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Presence of antibiotic-resistant bacteria in pigs for consumption - one health challenge - Literature review

Presença de bactérias resistentes a antibióticos em suínos para consumo - desafio à saúde única - Revisão de literatura

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Highlights

Pig farming practices are closely linked to One Health.
The presence of resistant and multidrug-resistant bacteria in swine is a global issue.
The growth in swine production raises the need for research on related microorganisms.

Abstract

Pig farming is an area of livestock that has been developing the most in Brazil and the world, with production increasing every year, generating jobs, and being of great importance for the Brazilian economy. In swine production, great health enables these animals to reach their highest point of development and antimicrobials are used, either prophylactically or through food, as growth promoters. Within swine culture, there is a concern regarding antibiotic-resistant bacteria; however, *Staphylococcus* spp. do not receive the necessary prominence in research, since the pathologies caused by them do not tend to cause great economic losses. Therefore, this review aimed to highlight the importance of bacterial resistance within breeding stock, its possible origins, the importance of *Staphylococcus* spp. within this topic, and its evolution in swine farming over the years. For this, studies were selected, with an emphasis on information such as

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country, number of samples, presence of *Staphylococcus* spp. resistant to methicillin, breeding phase, and phenotypic and molecular tests. In addition, publications were selected that show the importance of understanding the biological and resistance profiles of *Staphylococcus* spp. in swine herds in Brazil and around the world.
Key words: Bacterial resistance. One health. *Staphylococcus* spp. Pig farming.

Resumo

A suinocultura é uma das áreas da pecuária que mais se desenvolveu e se desenvolve no Brasil e no mundo, com a sua produção aumentando todos os anos, gerando empregos diretos e indiretos, e sendo de grande importância para a economia brasileira. Destaca-se na produção de suínos a necessidade de grande sanidade para que estes animais alcancem seu maior ponto de desenvolvimento e, para tal, são utilizados antimicrobianos, seja de forma profilática ou através da alimentação, como promotores de crescimento. Dentro da suinocultura também está presente a preocupação envolvendo as bactérias resistentes a antibióticos, contudo, os *Staphylococcus* spp. não recebem o destaque necessário em pesquisas, já que as patologias causadas por estes ainda não tendem a causar grandes prejuízos econômicos de forma direta aos produtores. Por este motivo, esta revisão objetivou evidenciar a importância da resistência bacteriana dentro dos planteis, suas possíveis origens, a importância dos *Staphylococcus* spp. dentro deste tópico e a sua evolução na suinocultura através dos anos. Para este foram selecionados trabalhos encontrados em diferentes bases de dados com ênfase em informações como país, número de amostras, presença de *Staphylococcus* spp. resistentes a meticilina, fase de criação, e testes fenotípicos e moleculares, além de publicações que evidenciam a importância de se conhecer os perfis biológicos e de resistência dos *Staphylococcus* spp. nos planteis de suínos do Brasil e do mundo.
Palavras-chave: Resistência bacteriana. Saúde única. *Staphylococcus* spp. Suinocultura.

Introduction

Brazil is the third producer of animal protein in the world, including poultry, beef and pork. However, Brazil is the second largest exporter of meat in 2020, and keeps 13.4% of the total world production, or 7.4 million tons of exported meat (Guaraldo, 2021).

According to the Instituto Brasileiro de Geografia e Estatistica [IBGE] (2021a), in the first quarter of 2021, while there was a drop in Brazilian beef production, the production of pork and chicken meat grew. In this period 12.62 million heads of swine and 1.57 billion heads of chickens were slaughtered. In 2020, Brazil was the third largest producer of pork in the world and is among the ten largest exporters, moving 2.269 million US dollars, totaling more than 1 billion reais (Associação Brasileira de Proteína Animal [ABPA], 2021; IBGE, 2021a,b).

The quality of the products exported by Brazil comes from the biosecurity measures required by national law, which are extremely important for the Brazilian and world markets. Strict inspections and control measures are carried out so that animal health is maintained to high standards and pork exports continue to rise (Ministério da Agricultura Pecuária e Abastecimento [MAPA], 2016).

