Streptococcus suis; A Public Health Concern

Ashraf S. Hakim[1] Amany N. Dapgh[2], Hussien A. Abouelhag[1]

[1]Department of Microbiology and Immunology, National Research Centre, 33 Bohouth St., Dokki, Cairo, Egypt

[2]Department of Bacteriology, Animal Health Research Institute, Agriculture Research Center, Dokki, Giza, Egypt

***Corresponding author:** Ashraf S. Hakim **email:** migris410@yahoo.com

Received: 29-06-2025, **Accepted:** 16-07-2025. **Published online:** 23-07-2025

DOI: https://doi.org/10.33687/ricosbiol.03.07.67

Abstract

Pork is considered the second consumed meat worldwide, and may give rise to about twenty-five pork borne diseases. Pork could be contaminated either through infected pig or colonization in healthy reservoir population, during slaughtering by evisceration of intestinal contents, in processing and packing or even on display places in retail markets. Bacterial pathogen constitutes about 50% of pork born intoxication which may pose a zoonotic risk and threaten public health.

Streptococcus suis (*S. suis*) is a gram-positive coccal bacterial pathogen particular in pigs which can induce grave infections in human comprising meningitis, and septicaemia leading to serious complications. The pathogen can be transmitted to human via consumption or occupationally through handling and contact with contaminated pork result in sporadic or outbreak onset.

The topic was performed to investigate on *S. suis* pork born infection in human. Establishment of an efficient screening strategy and public health measures would be effective to promote understanding about the illness.

Keywords: *Streptococcus suis,* public health, *Sus scrofa domesticus,* Pork born infections.

Introduction

Domestic pigs (*Sus scrofa domesticus*) are omnivores and can consume a variety of food with proof of pig husbandry dating back to 5000 B.C., biologically, pigs are close similar to humans, thus are frequently used for human medical research. As well to pork, numerous valuable products come from swine as lard which is pig abdominal fat (Loren, 2016).

Pork is the culinary (related to kitchen) name for meat from a domestic pig. It is the most commonly consumed meat either freshly cooked or preserved, accounting for about 38% of meat production worldwide (USDA, 2024).

Pork is the most popular meat in Eastern and Southeastern Asia, and is also very prevalent in the Western world, particularly in Central Europe, Sub-Saharan Africa, the Americas and Oceania (Martins *et al.,* 2025).

Streptococcus suis (*S. suis*) is a gram-positive bacterial pathogen in pigs which can cause serious infections in human including meningitis, septicaemia, and others (Dutkiewicz *et al.,* 2017).

Rapid precise diagnosis of the pathogen which implicated in the disease through advanced serological identification and molecular characterization for source tracking to define the source of outbreak (Hatrongjit *et al*., 2020).

Looking at the previous public health concern, prevention of pork born *S. suis* contamination should take the attention through applying the proper hygienic measures in breeding places, slaughter house and processing factories besides the regarding of hygienic protective precautions of the contacts; veterinarians, raisers, workers, butchers, market vendors…etc. (Rayanakorn *et al*., 2018).

The present topic gives lights on specific pork-borne pathogen; *S. suis* that prevalent in the whole process from slaughtered pigs through pork and pork byproducts regarding their zoonotic concern importance and public health impact. Also how to improve the management of the pathogen hazards transmitted to humans through pork consumption or pig contact.

S. suis is a facultative anaerobic Gram-positive ovoid or coccal bacterium measuring, on average, 1.0–1.5 mm, occurring in pairs, short chains, or singly. The bacterium comprises commensal part of the respiratory microbiota of swine, in particular of the nasal cavities and tonsils as well as in the reproductive and digestive tracts of pigs, with colonization rate is up to 100% (Vötsch *et al*., 2018). It is counted a prime porcine pathogen endemic in almost all countries with a developed swine industry. In the track of evolution, some strains became virulent and invasive for pig hosts, causing meningitis, bronchopneumonia, arthritis, endocarditis, as well as septicemia and sudden death, resulting in significant economic losses worldwide (Dutkiewicz *et al*., 2017).

