

Methicillin-Resistant Staphylococci in Animals and Food Products

Subjects: Veterinary Sciences | Microbiology

Contributor: Chahrazed Belhout , Rachid Elgroud , Patrick Butaye

Staphylococci are Gram-positive bacteria responsible for a wide variety of suppurative infections in humans and animals. Methicillin resistance acquisition is due to the integration of the staphylococcal cassette chromosome *mec* (SCC*mec*), which contains the *mecA* gene conferring β -lactam resistance. Methicillin-resistance in Staphylococci (MRS) pose a specific problem as they are in general more difficult to treat and may eventually result in death. Those MRS are now also increasingly found in different animal species and may compromise animal health as well as human health through the transmission of those MRS from animals to humans. As such it is important to know the situation of MRS in animals and in foods.

methicillin-resistant staphylococci (MRS)

methicillin-resistant *S. aureus* (MRSA)

methicillin-resistant non-aureus staphylococci (MRNaS)

methicillin-resistant coagulase-negative staphylococci (MRCNS)

animals

food products

1. Methicillin-resistant *S. aureus* (MRSA)

1.1. MRSA in Food-Producing Animals

The first report of MRSA infections in food-producing animals was a case of bovine mastitis in Belgium in the early 1970s [1]; however, this was a strain of human origin and did not spread [2]. Since 2005, one of the most important events in the epidemiology of infectious diseases that has attracted considerable public health attention [3] is the emergence and spread of specific clones of MRSA in livestock, named Livestock-Associated MRSA (LA-MRSA) [4]. Subsequently, increasing numbers of reports have been published on LA-MRSA infection and colonization of both companion and food-producing animals, indicating a growing awareness of the role of these animals in the evolution, epidemiology, and dissemination of these microorganisms [5] and evidencing LA-MRSA as potential zoonotic pathogen though to a lesser extent an animal pathogen, as it has been shown only to be implicated in mastitis in bovines [6] and disease in turkeys [7]. However, LA-MRSA CC398 is thought to be less pathogenic for humans than other *S. aureus* lineages [8]. The initial LA-MRSA isolates belonged to clonal complex 398 (CC398), which was very uncommon in humans at the time [9]. Since its discovery, LA-MRSA CC398 has been isolated from cattle, horses, chickens, and turkeys, but currently, pigs appear to be its primary host [10]. The presence of LA-MRSA CC398 in food-producing animals is a matter of concern due to direct transmission to people in contact with

infected animals and/or their products, as well as possible contamination of food [9]. Although CC398 is still the most common LA-MRSA worldwide, other sequence types are involved, such as CC9, CC97 and CC1 [11].

In Arab countries, research on MRSA in animals/food is quite limited and there is only a little information available from some countries [12] with obviously fewer data on pigs from Arab countries, as there is only a minority of people consuming pig meat (consumption of pork is a religious taboo). The major focus of EFSA surveillance in European countries is pigs, however, as they represent the main reservoir of LA-MRSA [13]. The voluntary monitoring of the member states for the prevalence of MRSA in food and food-producing animals in 2018–2019 revealed that the prevalence varied between animal species, production systems, as well as the country [13].

In pigs, the prevalences varied between 0.1% for pig herds in Norway and 100% for fattening pigs in Portugal. Most strains were LA-MRSA CC398 [13]. In cattle, moderate MRSA prevalence was reported among herds of dairy cows and in herds of meat-producing animals (14.0% and 8.7%, respectively) in Belgium and slightly lower in Denmark (6.1% and 1.5%, respectively), while the higher level was reported from herds of veal calves in 2019 (9.6% and 54.5%) in Denmark and Belgium, respectively [13]. In poultry, a low MRSA prevalence was reported among laying hen flocks in Denmark in 2018 (3.2%), and a moderate level was reported among fattening turkey flocks by Germany in 2018 (17.2%) [13]. The majority of the MRSA isolates recovered from pigs, cattle, and poultry flocks on which molecular typing data were reported in 2019, were livestock-associated lineages [13].

MRSA in Cattle

In cattle, *S. aureus* is considered a contagious pathogen, causing clinical and subclinical mastitis [14][15][16]. Methicillin-resistant *S. aureus* has been reported from dairy farms worldwide and has been associated with transmission events between humans and animals [17][18]. In the Arab World, a comparison of MRSA prevalence studies is challenging because of differences in types of samples, inoculum volumes, pre-enrichment, and detection methods. Some studies used selective media and/or PCR confirmation for the isolation and confirmation of MRSA [19][20][21], while other studies determined the prevalence of phenotypic methicillin resistance in *S. aureus* [22][23]. Nevertheless, the prevalence of MRSA was, in general, rather high in milk samples and ranged between 3.60% [24] and 35.7% [23]. Carriage of MRSA in the noses of cattle has been reported to be in the range of 15.5 to 40% [25][26]. The higher prevalence of MRSA in cattle may be explained by the fact that intensive production systems are mostly used in cattle farming [27]. Moreover, the surveillance program that controls cattle importations and farm biosecurity measures for personnel visiting or returning from abroad are not sufficient or absent—this could represent the most important way of introducing MRSA.

Several MRSA lineages have been identified in specific geographical areas. In the Arab countries, MRSA ST97-t267 has been reported in healthy cows in Tunisia [28]. MRSA ST97 was first discovered in Italy in pigs [29]. ST97 and other related STs belonging to CC97 are traditionally closely associated with cattle and have been recently described in both healthy and diseased pigs in European countries [30]. In Egypt, CC1, CC5, and CC45 have been isolated from cattle [31]. CC1 and CC5 have been recognized as both HA- and CA-MRSA but have also been isolated from pork and pigs [32]. These CCs are highly prevalent in humans in Europe and the Middle East [33][34].

MRSA CC22 has been reported from cattle in Egypt [20] and is considered HA-MRSA. CC22 strains were first identified in the UK in the early 1990s and are the most prevalent HA-MRSA in the UK [35].

MRSA from cattle may represent a potential zoonotic issue, especially for people in direct contact with the animals, though also for the general public through the food chain. It is clear that in Arab countries, cattle are a significant reservoir for MRSA [36]; however, it is still unclear what is the real burden of MRSA in cattle in Arab countries as few data have been published. There is a need for more research on the prevalence of MRSA and their genetic background to have a clear view of the burden of MRSA in cattle rearing as well as for public health.

MRSA in Sheep and Goat

Historically, in Arab countries—in contrast with European countries—sheep and goats dominate, and they are considered a crucial source of meat and milk for the human population in that area [37]. The high consumption of sheep and goat meat in these countries compared to other European countries can be explained by the mainstream religious and socioeconomic conditions in this area [38]. Typically, in North African countries such as Tunisia, Morocco, and Algeria, sheep herds are distributed all over the country on small family farms, though there are also large farms with intensively reared animals [39]. Frequently, unpasteurized ovine milk is used for the artisanal production of cheeses, which increases the risk of transmission of pathogens through milk [40]. The exploitation of goat herds for meat and milk is widespread around the world [41], with the largest proportion in Asia and Africa [42][43]. Goat meat is widely regarded as a lean meat, and there are indications that the demand for this healthy meat will increase [44].

