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ANTIBIOTIC RESISTANCE OF STAPHYLOCOCCI FROM HUMANS, FOOD AND DIFFERENT ANIMAL SPECIES ACCORDING TO DATA OF THE HUNGARIAN RESISTANCE MONITORING SYSTEM IN 2001

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Based on data of the Hungarian resistance monitoring system the antibiotic resistance of *Staphylococcus* strains of human and animal origin was studied. No methicillin-resistant staphylococci harbouring *mec*A gene were isolated from animals in 2001. Penicillin resistance, mediated by penicillinase production, was the most frequent among *Staphylococcus aureus* strains isolated from humans (96%), from bovine mastitis (55%), from foods (45%) and from dogs. In staphylococci isolated from animals low resistance percentages to aminoglycosides (0–2%), fluoroquinolones (0.5–3%) and sulphonamides (0.5–4%) were found but in strains isolated humans these figures were higher (1–14%, 5–18% and 3–31%, respectively). The most frequent antibiotic resistance profiles of strains isolated from animals and food were penicillin/tetracycline, penicillin/lincomycin and penicillin/lincomycin/tetracycline. Penicillin/tetracycline resistance was exhibited by strains from mastitis (3), samples from the meat industry (31), poultry flocks (1), poultry industry (1), noodle (1) and horses (2). Penicillin/lincomycin resistance was found in 10 *Staphylococcus* strains from mastitis, 1 from the dairy industry, 1 from the meat industry and 6 from dogs. Isolates from mastitis (2), from the dairy industry (2), from pigs (1), from the meat industry (1) and from poultry (1) harboured penicillin/lincomycin/tetracycline resistance pattern. Multiresistant strains were usually isolated only from one and sometimes from two animal species; therefore, the spread of defined resistant strains (clones) among different animal species could not be demonstrated. These results also suggest that the transfer of antibiotic resistance of *S. aureus* from animals to humans probably occurs less frequently than is generally assumed.

Key words: *Staphylococcus aureus,* coagulase-negative staphylococci, antibiotic resistance, resistance pattern

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Due to the concern about the increase in the number of multidrug-resistant organisms and the need to monitor evolving patterns of resistance, since January of 2001 a nation-wide antibiotic resistance-monitoring program has been operating at the Central Veterinary Institute (Kaszanyitzky et al., 2002) to monitor antimicrobial resistance in pathogenic, zoonotic and commensal bacteria of animal and food origin. As infections due to staphylococci are of major importance in veterinary and human medicine, it is relevant to monitor antibiotic resistance in these bacteria and to assess whether the resistance patterns of human strains of *Staphylococcus* and those of strains of animal origin are related.

Staphylococci become resistant to antibiotics quickly and successfully. The most important risk factor for the emergence of resistant bacteria is the selective pressure due to the use of antibiotics. However, resistance traits located on plasmids, transposons or other mobile genetic elements have a chance of being transferred to another bacterium (Lacey, 1984; Lyon and Skurray, 1987; Udo and Grubb, 1991; Katayama and Hiramatsu, 2000). Genes present on the bacterial chromosome, but not on a transposon, have a much lower chance of being transferred (Summers, 1996).

In the present paper results of Hungarian veterinary and human surveillance systems regarding susceptibility of staphylococci to therapeutic antimicrobial agents are described and the antibiotic resistance phenotype of staphylococci from different animal species and food are compared.

As the *mecA* gene is generally present in all oxacillin- (methicillin-) resistant staphylococci, and it is absent from methicillin-susceptible strains, all the strains assumed to be oxacillin resistant by the result of the disk diffusion test were examined also by PCR.

Materials and methods

Bacteria from animals and food

A total of 806 staphylococcal isolates from animals were included in the study. The number and origin of the different bacterial species are given in Table 2. Strains of *Staphylococcus* spp. were isolated from carcasses or samples of animals submitted for diagnostic investigation (poultry: 49, dogs: 21, pigs: 10, horses: 7, cows with mastitis: 143 strains of *Staphylococcus aureus* and 226 strains of coagulase-negative staphylococci [CNS]). Strains from food (350) were cultured from statutory samples. All isolates were collected in 2001.