Isolation of *S. suis* could be achieved by blood and CSF cultures, after 24 h or 48 h of incubation, small beta-hemolytic colonies grew on horse blood agar plates. The bacteria were catalase negative and highly susceptible to penicillin. *S. suis* virulent strains cells are characterized by a polysaccharide capsule showing a various antigenicity, resulting in serologically classified into 35 serotypes; serotypes 1–34 and serotype 1/2 which react with both serotypes 1 and 2 antisera. Otherwise, PCR and modern molecular techniques have improved the rate of detection and discrimination of *S. suis*, as the 16S rRNA gene sequencing technique is a useful and definitive. *S. suis* strains have been genotyped into more than 700 sequence types (STs) (Hatrongjit *et al*., 2020).

Kerdsin *et al*. (2012) developed an expanded multiplex PCR assay capable of identifying all *S. suis* serotypes using four reactions. The serotypes were diminished in number to 33 because serotypes 32 and 34 were re-identified as *S. orisratti*. More recently, they were proposed to remove serotypes 20, 22, 26 and 33 from the *S. suis* taxon. Hence, it is presently considered that there are 29 true *S. suis* serotypes. This technique seemed to be beneficial in identifying the strains which lack capsule and failed to be typed by capsular agglutination test (Kerdsin *et al*., 2014).

It is believed that *S. suis* contaminates pig carcasses subsequently pork and its products through slaughtering process, Guntala *et al*. (2024) reported the existence of *S. suis* in pork byproducts collected from abattoirs and wet/retail markets in Thailand, and found high contamination rate with *S. suis* serotype 2 in internal organ samples.

Asian countries; where poor hygienic, high intensity swine raising is common, the direct handling with infected pigs or abattoir carcasses, as well as popular cultural habits; ingestion of undercooked pork meat and pork blood as traditional drink were identified as risk factors for human *S. suis* infection (Okello *et al*., 2015). On the other hand, *S. suis* is mediated a particular occupational pathogen that can be transferred from pigs to humans, this is hazard for butchers and abattoir workers, meat processing workers, people who transport pork, meat inspectors, and veterinary practitioners, particularly individuals have skin cuts or abrasions who handle raw pork without gloves or have close contact with infected pigs (Liu *et al*., 2025).

The risk concern not limited to clinically diseased pig but scoped the healthy carrier or asymptomatic pigs which are important not only regarding the spread of *S. suis* in herds, but also as source of infection for humans. Most isolates from diseased pigs restricted to definite serotypes including serotypes 2, 3, 7 and 9, while in humans, the majority of clinical cases are linked with serotypes 2 and 14 however, serotypes 4, 5, 9,16, 21, 24 and 31 have also been recorded (Meekhanon *et al*., 2017).

Although, serotype 2 was approved as the master cause of human infections, whereas, serotype 9 is much more common in Spain, *S. suis* serotype 5 seems to be a concern in the human cases reported in 5 cases in Japan (Taniyama *et al*., 2016). Besides sporadic cases recorded in Thailand (Kerdsin *et al*., 2022), Sweden (Gustavsson and Rasmussen, 2014), Poland (Bojarska *et al*., 2016), and US (Gomez *et al*., 2014). All cases comprised pig farmers, pork shop employees or raw pork feeders.

Public health impact of *S. suis*

S. suis is supposed an emerging zoonotic agent which can transmitted to humans causing meningitis and streptococcal toxic shock-like syndrome (STSLS). In contrast to swine, humans seem to be rarely colonized by *S. suis*, therefore, human carrier rates reported to be approximately 5% on average worldwide (Okura *et al*., 2019). Meningitis remained the most common presentation of infection in both Asia and European countries (84.6% and

75.2%, respectively), followed by sepsis (15.4% and 18.6%, respectively), which had a higher mortality rate. Other clinical presentations included enteritis, arthritis, endocarditis, pneumonia, spondylodiscitis, endophthalmitis, uveitis and peritonitis. Deafness was distinct sequelae (50.5% in Europe and 51.9% in Asia) after recovery from *S. suis* infection, especially in patients with meningitis (Haas *et al.,* 2018).

The first case of human infection with *S. suis* was reported in Denmark in 1968 (Arends and Zanen 1988), and since then, this infection has been increasingly recorded in many countries. The emergence of *S. suis* as a human pathogen was mostly clarified by the major outbreak of drastic toxic shock illness that caused high morbidity and mortality referred to infection with *S. suis* serotype 2 in Sichuan province, China, in 2005 and many patients have died and now become a great public regard worldwide (Yu *et al*., 2006).

