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ANTIMICROBIAL EFFICIENCY OF COMMERCIAL PRODUCTS FOR DRINKING WATER BASED ON ORGANIC AND/OR INORGANIC ACIDS AGAINST BACTERIA OF INTEREST IN ANIMAL AND HUMAN HEALTH

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ABSTRACT

Objective: This study aims to evaluate the effects of acidity regulators based on organic and inorganic acids for drinking water on pathogens of importance in swine and poultry farming using the Minimum Inhibitory Concentration (MIC) test.

Theoretical Framework: The presence of intestinal pathogens in livestock production systems is a major global concern due to their impact on both animal and public health. Pathogens like Salmonella spp. and Escherichia coli are among the main microorganisms that adversely affect these systems, resulting in significant economic losses. Limitations on the use of antimicrobials, due to microbial resistance, require adopting alternative solutions for pathogen control.

Method: The statistical analysis of the MIC of acidity regulators against the microorganisms was performed using the Kruskal-Wallis test, followed by the Student-Newman-Keuls post-test ($p<0.05$) with GraphPad Prism software, version 8.0.1.

Results and Discussion: It was observed that the sensitization profile of the microorganisms differed depending on the species. Among the *Salmonella* serovars, there was a difference in the resistance profile between typhoidal and non-typhoidal Salmonella concerning the evaluated products. The results showed that among the commercially available acidifiers evaluated, only five were effective against all the microorganisms tested.

Keywords: Drink Water, Poultry Farming, Bacterial Resistance, Swine Farming.

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EFICIÊNCIA ANTIMICROBIANA DE PRODUTOS COMERCIAIS PARA ÁGUA POTÁVEL À BASE DE ÁCIDOS ORGÂNICOS E/OU INORGÂNICOS CONTRA BACTÉRIAS DE INTERESSE PARA A SAÚDE ANIMAL E HUMANA

RESUMO

Objetivo: Este estudo tem como objetivo avaliar os efeitos de reguladores de acidez baseados em ácidos orgânicos e inorgânicos para água potável sobre patógenos de importância na suinicultura e avicultura utilizando o teste de Concentração Inibitória Mínima (MIC).

Quadro teórico: A presença de agentes patogênicos intestinais nos sistemas de produção pecuária constitui uma grande preocupação a nível mundial devido ao seu impacto na saúde animal e pública. Patógenos como Salmonella spp. e Escherichia coli estão entre os principais microrganismos que afetam adversamente esses sistemas, resultando em perdas econômicas significativas. As limitações à utilização de agentes antimicrobianos, devido à resistência microbiana, exigem a adoção de soluções alternativas para o controlo de agentes patogênicos.

Método: A análise estatística do MIC de reguladores de acidez contra os microrganismos foi realizada pelo teste Kruskal-Wallis, seguido pelo pós-teste Student-Newman-Keuls ($p<0,05$) com o software GraphPad Prism, versão 8.0.1.

Resultados e Discussão: Observou-se que o perfil de sensibilização dos microrganismos diferia conforme a espécie. Entre os serovares de Salmonella, verificou-se uma diferença no perfil de resistência entre as salmonelas tifoides e não tifoides no que respeita aos produtos avaliados. Os resultados mostraram que, entre os acidificadores avaliados comercialmente disponíveis, apenas cinco foram eficazes contra todos os microrganismos testados.

Palavras-chave: Água Potável, Aves de Capoeira, Resistência Bacteriana, Suinicultura.

EFICIENCIA ANTIMICROBIANA DE PRODUCTOS COMERCIALES PARA AGUA POTABLE A BASE DE ÁCIDOS ORGÁNICOS Y/O INORGÁNICOS FRENTE A BACTERIAS DE INTERÉS PARA LA SALUD ANIMAL Y HUMANA

RESUMEN

Objetivo: Este estudio tiene como objetivo evaluar los efectos de los reguladores de acidez basados en ácidos orgánicos e inorgánicos para el agua potable sobre patógenos de importancia en la cría de cerdos y aves de corral utilizando la prueba de Concentración Inhibidora Mínima (CMI).