Staphylococci have been isolated from various body sites, as well as from infections, mainly mastitis, from sheep and goats [45]. Nasal carriage of MRSA in sheep in Arab countries ranged between 3% and 28.9, respectively [25][46], while in milk samples, a prevalence of 29.8% has been reported in Jordan [19]. In goats, the highest prevalence of MRSA was 17.4% in milk samples [47], while a prevalence of 2% was detected using nasal swabs [48]. Only MRSA belonging to the CC80 has been found with ST80 and ST153 in Algeria and Tunisia, respectively [46][49]. ST80 is a typical CA-MRSA, first described in Europe but now spreading worldwide [50][51][52]. Mastitis in sheep and goats has been associated with different STs reported worldwide, such as ST291 [53], ST750, ST1729 [54], ST1 [55].

It is currently quite difficult to draw conclusions on the situation of MRSA in sheep and goats in Arab countries due to the lack of data, but current data indicate a rather high prevalence.

MRSA in Poultry

The growth of commercial poultry farming in Arab countries has provided a fertile field for staphylococcal infections and zoonotic transfer [56]. Its intensive nature engenders the extensive use of different antibiotic agents for treatment, imposing a considerable selection pressure for resistance. The first detection of LA-MRSA in poultry came from Belgium, where LA-MRSA was isolated from healthy broilers [57]. Consequentially, MRSA has been detected in poultry in several Arab countries [58]. Two studies from Algeria showed a prevalence between 30% [59]

and 57% of MRSA in poultry [22]. The prevalence of methicillin resistance among *S. aureus* was 27% in Egypt [60] and 27.3% in Iraq [61].

The majority of the MRSA isolates belonged to CC398 with a single CC5 isolated from a turkey, though it should be noted that typing has only been performed in a single study from Egypt [60]. The most frequent spa types were the typical animal-associated t011, t034, and t899 [60]. CC398 has previously been reported in several cases in poultry [62][63][64][65]. CC5 is commonly associated with human infections and has been isolated from pork and pigs in the USA [32] and Canada [66]. It has been shown that CC5 originally comes from humans and has been adapted to poultry, causing infections [67].

MRSA in Camelids

There are about 30 million dromedary camels in the world, with the highest number in Africa and the Middle East [68]. Particularly, in Arab world countries, the dromedary camel (*Camelus dromedarius*, one-humped camel) is a multipurpose animal and an important livestock species adapted to hot and dry environments [69], formerly used strictly for transport [70], but nowadays also production animal for milk, meat, and hides [71]. The consumption of camel milk is ten times more than that of its meat, and it is expected that milk production will double in the near future [72]. Camels were formerly thought not to be affected by many of the diseases commonly impacting livestock [73]. However, recent data have confirmed their susceptibility to a high number of pathogens [68], and camels are currently believed to act as a carrier or reservoir for the transmission of several transboundary animal diseases and zoonoses [68], such as Middle East respiratory syndrome virus (MERSV) [74] and prion disease [75].

While there are data on *S. aureus* and MRSA on camel-derived food products [76][77][78], there is only one study that confirms the presence of methicillin resistance in *S. aureus* in these animals [49]. The MRSA isolates belonged to the European community-associated CA-MRSA CC80, which could indicate that the origin of these strains is human as it is one of the most reported CCs in humans in the Arab world [79]. Further studies are necessary to determine the extent and potential zoonotic aspect of MRSA in camelids.

1.2. MRSA in Other Animals

MRSA has also been detected in pet animals, pest animals and wildlife [80][81]. Generally, MRSA strains of these animals differ from those of livestock and production animals [82]. Different studies showed that MRSA strains isolated from companion animals are mainly of human origin and are passed between human owners and their animals due to intimate contact [83][84]. Likewise, they can pass these strains back to humans. However, in Arab countries, data on the prevalence and characteristics of MRSA in non-farm animals are scarce [85][86][87]. The prevalence of MRSA in pets ranged between 5.3% and 25% [85][86]. Only one study on bat guano found an indication of the presence of MRSA in wildlife. The MRSA were the typical human-associated CC5-ST149 Maltese clone [88]. By and large, the presence of MRSA in wildlife in Arab countries remains unknown.

1.3. MRSA in Livestock-Derived Food Products

While the direct transmission of MRSA has been well studied, the role of MRSA on food is still poorly understood [89]. Staphylococcal foodborne disease (SFD) is a common food-borne toxin-infection resulting from the contamination of food by enterotoxins [90][91], of which many types have been found [92]. These enterotoxins function as superantigens, cause immunosuppression and trigger non-specific proliferation of T cells leading to high fever; the clinical symptoms of *S. aureus* food poisoning are, however, mostly relatively mild [93]. The number of foodborne illnesses caused by *S. aureus* is estimated to be much higher than those reported [93]. It has been shown that variation in the consumption of foods and food habits are the major causes of differences in the incidence of SFD [94]. Food handlers carrying enterotoxin-producing *S. aureus* in their noses or on their hands are regarded as the main source of food contamination, via manual contact or through respiratory secretions [95]. Because *S. aureus* does not compete well with indigenous microbiota in raw foods, contamination is mainly associated with improper handling of cooked or processed foods, followed by storage in conditions that allow for the growth of *S. aureus* and production of the enterotoxin [96]. In contrast, food poisoning caused by MRSA strains is very rare. The first outbreak of gastrointestinal illness caused by MRSA originates in the United States [97], where a colonized food handler was found to be the cause of the outbreak by contaminated coleslaw [97].

In Arab countries, MRSA has been reported to be present in different types of foods, such as beef, poultry meat, raw cow's milk, and camel and sheep milk [76][77][98][99][100][101][102][103][104], but if MRSA can act as a food-borne pathogen remains unclear. CA-MRSA, LA-MRSA and even HA-MRSA in foods have been reported in these countries [104][105], revealing both the human and animal origin of the strains [78].

Some ready-to-eat food products (turkey parts, hot meals, salads) have also been found to be contaminated with MRSA strains [105][106][107] and are likely to be a source of contamination and transmission of resistant strains that pose a risk to human health [106].

MRSA have been reported in Europe in meat samples from cattle, pigs, broilers, and turkeys during the 2018 and 2019 surveillance, though the prevalence varied between meats of different origins and ranged from very low (0.3%) to very high (100%) [13]. Notably, turkey meat tested in the Netherlands and Austria were all positive for MRSA [13]. Additionally, MRSA was detected in samples of raw cow's milk in 2019 in Germany [13]. Overall, most of the MRSA isolates were typical LA-MRSA [13]. In general, the transmission of MRSA via the food chain is considered to be a minor transmission route to humans, and detection often involves selective culture techniques that may detect very low levels of contamination.

MRSA on Meat and Meat Products

MRSA has been detected on beef, chicken, and camel meat in some Arab countries. However, most of the studies were limited to phenotypic detection of methicillin resistance in *S. aureus*, and as such, the true prevalence of MRSA in meats are difficult to estimate. MRSA strains have been found in raw meat in Tunisia and Saudi Arabia [104][105]. Six sequence types have been identified (ST30, ST398, CC1, CC15, CC80, CC88) [104][105]. Most of these CCs are associated with humans, CA-MRSA (CC15, CC1, CC80, CC88, ST30), indicating that most of the MRSA

on food are from food handlers. It was only in Tunisia where LA-MRSA ST398 was reported to be found on chicken meat [104].