Shi *et al*. (2016) reported 10 recurrent cases of human *S. suis* infections during 2008–2015 in southern China. Most of the hospitalized patients were male workers in close contact with pigs, pork products, or both. These patients typically displayed clinical signs of meningitis, including headache, vomiting, fever and coma. Microbial and molecular check confirmed that these clinical isolates were *S. suis* serotype 2.

Thailand had the second top number of mentioned public health cases, regarding for 11% of all reported cases worldwide. Data proposed a high incidence rate (6.2/100,000) of *S. suis* infection in the general population in 2010, primarily associated to consumption of raw pork products (Takeuchi *et al.,* 2012). Maneerat *et al.* (2013) assayed the genetic linkage between *S. suis* serotype 2 isolates from pigs and humans through the 2007 infection outbreak in Thailand. A strong link between virulence gene profiles, assuring *S. suis* transmission from pigs to humans.

Mai *et al.* (2008) tested 450 cerebrospinal fluid aspirates of patients with suspected bacterial meningitis in southern Vietnam using qPCR. *S. suis* was the most common pathogen and recovered in 151 (33.6%) of the cases. Fifty (33.1%) of these 151 patients were reported a confirmed exposition to pigs or pork. Mortality was minimal (2.6%; 4 of 151 patients died), but mild to intense hearing loss occurred in 93 (66.4%) of 140 patients. Ninety-one of 92 *S. suis* isolated strains had serotype 2.

The first case of human confirmed *S. suis* infection in Korea, represented by an 81-yr-old Korean woman had arthralgia of both knees, and neck stiffness was admitted to hospital in southern region of Korea where abundant pig farms were present around her house, and pork is the prime type of meat in Korea, and housewives often come in touch with raw pork during cooking (Kim *et al*., 2011). A recent outbreak of *S. suis* infection in humans resulted in three confirmed cases. Three confirmed patients had some form of contact with pig history. The patients were recognized with subdural empyema, septicemia, and infectious spondylitis. *S. suis* was recovered from their blood (Kim *et al*., 2024).

Till 2016 – 2017, there has not been any case determined from Malaysia or Indonesia rather because of the restricted pig breading due to cultural and religious purposes. Two multiplex PCR confirmed *S. suis* cases from Malaysia were reported. The first patient was a feverish, reduced hearing, 41-year-old man who reared four pigs at home and had daily contact with them. The second patient was a 44-year-old butcher in local market handling pork and had harmed his thumb while slaughtering a pig two days before starting of fever, headache and vomiting (Rajahram *et al*., 2017).

In contrast to Asian countries, human *S. suis* infection is mainly deemed a swine-related occupational disease in Western countries. Infection average in the general and in-risk population are little known because *S. suis* infection is not a notifiable disease. The Netherlands recorded the most *S. suis* infections in the West, and recently set *S. suis* among its top ten primacy zoonotic pathogens as the annual incidence rate of 0.002 per 100,000 persons at risk, therefore raised awareness and disease observation is ensured (Dame-Korevaar *et al.,* 2025).

Also, there were some individual cases have been recorded in other European countries; a case of a butcher with supposed meningitis, worked in pork processing plant in Poland and had a medical history of injury during the pork processing (Zalas-Wiecek *et al*., 2013). Another sole case was reported in Portugal a 48-year-old butcher with meningitis and bilateral hearing loss, who had suffered from a finger cutting while pork meat preparing (Sena Esteves *et al.,* 2017).

Auger *et al*. (2016) mentioned that the *S. suis* Serotype 2 isolates obtained from human cases in Canada and USA; “the two countries that together are the second most important swine producers worldwide after China” were less virulent than the Eurasian strains. On the contrary the seventeen human *S. suis* strains recovered in Argentina (16 serotype 2 strains and a serotype 5 strain) as well as14 isolates from pigs were analyzed. All human serotype 2 strains and most swine isolates were typed as sequence type 1 (ST1), a genotype typical of virulent Eurasian ST1 strains.

Data from Africa were scarce until the recent report of 15 cases with severe hearing troubles and reported constant contact with pork products in Togo (Tall *et al*., 2016). Other report of 2 *S. suis* meningitis cases in Antananarivo, Madagascar presented a 24-year-old man worked in a swine slaughter house and suffered from fever, headache, and unilateral sixth nerve palsy in 2015, besides a 60-year-old febrile woman frequently cooked pork meat in 2016, (Raberahona *et al*., 2018). These reports highlighted the up growth of this pathogen in Africa and boosted the need for precise epidemiological and surveillance studies of *S. suis* infections and for educating clinicians and risk groups in non-endemic countries (Prince-David *et al*., 2016).