Bacterial identification

The staphylococci were isolated on Columbia agar (Merck, KgaA, Darmstadt, Germany) containing 5% sheep blood and, in the case of milk samples, 0.01% esculin. All the plates were incubated at 37 °C, and were evaluated after 16 to 24 h and next day the reading was repeated. The catalase-positive, round,

smooth and glistening colonies with usually golden-yellow pigmentation and complete-incomplete haemolysis were tentatively identified as *S. aureus*. The pure cultures were identified with the tube coagulase and DNase test based on the recommendations of Honkanen-Buzalski and Seuna (1995) and Quinn et al. (1994). The identification was confirmed with Slidex Staph Plus (bioMérieux, France) rapid agglutination test, which detects clumping factor, protein A, and *S. aureus*-specific peripheral structures bound to monoclonal antibodies.

Antimicrobial susceptibility testing

Antibiograms were determined by disk diffusion on Mueller-Hinton agar according to the National Committee for Clinical Laboratory Standards (NCCLS, 2001). The quality control guidelines of NCCLS were also followed. For the strains isolated from milk, the following antimicrobial agents and doses were used: amoxicillin/clavulanic acid (20/10 μg), cephalexin (30 μg), oxacillin (1 μg), penicillin (10 μg), erythromycin (15 μg), lincomycin (2 μg), bacitracin (10 μg), tetracycline (30 μg), novobiocin (30 μg), marbofloxacin (5 μg), neomycin (30 μg), gentamicin (30 μg), streptomycin (10 μg), sulphamethoxazole/trimethoprim (1.25/23.75 μg). Virginiamycin was also applied for the other strains.

Except ceftiofur (Becton-Dickinson) and virginiamycin (Rosco) the disks were purchased from Oxoid.

The minimal inhibitory concentration (MIC) of oxacillin was determined for strains that showed decreased susceptibility to oxacillin in the disk diffusion test. The MIC was determined by oxacillin E-test strip (AB Biodisk).

PCR detection of Staphylococcus *16S rRNA and* mecA *genes*

A single colony was taken from an overnight culture of each strain with reduced susceptibility to oxacillin using a sterile toothpick and suspended in 100 μl sterile distilled water. The suspension was incubated at 98 °C for 5 min, cooled and centrifuged, and 1 μl of this DNA sample was used in the PCR reaction with a total volume of 25 μl.

PCR reactions amplifying *Staphylococcus* 16S rRNA and *mecA* genes were performed as described by Jaffe et al. (2000). Primers used in this study are listed in Table 1. The products were detected on ethidium-bromide stained agarose gels.

Table 1

Primer sets used in this study

DNA target	Primer pair	Size (bp)
mecA gene	5'-CATTTTGAGTTCTGCACTACC-3' 5'-GCAATACAATCGCACATACATTAATAG-3'	967
Staphylococcus 16S rRNA	5'-GTTATTAGGGAAGAACATATGTG-3' 5'-CCACCTTCCTCCGGTTTGTCACC-3'	750

Table 2

Origin and number of strains susceptible to all drugs tested

Origin	*S. aureus*		CNS		Staphylococci	
	n	S	n	S	n	S
Animals						
Cattle with subclinical or clinical mastitis	143	51	226	88		
Pigs	10	2				
Poultry	49	9				
Total no. of strains from food-producing animals					*428*	*150*
Horses	7	1			7	1
Dogs	3	0			21*	0
Food						
Milk: raw	117	60				
processed	5	0				
Total no. of strains from the milk industry					*122*	*60*
Meat (pig, cattle): raw	18	7				
semi-finished	77	10				
processed	40	6				
Total no. of strains from the meat industry					*135*	*23*
Poultry meat: raw	13	2				
processed	4	0				
Total no. of strains from the poultry industry					*17*	*2*
Noodles	76	50			76	50
n	*562*	*198*	*226*	*88*	*806**	*286*

*The figure includes 17 strains of *S. intermedius* and 1 strain of *S. hyicus* isolated from dogs.
S = number of strains susceptible to all drugs

Results

Out of the 806 strains examined 286 were susceptible to all antimicrobial agents tested. The resistance of the 620 strains is shown in Tables 3 and 4.