MRSA in Milk and Milk Products

It is well known that staphylococci, including methicillin-resistant strains, are an important cause of mastitis in dairy cows, ewes, buffalo and camels [76][108][109]. The bacteria are subsequently excreted into the milk without organoleptic alteration, allowing them to spread through the food chain if the milk is not treated properly [20][98][109][110][111]. MRSA has been reported in both raw and pasteurized milk from cattle and camels [77][98][111][112]. The traditional dairy products, which occupy an important place in the diet in Arab countries and particularly in the North African countries (Algeria, Tunisia, Morocco), have also been shown to carry MRSA [113]. The MRSA types belonged to well-known human types (ST80, ST8, ST4114, ST4120) [27][98][111], though some, like the ST80 strains highly prevalent in the Mediterranean region, have also been detected in animals and food products [49][111]. The ST8 lineage, detected in raw milk in Algeria [98], is related to the USA300 clone, which is predominant in the United States, South America [114] and the Caribbean [115]. ST4120 belongs to CC5, frequently detected in human infections [116]. These MRSA were probably transmitted by humans, indicating that improving food hygiene is the solution to the problem.

In EFSA surveillance, there are data about the prevalence of MRSA in milk and milk products. MRSA was reported in raw cow's milk in Germany and Denmark, with *mecC*-MRSA CC130 (spa-type t843) identified for the first time from bulk tank milk in Denmark [13].

2. Methicillin-resistant non-aureus staphylococci (MRNaS)

Methicillin-resistant non-aureus staphylococci (MRNaS) are all staphylococci but *S. aureus*, resistant to β -lactam antibiotics [117]. The former *Staphylococcus* species that have been reclassified as *Mammaliicoccus* species are also included here since they were only recently transferred to this new genus and were also shown to carry similar SCCmec elements as other staphylococci [118]. Methicillin resistance has been detected in nearly all staphylococcal species showing that SCCmec is likely more mobile than assumed [11]; however, there is not always a lot of information on them as in general, they cause less pathology and as such, are studied to a lesser extent. Nevertheless, given their abundance, they probably play an important role in the spread of methicillin resistance in staphylococci. The MRNaS species on which most information is available are methicillin-resistant *Staphylococcus epidermidis* (MRSE) [119] and methicillin-resistant *Staphylococcus pseudintermedius* (MRSP) [120][121]. MRNaS are of interest as they represent a reservoir of SCCmec [122]. Though indirectly based on epidemiological studies, the transfer of (parts of) SCCmec between MRNaS and *S. aureus* has been shown in several studies [123][124].

The available literature on MRNaS in animals and food is still very limited to non-existent in terms of most Arab countries. In Egypt, *S. epidermidis* and *S. warneri* strains obtained from goats and cattle (nasal swabs), respectively, were shown to harbor the *mecA* gene [125]. In addition, in *S. intermedius*, *S. cohnii*, *S. capitis*, *M. sciuri* [86] and *S. pseudintermedius* [87] from Libyan cats and dogs, the *mecA* gene has been detected [86]. On food

products, *mecA*-positive *S. hyicus*, *S. intermedius*, *S. lugdunensis* have been detected [126]. Frequently those isolates were *mecA* positive but did not show phenotypic resistance [126]. There is clearly a need for more data so as to be able to determine the role of MRNaS in Arab countries.

References

1. Devriese, L.A.; Van Damme, L.R.; Fameree, L. Methicillin (cloxacillin)-resistant *Staphylococcus aureus* strains isolated from bovine mastitis cases. *Zentralbl. Veterinarmed. B* 1972, 19, 598–605.
2. Devriese, L.A.; Hommez, J. Epidemiology of methicillin-resistant *Staphylococcus aureus* in dairy herds. *Res. Vet. Sci.* 1975, 19, 23–27.
3. Larsen, J.; Petersen, A.; Sørum, M.; Stegger, M.; van Alphen, L.; Valentiner-Branth, P.; Knudsen, L.K.; Larsen, L.S.; Feingold, B.; Price, L.B.; et al. Meticillin-resistant *Staphylococcus aureus* CC398 is an increasing cause of disease in people with no livestock contact in Denmark, 1999 to 2011. *Euro. Surveill.* 2015, 20, 10.
4. Denis, O.; Suetens, C.; Hallin, M.; Catry, B.; Ramboer, I.; Dispas, M.; Willems, G.; Gordts, B.; Butaye, P.; Struelens, M.J. Methicillin-resistant *Staphylococcus aureus* ST398 in swine farm personnel, Belgium. *Emerg. Infect. Dis.* 2009, 15, 1098–1101.
5. Ryser-Degiorgis, M.P. Wildlife health investigations: Needs, challenges and recommendations. *BMC Vet. Res.* 2013, 9, 223.
6. Vanderhaeghen, W.; Cerpentier, T.; Adriaensen, C.; Vicca, J.; Hermans, K.; Butaye, P. Methicillin-resistant *Staphylococcus aureus* (MRSA) ST398 associated with clinical and subclinical mastitis in Belgian cows. *Vet. Microbiol.* 2010, 144, 166–171.
7. Argudín, M.A.; Cariou, N.; Salandre, O.; Le Guennec, J.; Nemeghaire, S.; Butaye, P. Genotyping and antimicrobial resistance of *Staphylococcus aureus* isolates from diseased turkeys. *Avian. Pathol.* 2013, 42, 572–580.
8. Cuny, C.; Wieler, L.H.; Witte, W. Livestock-Associated MRSA: The Impact on Humans. *Antibiotics* 2015, 4, 521–543.
9. Van Cleef, B.A.; Monnet, D.L.; Voss, A.; Krziwanek, K.; Allerberger, F.; Struelens, M.; Zemlickova, H.; Skov, R.L.; Vuopio-Varkila, J.; Cuny, C.; et al. Livestock-associated methicillin-resistant *Staphylococcus aureus* in humans, Europe. *Emerg. Infect. Dis.* 2011, 17, 502–505.
10. Fitzgerald, J.R. Livestock-associated *Staphylococcus aureus*: Origin, evolution and public health threat. *Trends. Microbiol.* 2012, 20, 192–198.
11. Butaye, P.; Argudín, M.A.; Smith, T.C. Livestock-Associated MRSA and Its Current Evolution. *Curr. Clin. Micro. Rpt.* 2016, 3, 19–31.

12. Senok, A.; Slickers, P.; Hotzel, H.; Boswihi, S.; Braun, S.D.; Gawlik, D.; Müller, E.; Nabi, A.; Nassar, R.; Nitschke, H.; et al. Characterisation of a novel SCCmec VI element harbouring *fusC* in an emerging *Staphylococcus aureus* strain from the Arabian Gulf region. *PLoS ONE* 2019, 14, e0223985.

13. EFSA, European Centre for Disease Prevention and Control. The European Union Summary Report on Antimicrobial Resistance in zoonotic and indicator bacteria from humans, animals and food in 2018/2019. *EFSA J.* 2021, 19, e06490.