Marco teórico: La presencia de patógenos intestinales en los sistemas de producción ganadera es una preocupación mundial importante debido a su impacto en la salud animal y pública. Patógenos como Salmonella spp. y Escherichia coli están entre los principales microorganismos que afectan negativamente a estos sistemas, lo que resulta en pérdidas económicas significativas. Las limitaciones en el uso de antimicrobianos, debido a la resistencia microbiana, requieren adoptar soluciones alternativas para el control de patógenos.

Método: El análisis estadístico de la CMI de los reguladores de acidez frente a los microorganismos se realizó mediante el test de Kruskal-Wallis, seguido del post-test de Student-Newman-Keuls ($p<0.05$) con el software GraphPad Prism, versión 8.0.1.

Resultados y Discusión: Se observó que el perfil de sensibilización de los microorganismos variaba según la especie. Entre los serovares de Salmonella, hubo una diferencia en el perfil de resistencia entre la Salmonella tifoidea y la no tifoidea con respecto a los productos evaluados. Los resultados mostraron que entre los acidificadores comercialmente disponibles evaluados, solo cinco fueron efectivos contra todos los microorganismos evaluados.

Palabras clave: Agua potable, Avicultura, Resistencia Bacteriana, Porcicultura.

1 INTRODUCTION

The use of antibiotics as growth promoters in farm animals has been reduced over the years due to residues left in animal-derived products and microbial resistance (Noschang et al., 2017; Adhikari et al., 2020; Lantmann et al., 2022). Considering this global trend, intensified by European, American, and Brazilian regulations that increasingly restrict the use of these biocidal molecules in animal production (Adhikari et al., 2020), there is a need to seek alternatives that contribute to good zootechnical performance, animal health, and well-being without compromising human and animal health (Silva et al., 2020).

Studies report that the use of acidity regulators via drinking water is considered a sustainable and efficient alternative in the control of enteropathogens (Sadurní et al., 2022; Hu et al., 2023). Currently, acidifiers based on lactic, propionic, butyric, formic, acetic, and citric acids are commer-cially available (Borges et al., 2015). Additionally, products based on inorganic acids such as phosphoric and hydrochloric acids have also proven effective in improving animal performance (Viola et al., 2008).

The presence of enteric pathogens in animal production systems has been a global concern due to the public health impacts caused by these microorganisms (Macedo et al., 2023). Salmonellosis is among the leading zoonoses impacting global public health, and it can spread throughout the entire production chain of both poultry and swine (Lantmann et al., 2022). Although widely distributed in nature, the intestinal tract of animals and humans is the primary reservoir, potentially leading to severe diarrheal conditions (Santos et al., 2022).

Poultry and poultry products are considered the main vectors of Salmonella spp. due to cross-contamination and/or improper food preparation. *S.* Heidelberg is the most common serotype associated with poultry; however, serotypes such as *S.* Enteritidis, *S.* Typhimurium, *S.* Pullorum, and *S.* Gallinarum can also be found (das Mercês Santos et al., 2022). On the other hand, the serotype *S.* Choleraesuis, specific to swine, is responsible for causing severe disease in pigs. Additionally, other serotypes such as *S.* Typhisuis and *S.* Typhimurium, the latter still considered a public health issue, can also be found (Lantmann et al., 2022).

Colibacillosis, a disease caused by the bacterium *Escherichia coli,* is also responsible for significant economic losses in poultry and swine production. The disease exhibits high morbidity with rapid colonization (Camargo & Suffredini, 2015). Given the great importance of these microorganisms in animal health and/or public health, and considering the oral-fecal route as the main form of contamination in animals, strategies for the application of products with antimicrobial efficacy via water or feed become important tools for controlling these

microorganisms.

Currently, there is information in the literature regarding the antimicrobial potential of organic and inorganic acids against various microorganisms of importance to human and animal health (Bedford & Gong, 2017; Gan et al., 2020; Moquet et al., 2018). However, studies evaluating the antimicrobial efficacy of commercial acids, which consist of mixtures of different types of acids—whether organic, inorganic, or a combination of both—are lacking, as well as studies on their interaction with other components of the formula, representing the actual products available in the market. Thus, the present study aimed to evaluate the antimicrobial action of different acidity regulators for drinking water available on the market for swine and poultry against pathogens of known importance in animal and public health through the Minimal Inhibitory Concentration (MIC) test.