The bad consequence of *S. suis* infection in human not restricted for meningitis and permanent deafness but may put out to another sequels, such as endocarditis. Three male cases aged 27–53 years in Thailand, were reported between January 2010 and December

2011. All in a common risk factor for eating undercooked pork, and the molecular analysis was positive for *S. suis* serotype 2 (Roodsant *et al*., 2021). As well, Yanase *et al*. (2018) pointed out the first human case who, its magnetic resonance imaging (MRI) revealed pyogenic ventriculitis in addition to meningitis. A 45-year-old male who handled raw pork and *S.suis* serotype 2 was confirmed.

Although the natural niche for *S. suis* is considered to be the pig, a wide range of host species found to be affected by this pathogen. Such issue was reported shortly in a notification of a 5-month-old crossbred beef steer died after exhibiting astasia in Japan. A postmortem examination revealed endocarditis and numerous renal hemorrhages. Gram-positive cocci were isolated and identified via biochemical tests and 16S rRNA gene sequence analysis as *S. suis* (Komatsu *et al*., 2018).

Before that, in USA, sixteen isolates of Gram-positive, coccoid bacteria were recovered from clinical cases of varied conditions in cattle and identified as *S. suis* using 16S r RNA gene sequencing. None of the isolates could be assigned to any of the known *S. suis* capsular types (Okwumabua *et al*., 2017).

Furthermore, *S. suis* was isolated from 2 lambs with a history of lameness. Identity of *S. suis* was confirmed by PCR and 16S rRNA gene sequencing. One isolate was non-typable by serotyping and non-encapsulated, while the other isolate was serotype 33. This will give attention for future probability of increasing the scope infection to livestock population and subsequently their meat (Muckle *et al*., 2014).

It is critical to remember that inner-ear impairment can occur frequently in *S. suis* meningitis surviving patient, so proper and rapid diagnosis concerning pig contact or improper pork consumption besides early antimicrobial treatment are the most significant factors in diminishing the bad functional dysfunction (Li *et al*., 2024).

Evolution of antimicrobial resistance in *S. suis* rises the risk for therapeutic fail in both animals and humans. Yu *et al*. (2018) discussed the synergism of augmentation therapy against multi-resistant *S. suis* isolates from swine. The blend of ampicillin plus apramycin and tiamulin plus spectinomycin exhibited the greatest synergism and may be potential strategies for treatment of multi-resistant *S. suis*.

In the absence of efficient human vaccines to combat *S. suis* and noticed rise of antibiotic resistance of *S. suis*, the seeking for new alternative antimicrobial strategies is of particular regard. Treatment with Nisin, 'the only approved bacteriocin for food preservation' results in bacterial lysis due to cell membrane breakdown. Significant synergistic effects of nisin were observed in combination with antibiotics presently used to treat *S. suis* infections (Zhu *et al*., 2021).

Continuation of research on production of an effective and safe vaccine is important. Positive examples of such studies are the results obtained recently by Chinese scientists.

Jiang *et al*. (2016) identified a natural low-virulence *S. suis* type 5 strain XS045 as a live vaccine candidate, and demonstrated its safety and effectiveness by providing cross-protection against challenges by type 2 and type 9 *S. suis* strains. In another study, Wang *et al.* (2017) detected significant genomic differences between the avirulent *S. suis* strain 05HAS68 and the highly virulent strain 05ZYH33. Piglets vaccinated with the avirulent strain were fully protected from challenge infection with the virulent strain.

Li *et al.,* (2021) prepared vaccine employing *S. suis* ghosts and its protective efficacy was assessed in mice. Serums were gathered from the groups and indirect ELISA results revealed that antibody titer of mice from group *S. suis* 2 ghosts and group *S. suis* 9 ghosts were significantly higher than blank group, but were near to the conventional inactivated vaccine group SS2. So, *S. suis* ghosts as candidate vaccine strategy displayed an excellent immunogenicity and give protection versus *S. suis* challenge in mice model.