14. Holmes, M.A.; Zadoks, R.N. Methicillin resistant *S. aureus* in human and bovine mastitis. *J. Mammary Gland. Biol. Neoplasia* 2011, 16, 373–382.

15. Cobirka, M.; Tancin, V.; Slama, P. Demiology and Classification of Mastitis. *Animals* 2020, 10, 2212.

16. Ruegg, P.L. Making Antibiotic Treatment Decisions for Clinical Mastitis. *Vet. Clin. N. Am. Food Anim. Pract.* 2018, 34, 413–425.

17. Juhász-Kaszanyitzky, E.; Jánosi, S.; Somogyi, P.; Dán, A.; van der Graaf-van Bloois, L.; van Duijkeren, E.; Wagenaar, J.A. MRSA transmission between cows and humans. *Emerg. Infect. Dis.* 2007, 13, 630–632.

18. Lee, J.H. Methicillin (Oxacillin)-resistant *Staphylococcus aureus* strains isolated from major food animals and their potential transmission to humans. *Appl. Environ. Microbiol.* 2003, 69, 6489–6494.

19. Obaidat, M.M.; Bani Salman, A.E.; Roess, A.A. High prevalence and antimicrobial resistance of *mecA* *Staphylococcus aureus* in dairy cattle, sheep, and goat bulk tank milk in Jordan. *Trop. Anim. Health Prod.* 2018, 50, 405–412.

20. El-Ashker, M.; Gwida, M.; Tomaso, H.; Monecke, S.; Ehricht, R.; El-Gohary, F.; Hotzel, H. *Staphylococci* in cattle and buffaloes with mastitis in Dakahlia Governorate, Egypt. *J. Dairy Sci.* 2015, 98, 7450–7459.

21. Abdel-Moein, K.A.; Zaher, H.M. Occurrence of multidrug-resistant methicillin-resistant *Staphylococcus aureus* among healthy farm animals: A public health concern. *Int. J. Vet. Sci. Med.* 2019, 7, 55–60.

22. Bounar-Kechih, S.; Taha Hamdi, M.; Aggad, H.; Meguenni, N.; Cantekin, Z. Carriage Methicillin-Resistant *Staphylococcus aureus* in Poultry and Cattle in Northern Algeria. *Vet. Med. Int.* 2018, 2018, 4636121.

23. Algammal, A.M.; Enany, M.E.; El-Tarabili, R.M.; Ghobashy, M.O.I.; Helmy, Y.A. Prevalence, Antimicrobial Resistance Profiles, Virulence and Enterotoxins-Determinant Genes of MRSA Isolated from Subclinical Bovine Mastitis in Egypt. *Pathogens* 2020, 9, 362.

24. Klibi, A.; Jouini, A.; Gómez, P.; Slimene, K.; Ceballos, S.; Torres, C.; Maaroufi, A. Molecular Characterization and Clonal Diversity of Methicillin-Resistant and -Susceptible *Staphylococcus aureus* Isolates of Milk of Cows with Clinical Mastitis in Tunisia. *Microb. Drug. Resist.* 2018, 24, 1210–1216.

25. Alzohairy, M.A. Colonization and antibiotic susceptibility pattern of methicillin resistance *Staphylococcus aureus* (MRSA) among farm animals in Saudi Arabia. *Afr. J. Bacteriol. Res.* 2011, 3, 63–68.

26. Khudaier, B.Y.; Abbas, B.A.; Khudaier, A.M. Detection of Methicillin Resistant *Staphylococcus aureus* Isolated from Human and Animals in Basrah Province/Iraq. *MRVSA2013* 2013, 2, 12–21.

27. Dweba, C.C.; Zishiri, O.T.; El Zowalaty, M.E. Methicillin-resistant *Staphylococcus aureus*: Livestock-associated, antimicrobial, and heavy metal resistance. *Infect. Drug Resist.* 2018, 11, 2497–2509.

28. Khemiri, M.; Abbassi, M.S.; Couto, N.; Mansouri, R.; Hammami, S.; Pomba, C. Genetic characterisation of *Staphylococcus aureus* isolated from milk and nasal samples of healthy cows in Tunisia: First report of ST97-t267-ag1-SCCmecV MRSA of bovine origin in Tunisia. *J. Glob. Antimicrob. Resist.* 2018, 14, 161–165.

29. Battisti, A.; Franco, A.; Merialdi, G.; Hasman, H.; Iurescia, M.; Lorenzetti, R.; Feltrin, F.; Zini, M.; Aarestrup, F.M. Heterogeneity among methicillin-resistant *Staphylococcus aureus* from Italian pig finishing holdings. *Vet. Microbiol.* 2010, 142, 361–366.

30. Gómez-Sanz, E.; Torres, C.; Lozano, C.; Fernández-Pérez, R.; Aspiroz, C.; Ruiz-Larrea, F.; Zarazaga, M. Detection, molecular characterization, and clonal diversity of methicillin-resistant *Staphylococcus aureus* CC398 and CC97 in Spanish slaughter pigs of different age groups. *Foodborne Pathog. Dis.* 2010, 7, 1269–1277.

31. El-Ashker, M.; Gwida, M.; Monecke, S.; El-Gohary, F.; Ehricht, R.; Elsayed, M.; Akinduti, P.; El-Fateh, M.; Maurischat, S. Antimicrobial resistance pattern and virulence profile of *S. aureus* isolated from household cattle and buffalo with mastitis in Egypt. *Vet. Microbiol.* 2020, 240, 108535.

32. Buyukcangaz, E.; Velasco, V.; Sherwood, J.S.; Stepan, R.M.; Koslofsky, R.J.; Logue, C.M. Molecular typing of *Staphylococcus aureus* and methicillin-resistant *S. aureus* (MRSA) isolated from animals and retail meat in North Dakota, United States. *Foodborne Pathog. Dis.* 2013, 10, 608–617.

33. Earls, M.R.; Steinig, E.J.; Monecke, S.; Castruita, J.A.S.; Simbeck, A.; Schneider-Brachert, W.; Vremeră, T.; Dorneanu, O.S.; Loncaric, I.; Bes, M.; et al. Exploring the evolution and epidemiology of European CC1-MRSA-IV: Tracking a multidrug-resistant community-associated methicillin-resistant *Staphylococcus aureus* clone. *Microb. Genom.* 2021, 7, 000601.

34. Silva, V.; Sousa, T.; Gómez, P.; Sabença, C.; Vieira-Pinto, M.; Capita, R.; Alonso-Calleja, C.; Torres, C.; Capelo, J.L.; Igrejas, G.; et al. Livestock-Associated Methicillin-Resistant *Staphylococcus aureus* (MRSA) in Purulent Subcutaneous Lesions of Farm Rabbits. *Foods* 2020, 9, 439.

35. O'Neill, G.L.; Murchan, S.; Gil-Setas, A.; Aucken, H.M. Identification and characterization of phage variants of a strain of epidemic methicillin-resistant *Staphylococcus aureus* (EMRSA-15). *J. Clin. Microbiol.* 2001, 39, 1540–1548.