2 MATERIALS AND METHODS

2.1 STUDY LOCATION

The analyses were conducted in 2023 and 2024 at the Microbiology Laboratory of the Technological Center for Food Research and Production, part of the Scientific and Technological Park of the University of Vale do Taquari (CTPPA-TECNOVATES).

2.2 MICROORGANISMS

To conduct the experiments, we followed the recommendations of the Clinical Laboratory Standard Institute (CLSI, 2018), with adaptations. Standard strains of micro-organisms relevant to poultry and swine farming, with or without public health implications, were evaluated, along with a Gram-positive microorganism to determine if the composition and physicochemical properties of the cell wall could influence the performance of the acidifiers. The following were used: *Staphylococcus aureus* (ATCC 29923) - SA, *Escherichia coli* (ATCC 25922) - EC, *Salmonella* Typhimurium (ATCC 14028) - ST, *Salmonella* Enteritidis (ATCC 13076) - SE, *Salmonella* Choleraesuis (ATCC 10708) – SCh, *Salmonella* Heidelberg (ATCC 8326) - SH, *Salmonella* Gallinarum (ATCC 9184) - SG, *Salmonella* Pullorum (ATCC 13036) - SP, and *Salmonella* Bredney – field isolate.

2.3 ACIDITY REGULATORS

To conduct the study, nine commercially available water acidifiers were evaluated, and diluted according to the manufacturer's instructions. The acidifiers are described in Table 1, based on the product label information:

Table 1

Composition of Acidifiers Used in the Study

Product	Presentation	Composition
Acid Regulator 1	Liquid	Formic 29.8%, Propionic 34.7%, Phosphoric 25.5%.
Acid Regulator 2	Liquid	Lactic acid (min) 450g/kg; Vehicle; Citric acid (min) 80g/kg; Copper aminoquinate and Sodium phosphate.
Acid Regulator 3	Liquid	Propionic acid (min): 350 g/kg; Formic acid (min): 350 g/kg.
Acid Regulator 4	Liquid	Propionic acid; Formic acid; Phosphoric acid.
Acid Regulator 5	Liquid	Phosphoric acid 612,000 g/kg; Citric acid 8,000 g/kg; Ascorbic acid 6,000 g/kg; Lactic acid 10,000 g/kg; Ammonium acetate 382,000 mg/kg; Sodium chloride 125,000 mg/kg; Glycerin; Vehicle.
Acid Regulator 6	Liquid	Vehicle; Glycerin; Citric acid 35,000 g/kg; Lactic acid 35,000 g/kg; Ascorbic acid 25,000 g/kg; Ammonium acetate 10 g/kg; Orange flavor identical to natural.
Acid Regulator 7	Liquid	Propionic acid and citric acid.
Acid Regulator 8	Liquid	Formic acid (min) 520g/kg; Lactic acid (min) 60g/kg; Propionic acid (min) 130g/kg; Cinnamaldehyde (min) 20g/kg; Sodium formate; Glycerol; Propylene glycol.
Acid Regulator 9	Liquid	Formic acid (min) 448g/kg; Propionic acid (min) 100g/kg; Lactic acid (min) 100g/kg; Sorbic acid (min) 2,000 mg/kg; Sodium formate; Sodium propionate; Sodium sorbate; Vehicle.