Biosecurity programs within swine farms aim to minimize or prevent the entry of pathogenic agents that can cause serious diseases in the herd, or that cause damage to the environment in which these animals are found or even the spread of different pathogens with zoonotic potential, thus causing stagnation of the sector in relation to exports (MAPA, 2016; Massotti et al., 2017).

Diseases in swine are of great importance in the production chain, mainly due to industrialization, which increases the number of heads in a herd, increasing the chances of proliferation of agents causing bacterial, parasitic, and viral diseases (Davies, 2012; MAPA, 2013).

One of the most consequential bacterial groups in swine farming is the genus *Staphylococcus*, which causes diseases, such as exudative epidermitis and fatty disease. However, the presence of this type of bacteria in these animals is commensal, since they are part of the normal skin microbiota of these animals; however, the opportunistic characteristics of these microorganisms must be considered (Pereira et al., 2020; Schwarz et al., 2021).

One of the challenges related to bacterial diseases in swine is the presence of antibiotic-resistant agents, both when used as growth promoters and in the treatment of diseases caused by such microorganisms (Cromwell, 2002; J. Li, 2017a; Thacker, 2013).

Antibacterial resistance is a concern worldwide, and despite the efforts of the World Health Organization (WHO) to stop its spread in human, animal, and agricultural health, it causes an estimated 10 million deaths a year, which today is around 700,000 people (Alvim, 2020; Banin et al., 2017; Escudero, 2021; Zaman et al., 2017). Thus, this study aimed to determine the use of antibiotics and their importance in swine farming, emphasizing the effect of multidrug-resistant bacterial agents involved in the food production chain in One Health.

Literature Review

Overview of pig farming in Brazil

Currently, pig farming is one of the most important areas of Brazilian agribusiness, according to the IBGE (2021b). In the first quarter of 2021 alone, 12.62 million pigs were slaughtered, totaling 1,149,083 tons of meat, representing an increase of 4.9% compared to the first quarter of 2020 and 0.2% compared to the last quarter of 2020, leaving Brazil in 4th in the world in pork production.

In 2020, 77% of the total production was destined for the domestic market, representing the consumption of 16 kg of meat per capita among Brazilians. Brazil is also one of the largest pork exporters in the world, with 1.024 million tons exported, mainly to Asian countries, representing 23% of the total production in 2020, which generated a revenue of US$ 2.269 million (ABPA, 2021).

Among the Brazilian pork-producing states, Santa Catarina produced 30.73% of national production in 2020, followed by Parana (21.10 %), where the municipality is located with the largest herd of swine in Brazil, Toledo, with 1.2 million animals, and in third place is Rio Grande do Sul with 19.08% of production (ABPA, 2021; Confederação da Agricultura e Pecuária do Brasil [CAN], 2020).

The swine production chain is a huge socioeconomic asset for the country, according to data from the Serviço Brasileiro de Apoio às Micro e Pequenas Empresas [SEBRAE] (2016), Brazilian swine farming generated 126 thousand direct jobs and more than 900 thousand indirect jobs, involved in raising pigs, transport, slaughtering and cutting, storage, consumption and the activities of selling fresh meat and sausages, the feed industry and its raw materials, the animal health industry, and equipment manufacturers (Bassi, 2021).

According to the 2017 Agricultural Census, there are approximately 1,471,270 businesses that breed swine, a reduction of approximately 25,000 properties within 11 years. In 2006, the existence of 1,496,422 swine-producing establishments was reported (IBGE, 2017). Despite this drop, the number of slaughters of these animals has been growing every year, which can be attributed to a reduction in the raising of these animals for subsistence and clandestine slaughter (Anelli, 2018).

Clandestine slaughtering is widely distributed throughout Brazil, and these types of establishments are a risk to one's health since, in addition to this type of informal market not meeting food safety standards, they have a value 30% lower than that of a completely legal animal. This lower cost attracts consumer attention, who are subsequently exposed to a higher risk of infectious agents in meat without proven sanitary quality. In addition, such an establishment can lead to contamination of the environment through incorrect and illegal disposal of waste resulting from such processes (Azevedo & Bankuti, 2001; Freitas et al., 2001).

All factors that may interfere with the quality of life of these animals, in the final product destined for the consumer, or in economic factors, converge on the health of the pigs. Several factors related to the environment must be considered: where the pigs are located, their feeding, and their management (Melo, 2016).