36. Spoor, L.E.; McAdam, P.R.; Weinert, L.A.; Rambaut, A.; Hasman, H.; Aarestrup, F.M.; Kearns, A.M.; Larsen, A.R.; Skov, R.L.; Fitzgerald, J.R. Livestock origin for a human pandemic clone of community-associated methicillin-resistant *Staphylococcus aureus*. *mBio* 2013, 4, e00356-13.

37. Cristina, M. Building Sustainable Agriculture for Food Security in the Euro-Mediterranean Area: Challenges and Policy Options edited by Maria Cristina Paciello. In Books & Reports; Policy Center for the New South: Rabat, Morocco, 2018; Volume 3, pp. 23–26. ISBN 978-88-6812-508-0.

38. Statista. MENA: Per Capita Meat Consumption by Country. 2014. Available online: <https://www.statista.com/statistics/730843/mena-per-capita-meat-consumption-by-country/> (accessed on 13 April 2022).

39. Ouchene-Khelifi, N.A.; Lafri, M.; Pompanon, F.; Ouhrouch, A.; Ouchene, N.; Blanquet, V.; Lenstra, J.A.; Benjelloun, B.; Da Silva, A. Genetic homogeneity of North-African goats. *PLoS ONE* 2018, 13, e0202196.

40. Hilali, M.; El-Mayda, E.; Rischkowsky, B. Characteristics and utilization of sheep and goat milk in the Middle East. *Small Rumin. Res.* 2011, 101, 92–101.

41. Liu, M.; Cheng, J.; Chen, Y.; Yang, L.; Raza, S.H.A.; Huang, Y.; Lei, C.; Liu, G.E.; Lan, X.; Chen, H. Distribution of DGAT1 copy number variation in Chinese goats and its associations with milk production traits. *Anim. Biotechnol.* 2021, 122, 1–6.

42. Miller, B.A.; Lu, C.D. Current status of global dairy goat production: An overview. *Asian-Australas. J. Anim. Sci.* 2019, 32, 1219–1232.

43. Rees, C.; Mullumby, J. Trends in Australian meat consumption. *Agric. Commodity* 2017, 7, 82–85. Available online: <https://search.informit.org/doi/10.3316/informit.224110136329092> (accessed on 23 April 2022).

44. Webb, E.C. Goat meat production, composition, and quality. *Anim. Front.* 2014, 4, 33–37.

45. Vasileiou, N.G.C.; Chatzopoulos, D.C.; Sarrou, S.; Fragkou, I.A.; Katsafadou, A.I.; Mavrogianni, V.S.; Petinaki, E.; Fthenakis, G.C. Role of staphylococci in mastitis in sheep. *J. Dairy Res.* 2019, 86, 254–266.

46. Gharsa, H.; Ben Slama, K.; Lozano, C.; Gómez-Sanz, E.; Klibi, N.; Ben Sallem, R.; Gómez, P.; Zarazaga, M.; Boudabous, A.; Torres, C. Prevalence, antibiotic resistance, virulence traits and genetic lineages of *Staphylococcus aureus* in healthy sheep in Tunisia. *Vet. Microbiol.* 2012, 156, 367–373.

47. Alghizzi, M.; Shami, A. The prevalence of *Staphylococcus aureus* and methicillin resistant *Staphylococcus aureus* in milk and dairy products in Riyadh, Saudi Arabia. *Saudi J. Biol. Sci.* 2021, 28, 7098–7104.

48. El-Deeb, W.; Fayed, M.; Elmoslemany, A.; Kandeel, M.; Zidan, K. Methicillin resistant *Staphylococcus aureus* among goat farms in Eastern province, Saudi Arabia: Prevalence and risk factors. *Prev. Vet. Med.* 2018, 156, 84–90.

49. Agabou, A.; Ouchenane, Z.; Ngbaga Essebe, C.; Khemissi, S.; Chehboub, M.T.E.; Chehboub, I.B.; Sotto, A.; Dunyach-Remy, C.; Lavigne, J.P. Emergence of Nasal Carriage of ST80 and ST152 PVL+ *Staphylococcus aureus* Isolates from Livestock in Algeria. *Toxins* 2017, 9, 303.

50. Alioua, M.A.; Labid, A.; Amoura, K.; Bertine, M.; Gacemi-Kirane, D.; Dekhil, M. Emergence of the European ST80 clone of community-associated methicillin-resistant *Staphylococcus aureus* as a cause of healthcare-associated infections in Eastern Algeria. *Med. Mal. Infect.* 2014, 44, 180–183.

51. Ben Slama, K.; Gharsa, H.; Klibi, N.; Jouini, A.; Lozano, C.; Gómez-Sanz, E.; Zarazaga, M.; Boudabous, A.; Torres, C. Nasal carriage of *Staphylococcus aureus* in healthy humans with different levels of contact with animals in Tunisia: Genetic lineages, methicillin resistance, and virulence factors. *Eur. J. Clin. Microbiol. Infect. Dis.* 2011, 30, 499–508.

52. Udo, E.E.; Sarkhoo, E. The dissemination of ST80-SCCmec-IV community-associated methicillin resistant *Staphylococcus aureus* clone in Kuwait hospitals. *Ann. Clin. Microbiol. Antimicrob.* 2010, 9, 31.

53. Dastmalchi Saei, H.; Panahi, M. Genotyping and antimicrobial resistance of *Staphylococcus aureus* isolates from dairy ruminants: Differences in the distribution of clonal types between cattle and small ruminants. *Arch. Microbiol.* 2020, 202, 115–125.

54. De Almeida, L.M.; de Almeida, M.Z.; de Mendonça, C.L.; Mamizuka, E.M. Novel sequence types (STs) of *Staphylococcus aureus* isolates causing clinical and subclinical mastitis in flocks of sheep in the northeast of Brazil. *J. Dairy Res.* 2011, 78, 373–378.

55. Azara, E.; Piras, M.G.; Parisi, A.; Tola, S. Antimicrobial susceptibility and genotyping of *Staphylococcus aureus* isolates collected between 1986 and 2015 from ovine mastitis. *Vet. Microbiol.* 2017, 205, 53–56.

56. Murray, S.; Pascoe, B.; Méric, G.; Mageiros, L.; Yahara, K.; Hitchings, M.D.; Friedmann, Y.; Wilkinson, T.S.; Gormley, F.J.; Mack, D.; et al. Recombination-Mediated Host Adaptation by Avian *Staphylococcus aureus*. *Genome Biol. Evol.* 2017, 9, 830–842.

57. Nemati, M.; Hermans, K.; Lipinska, U.; Denis, O.; Deplano, A.; Struelens, M.; Devriese, L.A.; Pasmans, F.; Haesebrouck, F. Antimicrobial resistance of old and recent *Staphylococcus aureus* isolates from poultry: First detection of livestock-associated methicillin-resistant strain ST398. *Antimicrob. Agents Chemother.* 2008, 52, 3817–3819.

58. Zaheer, Z.; Rahman, S.U.; Zaheer, I.; Abbas, G.; Younas, T. Methicillin-resistant *Staphylococcus aureus* in poultry—an emerging concern related to future epidemic. *Matrix Sci. Medica* 2017, 1, 15–18.