2.4 INOCULUM STANDARDIZATION

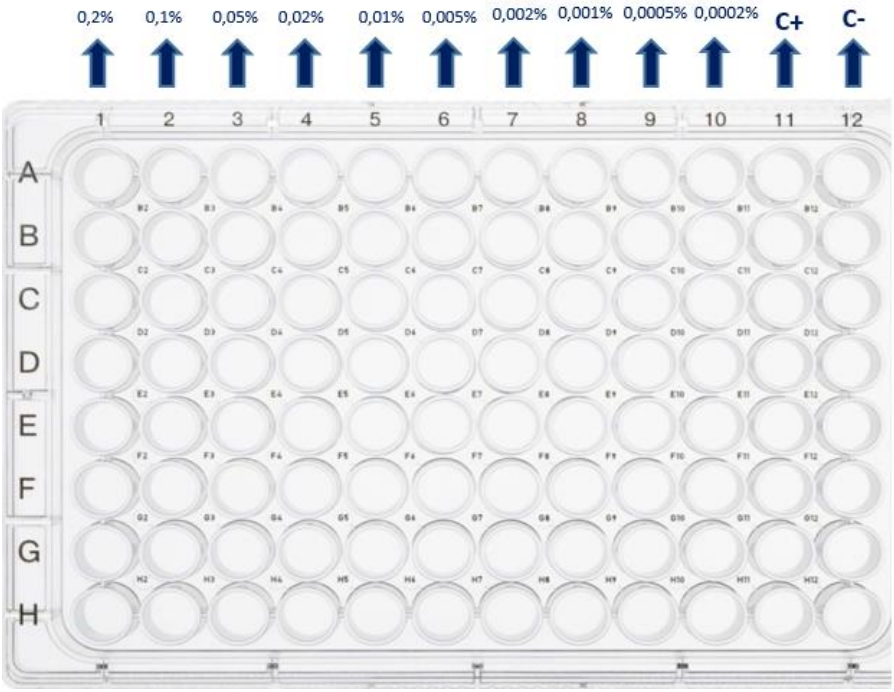
The microorganisms used in this study were reactivated in 3 mL of brain heart infu-sion (BHI) broth (Oxoid; Hampshire, England) and incubated for 18-24 hours at 37 ± 1°C. Subsequently, they were plated on plate count agar (PCA) (Kasvi; Conda, Spain) and in-cubated under the same conditions as previously described. 3 to 5 colonies were resus-pended in a 0.85% saline solution and homogenized for standardization. The turbidity was then adjusted to a McFarland scale of 0.5, corresponding to a range of 0.08 to 0.10 ab-sorbance in a spectrophotometer at a wavelength of 610 nm (UV-Vis Spectrometer Lamb-da 25 – Perkin Elmer) (Biospectro; São Paulo, Brazil), providing approximately 1.5 x 10^8 CFU/mL.

2.5 MICROPLATE PREPARATION

For the test, sterile disposable 96-well flat-bottomed polystyrene microtitration plates (Kasvi; São José dos Pinhais, Brazil) were used. The assays were performed in triplicate (technical and biological). In summary, three rows of the microplate were used for each product, and decreasing concentrations ranging from 0.2% to 0.0002% were evaluated, corresponding to wells in columns 1 to 10, respectively, and encompassing the indication of all commercial products tested. The last two columns were used as controls for the test. For the positive control, TSB broth with the test microorganism without the addition of the product was used, and for the negative control, only TSB broth was used (Figure 1). The microplates were then incubated at 37° ± 1°C for 18-24 hours.

Figure 1

Detailed dilutions of the products used for antimicrobial efficiency tests.

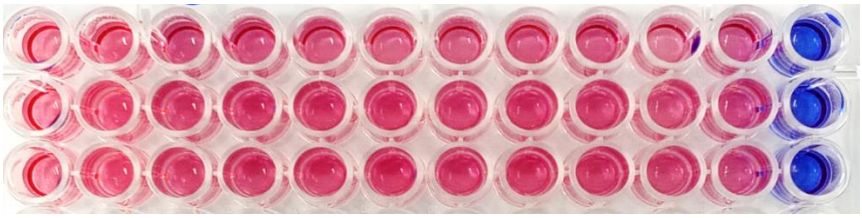


The plates were read using the resazurin indicator (7-hydroxy-3H-phenoxazin-3-one 10-oxide) at a concentration of 0.2%. A total of 15µL was added to each well, and the plates were incubated for 2 hours at 37°C. The detection mechanism is based on the reduction of resazurin (initially purple) to resorufin (pink color). There is a direct correlation between the quantity/proliferation of live cells and the color change of the medium to pink (Figure 2). To verify the test's integrity and the indicator's performance, an interaction curve between the

tested acidifier and resazurin was performed for each test, as this inter-action—particularly at higher concentrations—can alter the indicator's coloration. Addi-tionally, at the concentrations where the MIC was detected and at the subsequent concen-tration, plating on PCA agar was performed, followed by incubation at 37° ± 1°C for 18-24 hours to confirm microbial growth.