All isolates were susceptible to amoxicillin/clavulanic acid and cephalexin, only one *S. aureus* strain from dog was resistant to gentamicin, 6 CNS strains showed intermediate susceptibility to bacitracin, 2 *S. aureus* from dogs and 1 from pig were intermediately susceptible to neomycin.

Table 3

Occurrence of resistance among staphylococci isolated from food-producing animals and animal food products

Origin	**Staphylococci from food animals**		Cattle (subclinical or clinical mastitis)				Pig		Poultry		***S. aureus* from food industry**		Milk industry		Meat industry		Poultry industry		Noodles	
	Total		CNS		*S. aureus*		*S. aureus*		*S. aureus*		**Total**		*S. aureus*		*S. aureus*		*S. aureus*		*S. aureus*	
Total	**428**		226		143		10		49		**350**		122		135		17		76	
	I %	**R %**	I %	R %	I %	R %	I %	R %	I %	R %	**I %**	**R %**	I %	R %	I %	R %	I %	R %	I %	R %
Oxacillin*	**1.2**	**0.9**	0	0.4	3	2			2	0	**0.3**	**0.3**	1	1	0	0.7				
Penicillin	**0**	**30**	0	**22**	**0**	**55**	0	40	0	27	**0**	**45**	0	**41**	0	**70**	0	**47**	0	7
Erythromycin	**7**	**7**	8	9	7	1	0	20	4	16	**3**	**2**	2	1	6	2	0	29	1	0
Lincomycin	**6**	**17**	**8**	**22**	4	8	10	20	2	20	**0.3**	**4**	1	5	0	4	0	18		
Bacitracin	**1**	**0**	3	0																
Tetracycline	**2**	**13**	1	5	3	2	0	**80**	**2**	**71**	**1**	**14**	1	5	1	27	0	29	4	4
Novobiocin	**4**	**10**	6	19	1	0					**1**	**0.3**			3	1				
Marbofloxacin	**0.5**	**3**	0	0.4			0	10	4	18	**0.3**	**0.3**			0	1	6	0		
Neomycin	**2**	**0**	2	0	2	0	10	0			**3**	**0**	2	0	1	0			8	0
Streptomycin	**0.2**	**0.5**					10	20												
Sulph./trim.	**0.5**	**4**	1	4	0	1			0	12	**0.6**	**1**	0	1	**1**	2				
Virginiamycin			nt		nt						**1**	**0.3**	0	1	**1**	0	29	0		

**mecA* gene negative; I: intermediate; R: resistant

Table 4

Occurrence of resistance among staphylococci isolated from dog and horse

	Dog								Horse	
	S. intermedius		*S. aureus*		*S. hyicus*		Total		*S. aureus*	
Total	17		3		1		21		7	
	I	R	I	R	I	R	I	R	I	R
Amox./clav. acid										
Cephalexin										
Oxacillin*									0	1
Penicillin	0	13	0	3	0	1	17	17	0	3
Erythromycin	1	2	1	1	0	1	2	5	1	0
Lincomycin	2	8	2	1			4	12		
Bacitracin										
Tetracycline	0	5	0	2	0	1	0	10	0	3
Novobiocin										
Marbofloxacin	0	1					0	1		
Neomycin	2	0	2	0			4	0		
Gentamicin			0	1			0	1		
Streptomycin										
Sulph./trim.	2	2	1	0	0	1	3	3		