59. Benrabia, I.; Hamdi, T.M.; Shehata, A.A.; Neubauer, H.; Wareth, G. Methicillin-Resistant *Staphylococcus aureus* (MRSA) in Poultry Species in Algeria: Long-Term Study on Prevalence and Antimicrobial Resistance. *Vet. Sci.* 2020, 7, 54.

60. El-Adawy, H.; Ahmed, M.; Hotzel, H.; Monecke, S.; Schulz, J.; Hartung, J.; Ehricht, R.; Neubauer, H.; Hafez, H.M. Characterization of Methicillin-Resistant *Staphylococcus aureus* Isolated from Healthy Turkeys and Broilers Using DNA Microarrays. *Front. Microbiol.* 2016, 7, 2019.

61. Assafi, M.S.; Hado, H.A.; Abdulrahman, I.S. Detection of methicillin-resistant *Staphylococcus aureus* in broiler and broilers farm workers in Duhok, Iraq by using conventional and PCR techniques. *Iraqi J. Vet. Sci.* 2020, 34, 15–22.

62. Peeters, L.E.; Argudín, M.A.; Azadikhah, S.; Butaye, P. Antimicrobial resistance and population structure of *Staphylococcus aureus* recovered from pigs farms. *Vet. Microbiol.* 2015, 180, 151–156.

63. Crombé, F.; Argudín, M.A.; Vanderhaeghen, W.; Hermans, K.; Haesebrouck, F.; Butaye, P. Transmission Dynamics of Methicillin-Resistant *Staphylococcus aureus* in Pigs. *Front. Microbiol.* 2013, 4, 57.

64. Nemeghaire, S.; Roelandt, S.; Argudín, M.A.; Haesebrouck, F.; Butaye, P. Characterization of methicillin-resistant *Staphylococcus aureus* from healthy carrier chickens. *Avian Pathol.* 2013, 42, 342–346.

65. Fessler, A.T.; Kadlec, K.; Hassel, M.; Hauschild, T.; Eidam, C.; Ehricht, R.; Monecke, S.; Schwarz, S. Characterization of methicillin-resistant *Staphylococcus aureus* isolates from food and food products of poultry origin in Germany. *Appl. Environ. Microbiol.* 2011, 77, 7151–7157.

66. Khanna, T.; Friendship, R.; Dewey, C.; Weese, J.S. Methicillin resistant *Staphylococcus aureus* colonization in pigs and pig farmers. *Vet. Microbiol.* 2008, 128, 298–303.

67. Lowder, B.V.; Guinane, C.; Ben Zakour, N.L.; Weinert, L.A.; Conway-Morris, A.; Cartwright, R.A.; Simpson, A.J.; Rambaut, A.; Nübel, U.; Fitzgerald, J.R. Recent human-to-poultry host jump, adaptation, and pandemic spread of *Staphylococcus aureus*. *Proc. Natl. Acad. Sci. USA* 2009, 106, 19545–19550.

68. Zhu, S.; Zimmerman, D.; Deem, S.L. A Review of Zoonotic Pathogens of Dromedary Camels. *Ecohealth* 2019, 16, 356–377.

69. Abdallah, H.R.; Faye, B. Phenotypic classification of Saudi Arabian camel (*Camelus dromedarius*) by their body measurements. *Emir. J. Food Agric.* 2012, 24, 272–280.

70. Khalaf, S. Poetics and Politics of Newly Invented Traditions in the Gulf: Camel Racing in the United Arab Emirates. *Ethnology* 2000, 39, 243–261.

71. Alhadrami, G.A.; Faye, B. Animals that produce dairy foods: Camel. In Reference Module in Food Science; Elsevier: Amsterdam, The Netherlands, 2016.

72. Singh, R.; Mal, G.; Kumar, D. Camel Milk: An Important Natural Adjuvant. *Agric. Res.* 2017, 6, 327–340.

73. Harrak, M.E.; Faye, B.; Bengoumi, M. Main Pathologies of Camels, Breeding of Camels, Constraints, Benefits and Perspectives. 2011. Available online: <https://www.oie.int/doc/ged/D12812.PDF> (accessed on 20 April 2022).

74. Alagaili, A.N.; Briese, T.; Mishra, N.; Kapoor, V.; Sameroff, S.C.; Burbelo, P.D.; de Wit, E.; Munster, V.J.; Hensley, L.E.; Zalmout, I.S.; et al. Middle East respiratory syndrome coronavirus infection in dromedary camels in Saudi Arabia. *mBio* 2014, 5, e00884-14.

75. Babelhadj, B.; Di Bari, M.A.; Pirisinu, L.; Chiappini, B.; Gaouar, S.B.S.; Riccardi, G.; Marcon, S.; Agrimi, U.; Nonno, R.; Vaccari, G. Prion Disease in Dromedary Camels, Algeria. *Emerg. Infect. Dis.* 2018, 24, 1029–1036.

76. Yehia, H.M.; Al-Masoud, A.H.; Alarjani, K.M.; Alamri, M.S. Prevalence of methicillin-resistant (*mecA* gene) and heat-resistant *Staphylococcus aureus* strains in pasteurized camel milk. *J. Dairy Sci.* 2020, 103, 5947–5963.

77. Aljahani, A.H.; Alarjani, K.M.; Hassan, Z.K.; Elkhadragy, M.F.; Ismail, E.A.; Al-Masoud, A.H.; Yehia, H.M. Molecular detection of methicillin heat-resistant *Staphylococcus aureus* strains in pasteurized camel milk in Saudi Arabia. *Biosci. Rep.* 2020, 40, BSR20193470.

78. Raji, M.A.; Garaween, G.; Ehricht, R.; Monecke, S.; Shibli, A.M.; Senok, A. Genetic Characterization of *Staphylococcus aureus* Isolated from Retail Meat in Riyadh, Saudi Arabia. *Front. Microbiol.* 2016, 7, 911.

79. Tabaja, H.; Hindy, J.R.; Kanj, S.S. Epidemiology of Methicillin-Resistant *Staphylococcus aureus* in Arab Countries of the Middle East and North African (MENA) Region. *Mediterr. J. Hematol. Infect. Dis.* 2021, 13, e2021050.

80. Pletinckx, L.J.; Verhegge, M.; Cromb  , F.; Dewulf, J.; De Bleecker, Y.; Rasschaert, G.; Butaye, P.; Goddeeris, B.M.; De Man, I. Evidence of possible methicillin-resistant *Staphylococcus aureus*

ST398 spread between pigs and other animals and people residing on the same farm. *Prev. Vet. Med.* 2013, 109, 293–303.

81. Abdullahi, I.N.; Fernández-Fernández, R.; Juárez-Fernández, G.; Martínez-Álvarez, S.; Eguizábal, P.; Zarazaga, M.; Lozano, C.; Torres, C. Wild Animals Are Reservoirs and Sentinels of *Staphylococcus aureus* and MRSA Clones: A Problem with “One Health” Concern. *Antibiotics* 2021, 10, 1556.

82. Haag, A.F.; Fitzgerald, J.R.; Penadés, J.R. *Staphylococcus aureus* in Animals. *Microbiol. Spectr.* 2019, 7, 1–19.

83. Van Duijkeren, E.; Wolfhagen, M.J.; Box, A.T.; Heck, M.E.; Wannet, W.J.; Fluit, A.C. Human-to-dog transmission of methicillin-resistant *Staphylococcus aureus*. *Emerg. Infect. Dis.* 2004, 10, 2235–2237.