To ensure adequate health for these animals, producing farms must implement and comply with basic biosecurity requirements, which, aim to prevent the entry of pathogens that cause different diseases and consequently their spread within the herd, as well as to minimize the entry and proliferation of agents that are harmful to the environment, workers, or that interfere with pig farming (Massotti et al., 2017).

Taking health into account in the swine production chain, the Ministry of Agriculture, Livestock and Supply (MAPA) instituted the National Swine Health Program (PNSS), which highlights diseases of importance to the World Organization for Animal Health. (OIE) or for its transmissibility, diffusion, economic, and/or sanitary importance, focusing on diseases that may have repercussions on pork imports (MAPA, 2004, 2016).

Among the diseases subject to the application of sanitary defense measures in swine farming are swine vesicular disease, exudative epidermitis, Nipah virus encephalomyelitis, transmissible gastroenteritis, African and classical swine fever, and porcine reproductive and respiratory syndrome (PRRS). The latter has never been registered in Brazil, in addition to foot-and-mouth disease, and Brazil is considered a free zone, in addition to other viral, parasitic, and bacterial diseases (MAPA, 2013).

Use of antibiotics in pig farming

The use of antibiotics in swine farming is one of the largest among production animals, In the United States of America in the early 2000s, eight million kilograms were used (Broom, 2017; Cheng et al., 2020; Cromwell, 2002; Noschang et al., 2017; Ollé et al., 2017; Yang et al., 2019).

In Brazil, 6,448 tons of antibiotics were sold for animal feed in 2013, and an increase of 29.08% in this number was estimated until 2030, when it is estimated that 9,092 tons of antibiotics will be sold for use as growth promoters (Böll-Stiftung, 2021).

Antibiotics have been used in swine farming for more than 50 years, mainly via food, with the aim of preventing bacterial diseases inside the farm and as growth promoters, regardless of the stage of growth in which these animals are, be it the nursery, sows, or adult pigs (Broom, 2017; Cromwell, 2002; Muurinen et al., 2021). The antibiotic classes most commonly used for this purpose are Fluoroquinolones and Cephalosporins, both of which are used extensively in human and animal medicine (Food and Drug Administration [FDA], 2021).

In addition to their common use against bacterial pathogens, antibiotics are used as growth promoters in animal nutrition, thus resulting in an improvement in their zootechnical performance, antibiotics can be used alone or with the addition of chemotherapeutics, and provide improvement in growth, fattening, feed efficiency, and disease prevention, these objectives being differentiated by the dosage of these antibiotics. However, there are studies that show that animals raised without the use of these antimicrobials do not differ in relation to the performance of other animals (Broom, 2017; Noschang et al., 2017; Ollé et al., 2017).

Such studies show that the effect of antibiotics, whether as growth promoters or as prophylactic elements, is minimal and almost irrelevant in an environment where hygienic-sanitary conditions are ideal (F. Aarestrup, 2012; Close, 2000; Noschang et al., 2017; Ollé et al., 2017). In addition to the health conditions in which pigs must be housed, these studies show alternatives to antibiotic growth promoter that demonstrate satisfactory efficacy (F. Aarestrup, 2012; Brown et al., 2017; Close, 2000; Marquardt & Li, 2018; Mourenza et al., 2020; Thacker, 2013).

The use of antimicrobials related to growth promotion is due to the higher performance achieved by pigs in environments with greater health, physiologically, there is a decrease of bacteria in the animals' system, including in the intestinal wall of pigs due to the drop in intestinal mucus production, and, consequently, decreased enterocyte turnover, increasing and facilitating feed conversion (Kich et al., 2021; Ollé et al., 2017).

The high density of animals inside farms highlights the possibility of sharing pathogenic or commensal bacteria, making the use of antibiotics an important requirement in the modern production chain (Landers et al., 2012). However, the irrational use of these antimicrobials in swine farming, either as feed additives to aid in feed conversion or as prophylactic therapies, highlights the problem of bacterial resistance to antibiotics that are widely used in both human and veterinary medicine (Muurinen et al., 2021; Landers et al., 2012).