**mecA* gene negative; I: intermediate; R: resistant

Table 5

Occurrence of resistance among staphylococci isolated from humans

Antibiotic	Staphylococci from humans		Staphylococci from community				Staphylococci from hospitals			
	n		*S. aureus*		CNS		*S. aureus*		CNS	
	Inter-mediate %	Resis-tance %	Inter-mediate %	Resis-tance %	Inter-mediate %	Resis-tance %	Inter-mediate %	Resis-tance %	Inter-mediate %	Resis-tance %
Penicillin	**0**	**91**	0	**92**	**0**	**88**	**0**	**92**	**0**	**89**
Oxacillin*	**0.4**	**17**	0.1	2	**0.3**	**49**	0.3	4	**0.4**	**40**
Erythromycin	**0.7**	**26**	**0.5**	**10**	**0.7**	**56**	**1**	**14**	**0.6**	**53**
Clindamycin	**0.7**	**18**	**0.4**	**5**	**1**	**38**	**1**	**9**	**1**	**39**
Tetracycline	**1**	**27**	**1**	**20**	**2**	**46**	**1**	**22**	**1**	**43**
Ciprofloxacin	**2**	**12**	**0.6**	**3**	**3**	**29**	**2**	**5**	**2**	**24**
Gentamicin	**2**	**14**	**0.36**	**2**	**4**	**29**	**1**	**10**	**3**	**27**
Netilmicin	**1**	**8**	0.6	1	2	5	1	6	2	15
Amikacin	**1**	**11**	1	3	2	8	2	8	1	22
Sulph./trim.	**2**	**31**	0.6	7	**3**	**51**	1	5	**2**	**37**

**mecA* gene positive

Seven strains of *S. aureus,* 1 strain of CNS and a single strain of *S. aureus* from each of samples from chicken, horse, raw milk and raw smoked sausage were found phenotypically intermediately susceptible or resistant to methicillin by the disk diffusion test. However, all strains were *mecA*-negative by PCR.

Distribution of resistance patterns of staphylococci is presented according to the source of isolation. We did not distinguish between intermediate and resistant strains. In the presentation of resistance patterns the following abbreviations are used: Ery, erythromycin; Ge, gentamicin; Li, lincomycin; Mar, marbofloxacin; Novo, novobiocin; P, penicillin; SXT, sulphonamide/trimethoprim; Te, tetracycline; Vi, virginiamycin.

Out of 143 *S. aureus* strains from clinical and subclinical bovine mastitis, 79 (55%) produced β-lactamase enzyme. The resistance patterns of *S. aureus* from bovine mastitis were: P (59); P/Li (7); P/Ery (4); P/SXT (1); P/Ery/Li (2); P/Li/Te (1); P/Ery/Li/Te (4); P/Li/Te/Novo (1); Ery/Te (1); Ery/Li/Neo (1); Li/Neo (1); Novo/Neo (1). Four strains were resistant only to erythromycin, 2 to neomycin, 1 to lincomycin, 1 to novobiocin and 1 to marbofloxacin.

Among the 226 CNS strains from bovine mastitis resistance to lincomycin was the most frequent (intermediate: 19, resistant: 50). Phenotypes of the CNS strains from bovine mastitis were: Li (14); Li/Novo (13); Li/Ery (9); Li/P (3); Li/P/Novo (7); Li/Ery/Novo (10); Li/SXT (2); Li/P/Te (1); Li/Te/Novo (1); Li/Ery/Te (1); Li/Ery/P/Te/Novo (3); Li/Ery/Te/Novo (1); Li/P/Novo/SXT (1); Li/P/Te/Neo (1); Li/Ery/P/SXT (1); Li/Ery/Novo/Neo/SXT (1); P/Novo (5); P/Te (3); P/SXT (2); P/Neo (2); P/Ery (1); P/Te/Novo (2); P/Novo/SXT (1); Ery/Mar (2); Ery/Novo (1); Ery/Neo (1). Seventeen CNS strains were only penicillin resistant, 12 novobiocin resistant, 7 erythromycin resistant, 6 bacitracin resistant, 4 sulphonamide/trimethoprim resistant, 2 tetracycline resistant and 1 marbofloxacin resistant.