84. Baptiste, K.E.; Williams, K.; Williams, N.J.; Wattret, A.; Clegg, P.D.; Dawson, S.; Corkill, J.E.; O’Neill, T.; Hart, C.A. Methicillin-resistant staphylococci in companion animals. *Emerg. Infect. Dis.* 2005, 11, 1942–1944.

85. Tarazi, Y.H.; Almajali, A.M.; Ababneh, M.M.K.; Ahmed, H.S.; Jaran, A.S. Molecular study on methicillin-resistant *Staphylococcus aureus* strains isolated from dogs and associated personnel in Jordan. *Asian Pac. J. Trop. Biomed.* 2015, 5, 902–908.

86. Elnageh, H.R.; Hiblu, M.A.; Abbassi, M.S.; Abouzeed, Y.M.; Ahmed, M.O. Prevalence and antimicrobial resistance of *Staphylococcus* species isolated from cats and dogs. *Open. Vet. J.* 2021, 10, 452–456.

87. Elmoslemany, A.; Elsohaby, I.; Alorabi, M.; Alkafafy, M.; Al-Marri, T.; Aldowerie, A.; Alaql, F.A.; Almubarak, A.; Fayed, M. Diversity and Risk Factors Associated with Multidrug and Methicillin-Resistant Staphylococci Isolated from Cats Admitted to a Veterinary Clinic in Eastern Province, Saudi Arabia. *Antibiotics* 2021, 10, 367.

88. Mairi, A.; Touati, A.; Pantel, A.; Yahiaoui Martinez, A.; Ahmim, M.; Sotto, A.; Dunyach-Remy, C.; Lavigne, J.-P. First Report of CC5-MRSA-IV-SCCfus “Maltese Clone” in Bat Guano. *Microorganisms* 2021, 9, 2264.

89. Da Silva, A.C.; Rodrigues, M.X.; Silva, N.C.C. Methicillin-resistant *Staphylococcus aureus* in food and the prevalence in Brazil: A review. *Braz. J. Microbiol.* 2020, 51, 347–356.

90. Kroning, I.S.; Iglesias, M.A.; Sehn, C.P.; Valente Gandra, T.K.; Mata, M.M.; da Silva, W.P. *Staphylococcus aureus* isolated from handmade sweets: Biofilm formation, enterotoxigenicity and antimicrobial resistance. *Food Microbiol.* 2016, 58, 105–111.

91. Wu, S.; Duan, N.; Gu, H.; Hao, L.; Ye, H.; Gong, W.; Wang, Z. A Review of the Methods for Detection of *Staphylococcus aureus* Enterotoxins. *Toxins* 2016, 8, 176.

92. Ono, H.K.; Omoe, K.; Imanishi, K.; Iwakabe, Y.; Hu, D.L.; Kato, H.; Saito, N.; Nakane, A.; Uchiyama, T.; Shinagawa, K. Identification and characterization of two novel staphylococcal enterotoxins, types S and T. *Infect. Immun.* 2008, 76, 4999–5005.

93. Mead, P.S.; Slutsker, L.; Dietz, V.; McCaig, L.F.; Bresee, J.S.; Shapiro, C. Food-Related Illness and Death in the United States. *Emerg. Infect. Dis.* 1999, 5, 607–625.

94. Le Loir, Y.; Baron, F.; Gautier, M. *Staphylococcus aureus* and food poisoning. *Genet. Mol. Res.* 2003, 2, 63–76.

95. Kluytmans, J.A.; Wertheim, H.F. Nasal carriage of *Staphylococcus aureus* and prevention of nosocomial infections. *Infection* 2005, 33, 3–8.

96. Argudín, M.Á.; Mendoza, M.C.; Rodicio, M.R. Food poisoning and *Staphylococcus aureus* enterotoxins. *Toxins* 2010, 2, 1751–1773.

97. Jones, T.F.; Kellum, M.E.; Porter, S.S.; Bell, M.; Schaffner, W. An outbreak of community-acquired foodborne illness caused by methicillin-resistant *Staphylococcus aureus*. *Emerg. Infect. Dis.* 2002, 8, 82–84.

98. Titouche, Y.; Hakem, A.; Houali, K.; Meheut, T.; Vingadassalon, N.; Ruiz-Ripa, L.; Salmi, D.; Chergui, A.; Chenouf, N.; Hennekinne, J.A.; et al. Emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) ST8 in raw milk and traditional dairy products in the Tizi Ouzou area of Algeria. *J. Dairy Sci.* 2019, 102, 6876–6884.

99. Abolghait, S.K.; Fathi, A.G.; Youssef, F.M.; Algammal, A.M. Methicillin-resistant *Staphylococcus aureus* (MRSA) isolated from chicken meat and giblets often produces staphylococcal enterotoxin B (SEB) in non-refrigerated raw chicken livers. *Int. J. Food Microbiol.* 2020, 328, 108669.

100. Al-Ashmawy, M.A.; Sallam, K.I.; Abd-Elghany, S.M.; Elhadidy, M.; Tamura, T. Prevalence, Molecular Characterization, and Antimicrobial Susceptibility of Methicillin-Resistant *Staphylococcus aureus* Isolated from Milk and Dairy Products. *Foodborne Pathog. Dis.* 2016, 13, 156–162.

101. Kanaan, M.H.G. Antibacterial effect of ozonated water against methicillin-resistant *Staphylococcus aureus* contaminating chicken meat in Wasit Province, Iraq. *Vet. World* 2018, 11, 1445–1453.

102. Naas, H.T.; Edarhoby, R.A.; Garbaj, A.M.; Azwai, S.M.; Abolghait, S.K.; Gammoudi, F.T.; Moawad, A.A.; Barbieri, I.; Eldaghayes, I.M. Occurrence, characterization, and antibiogram of *Staphylococcus aureus* in meat, meat products, and some seafood from Libyan retail markets. *Vet. World* 2019, 12, 925–931.

103. Iyer, A.; Kumosani, T.; Azhar, E.; Barbour, E.; Harakeh, S. High incidence rate of methicillin-resistant *Staphylococcus aureus* (MRSA) among healthcare workers in Saudi Arabia. *J. Infect. Dev. Ctries.* 2014, 8, 372–378.

104. Chairat, S.; Gharsa, H.; Lozano, C.; Gómez-Sanz, E.; Gómez, P.; Zarazaga, M.; Boudabous, A.; Torres, C.; Ben Slama, K. Characterization of *Staphylococcus aureus* from Raw Meat Samples in Tunisia: Detection of Clonal Lineage ST398 from the African Continent. *Foodborne Pathog. Dis.* 2015, 12, 686–692.

105. Mahros, M.A.; Abd-Elghany, S.M.; Sallam, K.I. Multidrug-, methicillin-, and vancomycin-resistant *Staphylococcus aureus* isolated from ready-to-eat meat sandwiches: An ongoing food and public health concern. *Int. J. Food Microbiol.* 2021, 346, 109165.