Different studies have correlated the use of antibiotics in the food of production animals and the colonization of humans by resistant and multidrug-resistant microorganisms through food, which has become a major health problem (Angen et al., 2021; Kumar et al., 2018; Landers et al., 2012; Muurinen et al., 2021; Ruiz-Ripa et al., 2020; Santos et al., 2021; Sun et al., 2017).

Therefore, studies aimed at finding alternatives to these growth promoters are being increasingly carried out, showing the promising use of substances such as probiotics and prebiotics, clay minerals, egg yolk antibodies, essential oils, isolated fatty acids, and phytobiotics (F. Aarestrup, 2012; Brown et al., 2017; Close, 2000; Gheisar & Kim, 2018; Liao & Nyachoti, 2017; Liu et al., 2018; Marquardt & Li, 2018; Mourenza et al., 2020; Thacker, 2013). Although there is a great deal of research involving alternatives to the use of antibiotics in several areas, it should focus on using them correctly, especially with regard to the mechanisms of acquired or intrinsic resistance in bacteria (Willing et al., 2018).

Bacterial resistance in one health

The use of substances with antimicrobial power dates back to 2,500 years ago by ancient people who inhabited China, Egypt, and Greece. However, it was not until the end of the 19th century and the beginning of the 20th century that the first antibiotics were discovered, Salvarsan and Penicillin, which were widely used between the 1940s and the 1950s, when streptomycin and tetracycline were discovered and widely used (Kumazawa & Yagisawa, 2002; Zaffiri et al., 2012).

The discovery of antibiotics increased the life expectancy of the world population by eight years, in addition to saving the lives of millions of people in its "golden age," however, almost immediately after the appearance of the first antibiotics, resistance appeared. Bacterial infections are a phenomenon that does not stop growing, mainly due to the indiscriminate use of antimicrobials, given that, today, there is an increasing number of resistant bacteria spread across the globe (Carlet et al., 2012; Del Fio et al., 2000).

Bacterial resistance is, by definition, the ability of some microorganisms to survive against a particular antibiotic, which can be an intrinsic property of a bacterial species, also called natural resistance, or it can be an acquired resistance (Antonio et al., 2009; Argudín et al., 2017; Del Fio et al., 2000).

Bacteria that are naturally resistant to specific antibiotics commonly do not have the targets for which these antibiotics need to have a bactericidal effect (Antonio et al., 2009; Del Fio et al., 2000). Acquired resistance is defined as the manifestation of resistance not previously described or visualized in this microorganism, which can be transferable, via the transfer of genetic material between microorganisms (Antonio et al., 2009; Carlet et al., 2012; Del Fio et al., 2000).

Another way in which bacteria acquire resistance is through the selective pressure exerted by antibiotics in routine or continuous use, which, despite not exerting any mutation in these microorganisms, selects bacteria that have the ability to resist this, which is an important factor related to the increase in multidrug-resistant bacteria, as they tend to survive in environments in which antimicrobials are present (Carlet et al., 2012; Del Fio et al., 2000; Kolář et al., 2001).

Another common use of antibiotics, especially in recent decades, is in agriculture, either as a way of maintaining health in animal housing environments or as growth promoters (Cromwell, 2002; Kich et al., 2021; Noschang et al., 2017; Ollé et al., 2017). This is the activity where antibiotics are most commonly used, and causes direct and indirect effects on humans who are in contact with these animals or their meat (Argudín et al., 2017; Landers et al., 2012).

When related to One Health (human, animal, and environmental) *Staphylococcus* spp. are among the most relevant bacteria in the production chain of meat animals. Methicillin-resistant *Staphylococcus* (MRS) and methicillin-resistant *Staphylococcus aureus* (MRSA) deserve a great focus given their prevalence in hospital environments and outside these, being found in healthy pigs and even in their by-products (Argudín et al., 2017; Beier et al., 2020; Bouchami et al., 2020; Fluit, 2012; Haulisah et al., 2021; Lassok & Tenhagen, 2013; Schoen et al., 2020; Smith, 2015).

Etiological agent

Staphylococcus are Gram-positive cocci bacteria, that is, they have a single peptidoglycan wall, and they tend to arrange themselves in the form of "grape clusters," they are facultative anaerobes, catalase positive, and oxidase negative, measuring around 1.0 µm. These microorganisms are present in many different places, from the skin of animals as opportunistic commensals to serious hospital infections, and these microorgnisms are subdivided into coagulase positive or coagulase negative (Quinn et al., 1999).