Most of the *S. aureus* strains from pigs were resistant to tetracycline (8 out of 10). Phenotypic resistance patterns of the strains were: Te (3); Te/Li (1); Te/P/Li (1); Te/P/Str (1); Te/P/Ery/Mar/Str (1); Te/P/Ery/Li/Neo/Str (1). Forty-nine *S. aureus* strains examined from poultry flocks were most often resistant to tetracyclines. Their resistance patterns were: Te (8); Te/Mar (4); Te/Ery (3); Te/SXT (3); Te/P (1); Te/Li (1); Te/P/Li (1); Te/P/Mar/SXT (2); Te/P/Ery/-Li/Mar (1); Te/P/Ery/Mar (1); Te/P/Ery/Li (1); Ery/Li/Mar (1); Ery/Li/Mar/P (1); Ery/Li (1); Ery/P (1); Li/Mar/SXT (1). Five strains were resistant to penicillin, 3 to lincomycin and 1 to SXT only.

Among the 122 *S. aureus* strains from the milk industry the β-lactamase-producing strains were the most frequent (41%). Their resistance patterns were: P (46); P/Li (1); P/Li/Te (2); P/Ery/Te (1); Ery/Te/Neo (1); Ery/Li/Te/Neo (1). Three 3 lincomycin-resistant, 2 virginiamycin-resistant, 1 erythromycin-resistant, 1 tetracycline-resistant and 1 sulphonamide/trimethoprim-resistant strains were also isolated.

Out of 135 strains from the meat industry 94 were β-lactamase positive. Their phenotypic resistance patterns were: P (42); P/Te (31); P/Ery (5); P/SXT (4); P/Novo (1); P/Li (1); P/Neo (1); P/Mar (1); P/Te/Novo (2); P/Te/SXT (1); P/Ery/Li (1); P/Li/Te (1); P/Ery/Novo (1); P/Te/Vi (1); P/Li/Te/Novo/Vi (1); Li/Te (1). Eleven strains were resistant only to tetracycline, 4 to erythromycin, 1 to lincomycin and 1 to novobiocin.

Out of the 17 strains from the poultry industry 8 (47%) produced β-lactamase enzyme. The resistance patterns of *S. aureus* from this group were: P (5); P/Vi (2); P/Te (1); Ery/Li (2); Te/Mar (1). Three strains were resistant to tetracycline and 1 to lincomycin only.

Out of 76 strains from noodles 6 strains exhibited resistance to tetracycline and also 6 to neomycin. Resistance patterns of the isolates were: Te (4); Te/P (1); Te/P/Ery (1); Neo (5); Neo/P (1). Two strains were only penicillin resistant.

Seventeen *S. intermedius,* 3 *S. aureus* and 1 *S. hyicus* were tested from dogs. All of them were penicillin resistant.

Resistance patterns of *S. intermedius* strains were: P (2); P/Li (5); P/Te (1); P/Te/Li/SXT (1); P/Te/Li/Ery/SXT (1); P/Li/Ery/SXT/Mar (1); P/Ery/Li/Te/Neo (1); P/Ery/Li/Te/Neo/SXT (1).

Resistance patterns of *S. aureus* were: P/Li (1); P/Ery/Li/Te/Neo (1); P/Ery/Li/Te/Neo/Ge/SXT (1).

The resistance pattern of *S. hyicus* was: P/Ery/Te/SXT (1).

The resistance patterns of 7 strains from horses were: P (1); P/Te (2); Ery/Te (1). Three strains were sensitive for all tested drugs.

There were resistance patterns that were found in bacteria isolated from two or more groups tested (Table 7).

Discussion

Antibiotic resistance in pathogenic bacteria is a great concern in both human and veterinary medicine. It is also evident that staphylococci cause a variety of infections, ranging from superficial skin wound infections to deep abscesses and septicaemia. They are a common cause of both hospital and community-acquired infections in humans and are frequently isolated from medical implant-related infections. *Staphylococcus aureus* along with *S. epidermidis* colonise medical devices by forming adherent biofilms, which are believed to make the organisms more resistant to antibiotics and disinfectants.