Until the human vaccines validated, the principle of reduce human risk based on the prevention of pig population pathogen colonization. Currently, both commercial vaccines and inactivated autogenous vaccine are used. Although the use of commercial vaccines is more suitable, they often supply protection only versus the most important capsular type 2 of *S. suis*, but not against a lot of other capsular types that can also arouse the disease. In contrast, the use of autogenous vaccines is upsetting because each new batch needs experimental screening on animals, but in the end, they give better protection and block the expansion of the disease in herds during outbreaks of *S. suis* infection. Nevertheless, a polyvalent commercial vaccine that would conserve pigs from infection with all *S. suis* types is strongly desired (Jeffery *et al.,* 2024).

Different approaches are the injection of piglets at birth with long-acting penicillin**,** such an injection may prevent the disease, but this way should be used with caution to avoid the risk of antibiotic-resistant strains up growth. *S. suis* type 2 has been shown to be susceptible to current used disinfectants, soaps and cleansers, such as 5% bleach at 1:800 dilution. Eradication of disease by slaughter, followed by disinfection and repopulation, may be effective in controlling the disease but may not be economically favorable (Lv *et al*., 2025).

Conclusion

Although *S. suis* infection is prevalent, low number of cases were recorded and this is attributed to under diagnosis and unawareness of the illness. The organism is often misrecognized by clinicians leading to delay or inadequate therapy. It is substantial that patients with proposed *S. suis* clinical signs with prospecting risk factors should receive suitable care while waiting for laboratory assertion in spite of negative bacterial culture either due to misrecognizing or former antibiotic application. Evolving a screening scheme would be beneficial to facilitate the remedy decision. Once a clear clinical picture is recognized, the diagnosis should be easier. The instant empirical treatment with penicillin or antimicrobial

that the pathogen is sensitive to before evolvement of complications especially deafness would be substantial in prohibiting long term mortality and morbidity.

In a miss of vaccination, the best mitigation measure is to restrict the illness transmission. Public health interventions involving a food safety campaign would be efficient to promote understanding about the illness particularly in settings where there is a strong link between raw pork consumption and conventional culture.

References

Arends J.P., and Zanen H.C. (1988). Meningitis caused by *Streptococcus suis* in humans. *Rev. Infect. Dis.*,10(1),131-7.

Auger J.P., Fittipaldi N., Benoit-Biancamano M.O., Segura M., and Gottschalk M. (2016). Virulence Studies of Different Sequence Types and Geographical Origins of *Streptococcus suis* Serotype 2 in a Mouse Model of Infection. *Pathogens*, 11; 5(3) pii: E48.

Bojarska A., Molska E., Janas K., Skoczyńska A., Stefaniuk E. and Hryniewicz W. (2016). *Streptococcus suis* in invasive human infections in Poland: clonality and determinants of virulence and antimicrobial resistance. *Eur. J. Clin. Microbiol. Infect. Dis.*, 35, 917–925.

Dutkiewicz J., Sroka J., Zając V., Wasiński B., Cisak E., Sawczyn A., Kloc A. and Wójcik-Fatla A. (2017). *Streptococcus suis*: a re-emerging pathogen associated with occupational exposure to pigs or pork products. Part I - Epidemiology. *Ann. Agric. Environ. Med.*, 23-24(4), 683-695.

Fernando P., Poester F.P., Poester K., Nielsen L., Samartino L., Samartino W., and Ling Y.,(2010). Diagnosis of Brucellosis. *The Open Veterinary Science Journal,* 4(1), 46-60

Food and Agriculture Organization (FAO). (2014). Sources of Meat. 25 November 2014.

Gomez E., Kennedy C.C., Gottschalk M., Cunningham S.A., Patel R. and Virk A. (2014). *Streptococcus suis*-related prosthetic joint infection and streptococcal toxic shock-like syndrome in a pig farmer in the United States. *J. Clin. Microbiol.*, 52, 2254–2258.

Guntala R., Khamai L., Srisai N., Ounjaijean S., Khamduang W., and Hongjaisee S. (2024). Contamination of *Streptococcus suis* and *S. suis* Serotype 2 in Raw Pork and Edible Pig Organs: A Public Health Concern in Chiang Mai, Thailand. *Foods*, *13*(13), 2119. https://doi.org/10.3390/foods13132119

Gustavsson C., and Rasmussen M. (2014). Septic arthritis caused by *Streptococcus suis* serotype 5 in pig farmer. *Emerg. Infect. Dis.*, 20, 489–490.

Haas B., Grenier D. (2018). Understanding the virulence of *Streptococcus suis*: A veterinary, medical, and economic challenge. Med. Mal. Infect. 48(3), 159-166. doi: 10.1016/j.medmal.2017.10.001.