More than 50 species of *Staphylococcus* have been described, including *S. aureus, S. epidermidis, S. saprophiticus, S. lugdunensis, S. haemolyticus, S. warneri, S. schleiferi* and *S. intermedius* (Foster, 1996; Quinn et al., 1999). These microorganisms have severe implications both in human and animal health, where *Staphylococcus aureus* stands out as the major focus of studies and concerns of the medical community, followed by other coagulase-positive staphylococci. However, only a few years ago, coagulase-negative species became of clinical interest, as they also demonstrated certain pathogenic power (Bhargava & Zhang, 2012; Becker et al., 2014; Foster, 1996; González-Martín, 2020).

Although *S. aureus* is present in most studies and is of concern within the One Health category, there are other underestimated species involved in the spread of bacterial resistance through gene exchange and microbiota sharing between the environment, animals, and humans (Becker et al., 2014; Rossi et al., 2020).

The main genes involved in bacterial resistance to *Staphylococcus* are *blaZ, ccr, mecI, mecR1,* and *mecA* (Shore et al., 2011). In this context, MRS, which is resistant to β-lactams, carbapenems, and quinolones, is usually linked to either *mecA*, a methicillin resistance gene located in the mobile staphylococcal chromosome cassette, or SCC*mec*, a chromosomal gene, which when absent *Staphylococcus* spp. are susceptible to methicillin (Blair et al., 2015; Ito et al., 2014; Lima et al., 2015).

Epidemiology

The discovery of the existence of Staphylococcus spp. resistant to penicillin dates to the early 1940s, more specifically in 1942, just two years after the introduction of this antibiotic in the clinic; in 1960, the first samples MRSA were discovered, just one year after the introduction of methicillin on the market, and in the early 1980s, new species of staphylococci with the same resistance profile were detected, and such findings continue to increase (Lakhundi & Zhang, 2018; Martins & Cunha, 2007).

MRSA was initially correlated with hospital and health care infections (HA-MRSA), and after some time, MRSA was identified in community-associated samples (CA-MRSA), including those who were not in hospital settings or with people who were in these environments, shortly after these microorganisms were isolated from production animals (Cunha, 2017; Martins & Cunha, 2007; Deleo et al., 2010).

MRS coagulase-negative and positive, deserve to be highlighted, as they are increasingly being isolated in the environment, in humans, and animals, in addition to being able to transfer genes, such as mecA, to other *Staphylococcus* that can cause greater damage to the One Health program (Buzón-Durán et al., 2018; Saber et al., 2017; Seng et al., 2017).

MRSA and MRS are present in different places, such as on surfaces, hospitals, in patient blood cultures, in the nasal cavities of healthy people, in pets, production, and in the people around them (Atyah et al., 2010; Buzón-Durán et al., 2018; Cunha, 2017; Martins & Cunha, 2007; Saber et al., 2017; Seng et al., 2017; Worthing et al., 2018).

The first report of MRS in livestock occurred in 1996 in Japan (Kawano et al., 1996), and in swine, the presence of MRSA was detected in 2005 in the Netherlands and France (Armand-Lefevre et al., 2005; Voss et al., 2005). After this discovery, this microorganism was isolated in many studies, mainly from high-density swine breeding, demonstrating the importance of these microorganisms for One Health (Figure 1) (Bonvegna et al., 2021).

Staphylococcus spp. resistant to methicillin and mecA gene in the swine production chain

The presence of multidrug-resistant microorganisms and carrying resistance genes in the production of animals is noteworthy, especially when considering the high population density to which most of these animals are subjected, the presence of humans who manage these animals in these places, and the risk of contamination by such bacteria (Back et al., 2020; Catry et al., 2003; Rushton et al., 2014; Sweeney et al., 2018; Xiong et al., 2018).

Antibacterial resistance in livestock is intrinsically linked to the use of antibiotics as growth promoters and as prophylactic therapy against different infectious diseases, swine farms are highlighted in this practice since the health of the animals is one of the biggest factors that generates economic gains in this market (Aguilar et al., 2015; Catry et al., 2003; Xiong et al., 2018).