106. Benjelloun Touimi, G.; Bennani, L.; Berrada, S.; Moussa, B.; Bennani, B. Prevalence and antibiotic resistance profiles of *Staphylococcus* sp. isolated from food, food contact surfaces and food handlers in a Moroccan hospital kitchen. *Lett. Appl. Microbiol.* 2020, 70, 241–251.

107. Mekhloufi, O.A.; Chieffi, D.; Hammoudi, A.; Bensefia, S.A.; Fanelli, F.; Fusco, V. Prevalence, Enterotoxigenic Potential and Antimicrobial Resistance of *Staphylococcus aureus* and Methicillin-Resistant *Staphylococcus aureus* (MRSA) Isolated from Algerian Ready to Eat Foods. *Toxins* 2021, 13, 835.

108. Quddoumi, S.S.; Bdour, S.M.; Mahasneh, A.M. Isolation and characterization of methicillin-resistant *Staphylococcus aureus* from livestock and poultry meat. *Ann. Microbiol.* 2006, 56, 155–161.

109. Haran, K.P.; Godden, S.M.; Boxrud, D.; Jawahir, S.; Bender, J.B.; Sreevatsan, S. Prevalence and characterization of *Staphylococcus aureus*, including methicillin-resistant *Staphylococcus aureus*, isolated from bulk tank milk from Minnesota dairy farms. *J. Clin. Microbiol.* 2012, 50, 688–695.

110. Osman, K.M.; Pires, Á.D.S.; Franco, O.L.; Orabi, A.; Hanafy, M.H.; Marzouk, E.; Hussien, H.; Alzaben, F.A.; Almuzaini, A.M.; Elbehiry, A. Enterotoxigenicity and Antibiotic Resistance of Coagulase-Negative *Staphylococci* Isolated from Raw Buffalo and Cow Milk. *Microb. Drug Resist.* 2020, 26, 520–530.

111. Chenouf, N.S.; Mama, O.M.; Messaï, C.R.; Ruiz-Ripa, L.; Fernández-Fernández, R.; Carvalho, I.; Zitouni, A.; Hakem, A.; Torres, C. Detection of methicillin-resistant coagulase-negative staphylococci and PVL/mecA genes in cefoxitin-susceptible *Staphylococcus aureus* (t044/ST80) from unpasteurized milk sold in stores in Djelfa, Algeria. *J. Dairy Sci.* 2021, 104, 2684–2692.

112. Bendahou, A.; Lebbadi, M.; Ennanei, L.; Essadqui, F.Z.; Abid, M. Characterization of *Staphylococcus* species isolated from raw milk and milk products (Iben and jben) in North Morocco. *J. Infect. Dev. Ctries.* 2008, 2, 218–225.

113. Bendahou, A.; Abid, M.; Bouteldoun, N.; Catelejine, D.; Lebbadi, M. Enterotoxigenic coagulase positive *Staphylococcus* in milk and milk products, Iben and jben, in northern Morocco. *J. Infect. Dev. Ctries.* 2009, 3, 169–176.

114. Herrera, F.C.; García-López, M.L.; Santos, J.A. Short communication: Characterization of methicillin-resistant *Staphylococcus aureus* isolated from raw milk fresh cheese in Colombia. *J. Dairy Sci.* 2016, 99, 7872–7876.

115. Vandendriessche, S.; Vanderhaeghen, W.; Larsen, J.; de Mendonça, R.; Hallin, M.; Butaye, P.; Hermans, K.; Haesebrouck, F.; Denis, O. High genetic diversity of methicillin-susceptible *Staphylococcus aureus* (MSSA) from humans and animals on livestock farms and presence of SCCmec remnant DNA in MSSA CC398. *J. Antimicrob. Chemother.* 2014, 69, 355–362.

116. Abdulgader, S.; Shittu, A.O.; Nicol, M.P.; Kaba, M. Molecular epidemiology of Methicillin-resistant *Staphylococcus aureus* in Africa: A systematic review. *Front. Microbiol.* 2015, 6, 348.

117. Stefani, S.; Varaldo, P.E. Epidemiology of methicillin-resistant staphylococci in Europe. *Clin. Microbiol. Infect.* 2003, 9, 1179–1186.

118. Nemeghaire, S.; Vanderhaeghen, W.; Argudín, M.A.; Haesebrouck, F.; Butaye, P. Characterization of methicillin-resistant *Staphylococcus sciuri* isolates from industrially raised pigs, cattle and broiler chickens. *J. Antimicrob. Chemother.* 2014, 69, 2928–2934.

119. Argudín, M.A.; Vanderhaeghen, W.; Vandendriessche, S.; Vandecandelaere, I.; André, F.X.; Denis, O.; Coenye, T.; Butaye, P. Antimicrobial resistance and population structure of *Staphylococcus epidermidis* recovered from animals and humans. *Vet. Microbiol.* 2015, 178, 105–113.

120. Van Duijkeren, E.; Catry, B.; Greko, C.; Moreno, M.A.; Pomba, M.C.; Pyörälä, S.; Ruzauskas, M.; Sanders, P.; Threlfall, E.J.; Torren-Edo, J.; et al. Review on methicillin-resistant *Staphylococcus pseudintermedius*. *J. Antimicrob. Chemother.* 2011, 66, 2705–2714.

121. Kim, S.G.; Giri, S.S.; Yun, S.; Kim, S.W.; Han, S.J.; Kwon, J.; Oh, W.T.; Lee, S.B.; Park, Y.H.; Park, S.C. Two Novel Bacteriophages Control Multidrug- and Methicillin-Resistant *Staphylococcus pseudintermedius* Biofilm. *Front. Med.* 2021, 8, 524059.

122. Hanssen, A.M.; Ericson Sollid, J.U. SCCmec in staphylococci: Genes on the move. *FEMS Immunol. Med. Microbiol.* 2006, 46, 8–20.

123. Berglund, C.; Söderquist, B. The origin of a methicillin-resistant *Staphylococcus aureus* isolate at a neonatal ward in Sweden—possible horizontal transfer of a staphylococcal cassette chromosome *mec* between methicillin-resistant *Staphylococcus haemolyticus* and *Staphylococcus aureus*. *Clin. Microbiol. Infect.* 2008, 14, 1048–1056.

124. Bloemendaal, A.L.; Brouwer, E.C.; Fluit, A.C. Methicillin resistance transfer from *Staphylococcus epidermidis* to methicillin-susceptible *Staphylococcus aureus* in a patient during antibiotic therapy. *PLoS ONE* 2010, 5, e11841.

125. Abdel-Moein, K.A.; Zaher, H.M. The Nasal Carriage of Coagulase-Negative Staphylococci Among Animals and Its Public Health Implication. *Vector-Borne Zoonotic Dis.* 2020, 20, 897–902.

126. Osman, K.; Alvarez-Ordóñez, A.; Ruiz, L.; Badr, J.; ElHofy, F.; Al-Maary, K.S.; Moussa, I.M.I.; Hessain, A.M.; Orabi, A.; Saad, A.; et al. Antimicrobial resistance and virulence characterization of *Staphylococcus aureus* and coagulase-negative staphylococci from imported beef meat. *Ann. Clin. Microbiol. Antimicrob.* 2017, 16, 35.

Retrieved from <https://encyclopedia.pub/entry/history/show/60040>