Figure 2

Example of a plate revealed with 0.02% resazurin.



2.6 STATISTICAL ANALYSIS

The statistical analysis of the Minimal Inhibitory Concentration (MIC) data for the different acidity regulators against the microorganisms of interest was performed using the non-parametric Kruskal-Wallis test to detect statistically significant differences be-tween the MIC distributions of the various regulators. When significant differences were identified ($p<0.05$), the Student-Newman-Keuls post-test was applied to determine which pairs of regulators presented statistically distinct MICs. All calculations and analyses were performed using GraphPad Prism software, version 8.0.1.

3 RESULTS

Various studies have demonstrated that organic acids are an alternative to the use of antibiotics in decontamination strategies due to their recognized antibacterial activity. Here, we focus on the effects of commercial acidifiers on enteropathogenic bacteria of importance in poultry and swine production (*E. coli* and *Salmonella* spp.).

The results of the minimum inhibitory concentration for each product and microorganism tested can be seen in Table 02. It was observed that the sensitivity profile of the microorganisms varied depending on the species and product evaluated. Among the Salmonella serovars, differences in sensitivity profiles were found between paratyphoid Salmonella and typhoid Salmonella, depending on the product. Product 1 was able to inhibit *S.* Pullorum at a concentration of 0.05%, and all other microorganisms were inhibited at a concentration of 0.1%.

Product 2 inhibited *Salmonella* strains responsible for diseases in humans and pigs, such as *S.* Typhimurium, *S.* Enteritidis, *S.* Bredeney, and *S.* Choleraesuis at a concentration of 0.2%. Product 3 showed inhibition results for *S.* Enteritidis, *S.* Gallinarum, *S.* Bredeney, and *S.* Choleraesuis with MICs ranging from 0.2% to 0.1%. Product 4 was not effective against *S.* Typhimurium, but for the remaining microorganisms, MICs ranged from 0.2% to 0.1%.

Product 5 exhibited antimicrobial activity against all strains evaluated. The concentration needed to achieve antimicrobial activity against microorganisms such as *E. coli*, *S.* Typhimurium, *S.* Heidelberg, and *S.* Pullorum was 0.05%. The *S. aureus* strain was inhibited at a concentration of 0.01%. On the other hand, the *S.* Gallinarum serovar was more sensitive compared to other *Salmonella* strains evaluated, showing growth inhibition at a concentration of 0.02%. The results indicated greater susceptibility of all strains to Product 6, with MIC values ranging between 0.02% and 0.001%, with *E. coli* (MIC of 0.02%) being the most resistant microorganism and *Salmonella* Gallinarum (MIC of 0.001%) the most sensitive. The *S. aureus*, *S.* Enteritidis, *S.* Bredeney, *S.* Choleraesuis, and *S.* Heidelberg strains showed sensitivity at a concentration of 0.005% for the product, while *S.* Typhimurium showed inhibition at a concentration of 0.01%. The *S.* Gallinarum and *S.* Pullorum serovars presented growth inhibition at concentrations of 0.001% and 0.01%, respectively, for this acidifier treatment.

Product 7 was effective against all microorganisms evaluated, with MICs ranging from 0.2% to 0.1%. On the other hand, Product 8 was not able to inhibit S. aureus, *S.* Heidelberg, and *S.* Choleraesuis, but was effective in inhibiting *E. coli*, *S.* Gallinarum, and *S.* Pullorum at a concentration of 0.2%, and *S.* Enteritidis at a concentration of 0.01%. Product 9 was able to inhibit all microorganisms evaluated at a concentration of 0.2%.

