reducing the odors from decomposing organic matter (Maillard and Pascoe, 2023). It also prepares caustic and scarifying solutions that eliminate cattle pustules, warts, and excrescences (Maksimović *et al.*, 2017).

Hydrated lime contains more than 65% calcium hydroxide (Ca(OH)) that looks like a fine white powder, is slightly soluble in water, and is used to inactivate pathogens (Thammakarn *et al.*, 2015). Mixed with water, it releases a significant amount of heat. It is also known as slaked lime because calcium oxide is "slaked" upon contact with water, releasing great heat. This situation should be considered during handling.

Hydrated lime disinfects inert objects and surfaces, destroying a wide variety of microorganisms (Maillard and Pascoe, 2023). However, it is sensitive to atmospheric carbon dioxide, which converts it into calcium carbonate. Therefore, it should be stored correctly

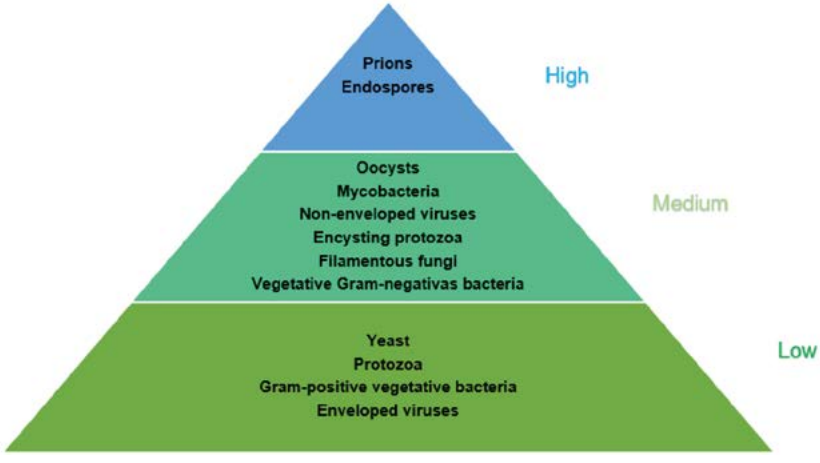

Figure 1. Susceptibility of microorganisms to disinfectants. Adapted from Maillard and Pascoe (2023).

in an airtight container protected from light or in a sealed vial with an oversaturated solution (using distilled water) (Oates, 2000).

According to Mohammadi *et al.* (2012), calcium hydroxide impacts bacterial cells in the following ways: it damages the cytoplasmic membrane of bacterial cells, denaturates proteins, and damages microbial DNA.

Damage to the cytoplasmic membrane of bacterial cells

The cell membrane plays several vital roles. It provides selective permeability, enables the transport of substances, facilitates oxidative phosphorylation in aerobic strains, contributes to enzyme production, and enables the transport of the molecules required for DNA biosynthesis, cellular polymers, and membrane lipids. When hydroxyl ions released from calcium hydroxide reach the cell membrane, they trigger a lipid oxidation process, forming free radicals and destroying phospholipids, structural components of cell membranes. Free radicals initiate a chain reaction that leads to the loss of unsaturated fatty acids and the deterioration of cell membranes.

Denaturation of proteins

The alkaline environment generated by calcium hydroxide leads to the denaturation of proteins. This process involves the destruction of the ionic bonds that hold together the protein structure. In an alkaline environment, the polypeptide chains of enzymes combine randomly, resulting in disordered and non-functional structures. These changes often lead to the loss of the biological activity of enzymes and the disruption of cellular metabolism.

Damage to microbial DNA

Hydroxide ions trigger reactions that lead to the cleavage of microbial DNA and cause gene damage, interfering with the DNA replication process. Furthermore, the radicals generated by these reactions can also induce destructive mutations in the genetic material (Mohammadi *et al.*, 2012).

Meanwhile, the resistance of microorganisms to pH changes since most of them multiply within a 6 to 9 pH range; however, some strains can survive with 8 or 9 pH, and they often cause secondary infections.