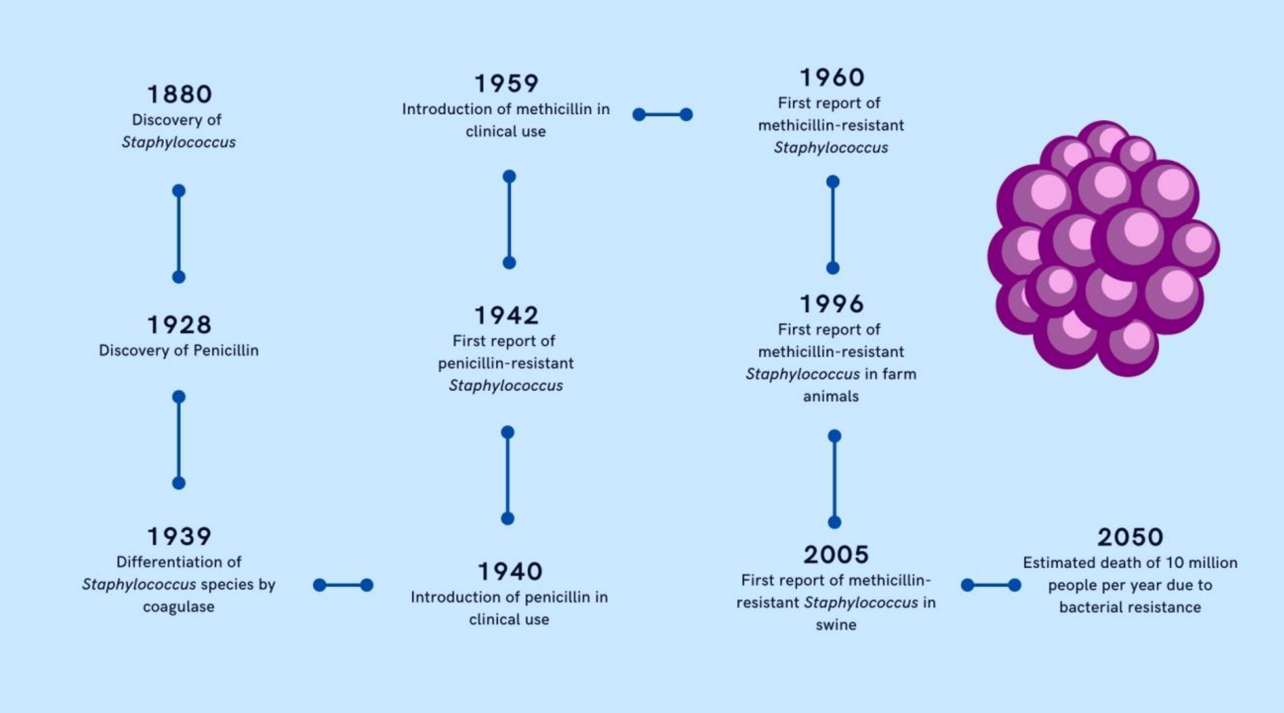

Figure 1. Timeline regarding the evolution and isolation of methicillin resistant *Staphylococcus* spp. in swine production.

Pigs are already known as major carriers of multiresistant *Staphylococcus* spp., these bacteria tend to be more resistant to antibiotics than isolates from bovine mastitis, which highlights the importance of these bacteria in the swine production chain, as well as in its branches (Oppliger et al., 2012).

In addition to the presence of microorganisms of medical concern in livestock and their resistance to antibiotics, there is widespread human colonization among veterinarians and workers directly linked to the husbandry of these animals, thus disseminating such bacteria beyond the swine farming environment (F. M. Aarestrup et al., 2008; Lassok & Tenhagen, 2013; Oppliger et al., 2012).

Staphylococcus spp. are commonly present in nasal cavities as commensals; therefore, they are not among the microorganisms targeted for prevention in the production chain, and the resistance present in these microorganisms of nasal colonization is not particularly triggered with antibiotics administered to these animals in their feed (F. M. Aarestrup et al., 2008; Lassok & Tenhagen, 2013; Oppliger et al., 2012).