Overall, Products 1, 5, 6, 7, and 9 were more effective against the microorganisms evaluated. Among these, Products 5 and 6 showed the best performance, with the lowest MICs ($p<0.05$), with Product 6 being the most effective ($p<0.05$), inactivating *S.* Enteritidis, S. Gallinarum, and *Staphylococcus aureus*, with MICs of 0.005%, 0.001%, and 0.005%, respectively, demonstrating bactericidal activity against both Gram-negative and Gram-positive bacteria.

Table 2

Minimum Inhibitory Concentration Results of Different Commercial Acidifiers Against Target Microorganisms.

Product	*Escherichia coli*	*Staphylococcus aureus*	*Salmonella* Typhimurium	*Salmonella* Enteritidis	*Salmonella* Heidelberg	*Salmonella* Gallinarum	*Salmonella* Pullorum	*Salmonella* Bredney	*Salmonella* Choleraesuis
Acid Regulator 1	0,1	0,1	0,1	0,1	0,1	0,1	0,05	0,1	0,1
Acid Regulator 2	NI	NI	0,2	0,2	NI	NI	NI	0,2	0,2
Acid Regulator 3	NI	NI	NI	0,1	NI	0,2	NI	0,1	0,2
Acid Regulator 4	0,1	0,2	NI	0,1	0,1	0,2	0,1	0,1	0,1
Acid Regulator 5	0,05	0,01	0,05	0,02	0,05	0,02	0,05	0,02	0,02
Acid Regulator 6	0,02	0,005	0,01	0,005	0,05	0,001	0,01	0,005	0,005
Acid Regulator 7	0,2	0,2	0,2	0,2	0,2	0,1	0,2	0,2	0,2
Acid Regulator 8	0,2	NI	NI	0,01	NI	0,2	0,2	0,2	0,2
Acid Regulator 9	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2

4 DISCUSSION

With increasingly demanding markets, the use of antibiotics in farm animals has been decreasing over the years, mainly due to the potential microbial resistance observed (Khan & Iqbal, 2016). Organic and inorganic acids have been suggested as potential substitutes for these molecules (Biagini et al., 2022; Robles-Huaynate et al., 2013), as they are not limited to antimicrobial action but can also act on the animals' metabolism (Viola et al., 2008), promoting growth (Dibner & Buttin, 2002). Commercial acidifiers are composed of mixtures of organic and inorganic acids, due to differences in their spectrum of antimicrobial action (Eklund, 1983), which justifies the use of acid blends in commercial formulations since these combinations may present synergistic effects and enhance results (Bassan et al., 2008).

The effectiveness of acidifiers is directly related to the acids present in their composition, which lead to a reduction in pH inside bacterial cells, altering the concentration of H+ ions, and forcing the bacteria to expend a lot of energy to maintain this balance (Reis & Vieites, 2019). This process is facilitated by protein channels in bacterial membranes, allowing low-molecular-weight compounds such as organic acids to diffuse into the cytoplasm (Madigan et al., 1997). As a result, DNA and protein synthesis decreases, leading to the microorganism's death by exhaustion (Reis & Vieites, 2019).

Although Gram-positive and Gram-negative microorganisms have distinct characteristics, such as chemical and morphological cell wall composition, wall, flagellar, and

capsular antigens related to virulence, and sensitivity profiles (Melaku et al., 2021), both were sensitive to the acidifiers evaluated. Only one acidifier did not show antimicrobial activity against the microorganisms tested, highlighting the importance of acids as an alternative to antibiotics in microbial control.

The antimicrobial activity of the acids used in the formulations evaluated here is widely known in the literature (Mumtaz et al., 2021; Wang et al., 2011). However, the results of the commercial products showed different sensitivity profiles between the products and microorganisms, suggesting that the combination of acids with other formula components, as well as the quantity of each ingredient, influences the antimicrobial response (Lantmann et al., 2022).

This synergy is evident when analyzing the formulations and results obtained. Product 3, based on propionic and formic acids, was able to inhibit three of the nine microorganisms tested. Meanwhile, Products 1 and 4, also based on formic and propionic acids, with the addition of phosphoric acid, were effective in inhibiting all tested micro-organisms. This result may be explained by the inclusion of the inorganic phosphoric acid (also known as orthophosphoric acid) in the formulations of Products 1 and 4. This class of acid is considered strong, with indirect bactericidal action, enhancing the reduction of pH in the medium, and preventing or delaying pathogen development (Hu et al., 2023), thus contributing to the effects of the acids in the formulation.