In Japan, the use of hydrated lime is recommended for sterilizing facilities. Farmers often use it —on its own or combined with quaternary ammonium compounds (Kabir *et al.*, 2021; Hassan *et al.*, 2022) or with cresol and sodium hypochlorite (Ruenphet *et al.*, 2019)— in footbaths to inactivate viruses and bacteria found on boots during the freezing season. However, hydrated lime may take 3 to 6 hours to inactivate pathogens (Bashandy *et al.*, 2016). Additionally, hydrated lime creates a sterile layer on the surface of remains or carcasses. When exposed to air, it absorbs carbon dioxide and releases water, hardening and forming a crust of solid calcium carbonate. This method has been applied to human remains, animal carcasses, and slaughterhouse waste to reduce the pathogen load, decrease putrefaction odors, and deter pathogen dispersion by scavengers (Bowden *et al.*, 2023).

To properly handle animal carcasses, two layers of hydrated lime should be applied in a pit (one beneath and one above the carcass), and the pit should be covered with soil. The

manufacturer's safety instructions must be followed when handling hydrated lime to avoid direct contact with skin, eyes, or mucous membranes. Handlers should wear gloves at all times. After the dead animals have been buried in the ground, a new layer of hydrated lime should be applied over the entire surface and up to 2 meters around the sanitary pit to seal the pit. This procedure helps to reduce the pathogen load and to maintain environmental hygiene. Finally, alterations by scavenger animals should be prevented, as they can negate its effect (Bowden *et al.*, 2023).

Lime slurry and lime water

On the one hand, the lime slurry is usually prepared by mixing one part hydrated lime with nine parts water (1:10), resulting in an opaque white suspension. On the other hand, lime water is obtained by filtering the lime slurry, and this alkaline solution quickly becomes turbid due to the absorption of atmospheric carbon dioxide and the formation of insoluble calcium carbonate (Oates, 2000). These dispersions are commonly applied in the decomposition of carcasses, and their residues are buried close to where the animals died, preferably in elevated areas rich in silica or calcium. This measure is recommended when cremating the carcasses is challenging or even impossible —given the scarcity and high price of the firewood required to reduce the carcasses to ashes (Sánchez *et al.*, 2008).

In addition, lime slurry and lime water are used to disinfect spaces such as premises, stables, chicken coops, and pens. Organic matter and food residues that have been in contact with infected animals or carcasses that will be incinerated should be removed from those facilities before they are disinfected. A 10% lime slurry can be applied for at least two hours to disinfect residues with high moisture content. Similarly, disinfection with a complete internal application of sodium hypochlorite and an external application of lime is effective against salmonellosis, classical swine fever, and scrapie (Gosling, 2018; Park *et al.*, 2020; Alarcon *et al.*, 2021). Subsequently, lime slurry is used to "whitewash" walls and wood. In addition to its bactericidal effect, it gives a cleaner appearance to poultry houses and chicken coops (Franz *et al.*, 2020). For this procedure, 10 kg of quicklime, 500 g of sodium chloride, and 10 L of water are commonly used to increase the solubility of lime slurry (Saipullaev *et al.*, 2020). Recently, Wang *et al.* (2024) found that pig excreta can be soaked for a longer time in anaerobic digestion systems to inhibit the impact of lime, consequently enhancing biogas production efficiency through the improvement of acidification and hydrolysis. A similar effect can be achieved by applying carbon dioxide bubbles (Li *et al.*, 2024).

Ultimately, in its various forms, lime plays a crucial role in animal husbandry and health promotion in the livestock industry. Due to its antibacterial properties and ability to neutralize pathogens, lime has become an invaluable tool for preserving health and hygiene in breeding environments and handling animal remains. However, it must be used with care, following recommended safety guidelines. The versatility of lime makes it a fundamental resource, both in disease prevention and in the disinfection of spaces, consequently contributing to the well-being of animals and the cleanliness and health of livestock environments.

CONCLUSIONS

This review provides essential knowledge for anyone interested in strengthening biosecurity in livestock operations, reducing risks to animal health, and safeguarding public health. The responsible and appropriate use of lime by-products was comprehensively addressed to avoid undesirable consequences. Additionally, the properties and uses of lime in animal husbandry were explored, highlighting its relevance for the disinfection of facilities, the management of carcasses, and the reduction of the pathogen load. Lime has emerged as a versatile and affordable tool that significantly contributes to biosecurity in the agricultural industry. Correctly applying disinfectants and having a comprehensive understanding of the processes involved are fundamental steps toward a safer and healthier future in livestock and agricultural production.

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