In the swine industry, *Staphylococcus* spp. are mainly searched for *Staphylococcus* spp. sensitive to methicillin (SSM), MRS, and Livestock-associated-MRS, which are considered endemic in Europe and North America, but there are also reports of these species in Brazil (Silva et al., 2020), Thailand (Chanchaithong et al., 2019), and Switzerland (Oppliger et al., 2012), where pig farming is economically important (Table 1) (X. Li et al., 2022; Smith et al., 2013; Voss et al., 2005).

Table 1
Studies published between 2011 – 2021* in different countries that isolated methicillin resistant Staphylococcus spp. mediated, or not, by resistance genes

Country	Total samples	SRM and SARM samples	Creation phase	Phenotypic test - Oxacillin Resistant	Found molecular	References
Italy	195	65.1% (127)	Nursery, finishing and boars	-	mecA	Bonvegna et al. (2021)
India	60	66.6% (40)	Growing	-	mecA	Kalai et al. (2021)
Thailand	204	5.4% (11)	Slaughtering	SRO	-	Tanomsridachchai et al. (2021)
Switzerland	2.812	17.2% (485)	Slaughtering	-	Spa type gene	Kittl et al. (2020)
Italy	440	17.5% (77)	Slaughtering	SRO	-	Rodríguez-López et al. (2020)
Japan	420	3.1% (13)	Slaughtering	-	-	Sasaki et al. (2020)
Brazil	30	23% (6)	Slaughtering	SRO	mecA	Silva et al. (2020)
Thailand	467	12.6% (60)	Nursery and growing	-	mecA, blaZ, e dfrG	Chanchaithong et al. (2019)
Poland	203	17.7% (36)	Growing	SRO	Spa type gene	Krupa et al. (2015)
Portugal	103	96% (98)	Growing	-	-	Lopes et al. (2019)
Italy	85	64.7% (55)	Slaughtering, growing and boars	SRO	-	Parisi et al. (2019)
Italy	475	46.1% (219)	Finishing	-	Spa type gene	Pirolo et al. (2019)
Korea	979	9% (88)	Growing	-	Spa type gene	Moon et al. (2019)
Portugal	101	99% (100)	Growing	SRO	Spa type gene	Conceição et al. (2017)
China	2.420	11.2% (270)	Slaughtering and finishing	SRO	mecA	J. Li et al. (2017b)
Netherlands	558	83% (461)	Slaughtering	-	mecA	Dierikx et al. (2016)
Norway	74	35.1% (26)	Slaughtering and boars	-	-	Grøntvedt et al. (2016)
Belgium	328	65.6% (215)	-	-	Spa type gene	Peeters et al. (2015)
United States of America	194	17.5% (34)	Nursery, finishing, growing and boars	SRO	mecA	Frana et al. (2013)
United States of America	1.085	4.6% (50)	Growing	-	Spa type gene LA-MSARM	Smith et al. (2013)
Switzerland	344	37.8% (130)	Nursery and growing	SRO	mecA	Oppliger et al. (2012)
Netherlands	500	13% (65)	Growing	-	mecA	Tulinski et al. (2012)

ORS, Staphylococcus spp. oxacillin resistant; SRM, Staphylococcus spp. methicillin resistant; MRSA, methicillin-resistant Staphylococcus aureus.
*Indexed in PubMed, Scholar Google, and SciELO databases, under the indexing terms Staphylococcus and Pigs. Articles in English and Portuguese containing the information shown in the table were selected.

Final considerations

The presence of antibiotic-resistant microorganisms in the swine production chain has generated great concern, whether in relation to economic losses due to drug spending, possible infectious problems remain in the herd and/or loss of animals due to these infectious processes, in addition to the possible transmission of these bacteria and bacterial resistance genes between animals, between animals and workers directly linked to swine farming, and even through food through the consumption of by-products of these animals.

Knowledge of the resistance profile of microorganisms has strong implications in swine farming ; thus, more research is needed related to the potential transmission of these bacteria to other animals, humans, and even the environment, treating them as both anthropozoonoses and zooanthroponosis. In addition, to a greater focus on the unbridled use of antimicrobials aimed at a greater development of these animals, generating a lot of worrying waste for the environmental.

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