Although formic and propionic acid-based acidifiers show in vitro antimicrobial effects, as demonstrated above, these results may not be replicated in the field because these acids, along with acetic acid, are unpalatable, especially for pigs due to their sensitivity. This generates responses related to pungency, spiciness, and burning (da Costa et al., 2012), possibly leading to feed intake restriction. Thus, it is important that, in addition to acids with proven antimicrobial effectiveness, these acids do not alter the animals' feed intake to avoid losses in performance.

Products 5 and 6, based on ascorbic, citric, lactic acids, glycerin, sodium, and ammonia salts, differing only by the presence or absence of phosphoric acid and ammonia salts, presented the most effective results. Considering this, it is proposed that the association of these acids with sodium chloride, ammonium acetate, and an alcohol matrix provides greater antimicrobial efficiency due to the synergistic action of the components. Although some acids do not have biocidal potential, they can modulate the microbiota through a process called competitive exclusion, which in the field practice may favor the development of probiotic microorganisms in the digestive system, such as Lactobacillus spp., which have antagonistic action against

Salmonella spp. and Escherichia coli (Madigan et al., 1997). Glycerin, ammonia salts, and sodium chloride act as a carbon source, favoring the devel-opment of beneficial microbiota in the gastrointestinal tract and as microbial growth in-hibitors, respectively (Krieg et al., 2021).

Product 8, based on formic, lactic, propionic acids, cinnamaldehyde, sodium for-mate, glycerol, and propylene glycol, showed lower antimicrobial activity, inhibiting six of the nine tested strains, compared to Product 9, with a similar formulation but with the addition of sodium salts and sorbic acid, which had antimicrobial effects against all the microorganisms evaluated. This suggests that the known antibacterial action of lactic, formic, and propionic acids (Poverenov et al., 2009) is being enhanced by the bactericidal effects of sorbic acid (Bassan et al., 2008), and these are further potentiated by the presence of sodium salts and potassium sorbate, providing better synergy to the formulation.

The combination of propionic and citric acids in the formulation of Product 7 produced satisfactory results against all microorganisms evaluated. This effectiveness is due to the action of citric acid, which mainly works by creating an acidic environment unfavorable to the growth of pathogenic bacteria such as Salmonella and E. coli (Mumtaz et al., 2021). Propionic acid and its salts are commonly used as food preservatives because they act in pH ranges close to 4.5 (Moro et al., 2022), thus having strong antimicrobial activity (Haque et al., 2009). Its main mode of action is through interaction with the microorganism's cell membrane at low pH, preventing it from using the amino acids in the medium, leading to the microorganism's death (Bassan et al., 2008).

Product 2, based on lactic, citric acids, as well as copper amino chelate and sodium phosphate, though not presenting broad-spectrum antimicrobial effects, was, along with Product 3, effective in inhibiting the growth of microorganisms relevant to swine production, such as *S.* Bredeney and *S.* Choleraesuis, as well as against strains of public health importance such as *S.* Enteritidis.

5 CONCLUSIONS

Given the current scenario, in which markets are increasingly resistant to the use of antibiotics, their replacement is becoming essential. The use of organic and inorganic ac-ids has shown promise as a substitute for antibiotics as growth promoters, also presenting positive effects on the control and functionality of the digestive system.

The results showed that five of the acidifiers evaluated in this study were effective against all the microorganisms tested. It is known from the literature that acids have proven

antimicrobial activity when evaluated individually, but their action in a commercial formula can vary due to the interaction of components. As previously discussed, the combination and concentration of acids are directly related to their antimicrobial efficiency. In general, it was observed that in the best-performing formulations, acids are combined with glycerol, sodium salts, ammonia, and essential oils, among others, which may confer synergy to the formulation and better antimicrobial action. Thus, it is important to consider the different options available in the market when selecting the best product to address health challenges, thereby minimizing impacts on animal health and, consequently, on human health.

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