Jiang X., Yang Y., Zhu L., Gu Y., Shen H., Shan Y., Li X., Wu J., and Fang W. (2016). Live *Streptococcus suis* type 5 strain XS045 provides cross-protection against infection by strains of types 2 and 9. *Vaccine*, 34(51), 6529-6538.

Kerdsin A. (2022). Human *Streptococcus suis* Infections in Thailand: Epidemiology, Clinical Features, Genotypes, and Susceptibility. Trop. Med. Infect. Dis., 7(11), 359. doi: 10.3390/tropicalmed7110359.

Kerdsin A., Akeda Y., Hatrongjit R., Detchawna U., Sekizaki T., Hamada S., Gottschalk M., and Oishi K. (2014). *Streptococcus suis* serotyping by a new multiplex PCR. *J. Med. Microbiol.*, 63(6), 824-30.

Kerdsin A., Dejsirilert S., Akeda Y., Sekizaki T., Hamada S., Gottschalk, M. and Oishi, K. (2012). Fifteen *Streptococcus suis* serotypes identified by multiplex PCR. *J. Med. Microbiol.* 61, 1669–1672.

Kerdsin A., Dejsirilert S., Sawanpanyalert P., Boonnark A., Noithachang W., and Sriyakum D. (2011). Sepsis and spontaneous bacterial peritonitis in Thailand. *Lancet*, 378, 960.

Kim E.T., Heo S.T., Yoo J.R., Kim M., Kim T.H., Kim Y.R. (2024). Case Report: *Streptococcus suis* Human Infections among Pork Consumers in Jeju, South Korea: Zoonotic Threats. Am. J. Trop. Med., 15, 111(6), 1243-1246. doi: 10.4269/ajtmh.24-0201.

Kim H., Lee S.H., Moon H.W., Kim J.Y., Lee S.H., Hur M., and Yun Y.M. (2011). *Streptococcus suis* causes septic arthritis and bacteremia: phenotypic characterization and molecular confirmation. *Korean J. Lab. Med.*, 31(2), 115-7.

Komatsu T., Watando E., Inaba N., Sugie K., Okura M., and Shibahara T. (2018). Bovine vegetative endocarditis caused by *Streptococcus suis*. *J. Vet. Med. Sci*., 1-20

Li S., Wang D., Guo C., Tian M., Liu Q., Pan Z. (2021). Study on preparation of a *Streptococcus suis* ghost vaccine. Microb. Pathog., 154, 104865. doi: 10.1016/j.micpath.2021.104865.

Loren G, (2016). Why pigs are so valuable for medical research". Fox News.

Lv R., Zhang W., Sun Z., Si X., Dong H., Liu X. (2025). Current prevalence and therapeutic strategies for porcine *Streptococcus suis* in China. Appl. Environ. Microbiol., 91(3):e0216024. doi: 10.1128/aem.02160-24.

Mai N.T., Hoa N.T., Nga T.V., Linh le D., Chau T.T., Sinh D.X., Phu N.H., Chuong L.V., Diep T.S., Campbell J., Nghia H.D., Minh T.N., Chau N.V., de Jong M.D., Chinh N.T., Hien T.T., Farrar J., and Schultsz C. (2008). *Streptococcus suis* meningitis in adults in Vietnam. *Clin. Infect. Dis.*, 46(5), 659-67.

Maneerat K., Yongkiettrakul S., and Kramomtong I. (2013). Virulence genes and genetic diversity of *Streptococcus suis* serotype 2 isolates from Thailand. *Transbound Emerg. Dis.* 60(Suppl. 2), 69–79.

Okura M., Maruyama F., Ota A., Tanaka T., Matoba Y., Osawa A., Sadaat S.M., Osaki M., Toyoda A., Ogura Y., Hayashi T. and Takamatsu D. (2019). Genotypic diversity of *Streptococcus suis* and the S. suis-like bacterium *Streptococcus ruminantium* in ruminants. Vet. Res., 50(1), 94. doi: 10.1186/s13567-019-0708-1.

Zhu H., Han L., Ni Y., Yu Z., Wang D., Zhou J., Li B., Zhang W., He K. (2021). *In vitro* and *In vivo* Antibacterial Effects of Nisin Against *Streptococcus suis*. Probiotics Antimicrob Proteins, 13(2), 598-610. doi: 10.1007/s12602-020-09732-w.