In animals, staphylococci are mainly involved in intramammary infections of dairy cows, sometimes superficial pyoderma and otitis in dogs, metritis, keratitis and abscesses in horses, dermatitis and arthritis in pigs, as well as dermatitis, arthritis, and septicaemia in poultry (Devriese, 1990; Takeuchi et al., 2002).

Staphylococcal diseases of animals are usually caused by *S. aureus* and in dogs by *S. intermedius* but very rarely by coagulase-negative staphylococci (CNS), except for bovine mastitis. CNS species represent the most frequent causes of subclinical cases of mastitis and elevated somatic cell count of milk samples in several dairy farms. That is why we summarised the antibiogram of *S. aureus* from different sources, CNS from milk and *S. intermedius* from dogs.

Our results concerning the resistance of staphylococci from humans and different animal species are largely in accordance with the use of antibiotics.

Since methicillin-resistant *S. aureus* (MRSA) was first recognised in England in 1961, MRSA strains have become common aetiologic agents of serious hospital infections in humans throughout the world (Fluit et al., 2001). According to the results of the SENTRY Antimicrobial Surveillance Program, between 1997 and 2000 the incidence of MRSA increased from 23% to 34% in Europe, from 26% to 36% in North America and from 49% to 54% in the Asia-Pacific region. The frequency of infections and outbreaks due to MRSA considerably differs by country. It is extremely high in Japan, where it is around 60% (Otsuki and Nishino, 2000), while in Switzerland and The Netherlands this percentage is approximately 2% (Fluit et al., 2001), and in hospitals of the USA 26.9% of the *S. aureus* and 71.5% of CNS strains are methicillin resistant (Pfaller et al., 1999).

In Hungary the prevalence of hospital MRSA was 4%, hospital methicillin-resistant CNS (MRCNS) 40%, community MRSA 2%, and community MRCNS was 49% according to the Annals of 'Béla Johan' National Centre for Epidemiology in 2001 (Table 5).

Methicillin-resistant staphylococci are very uncommon among animal isolates. In the few cases when they did occur in animals, the human origin of the infections could be demonstrated (Devriese et al., 1997; Hartmann et al., 1997; Gortel et al., 1999; Seguin et al., 1999; Tomlin et al., 1999; Yasuda et al., 2002).

To correspond with the guidelines of the NCCLS, oxacillin disk (1 μg) was used to examine penicillinase-resistant β-lactam antibiotics (oxacillin, methicillin, cloxacillin, nafcillin) in the disk diffusion test, because it is easily and well storable and gives reliable results in the detection of methicillin-resistant staphylococci.

In 2001, out of the 456 strains of *Staphylococcus* spp. of animal origin investigated in the present study only 11 *S. aureus* and 1 CNS were found phenotypically resistant or intermediate to methicillin. Special attention was paid to assessing if they were real methicillin-resistant strains.

Methicillin resistance in staphylococci is primarily mediated by the production of PBP2a, an additional altered penicillin-binding protein with low affinity for β-lactam antibiotics. β-lactam antibiotics bind to a group of bacterial proteins, the penicillin-binding proteins (PBPs), which are known to function as peptidoglycan transpeptidases. Penicillin-susceptible staphylococci have five of these proteins designated PBP1, PBP2, PBP3, PBP3' and PBP4. Strains of

methicillin-resistant staphylococci are able to produce another type of PBP, namely PBP2a that requires 2–10 times higher penicillin concentrations for inactivation than PBP2 and 20 times higher than PBP1. PBP2a may take over as a transpeptidase for continued peptidoglycan synthesis at methicillin concentrations which inhibit the normal PBPs (Brakstad and Mæland, 1997).

The *mecA* gene that has a very high level of homology in MRSA and MRCNS and is absent from methicillin-susceptible staphylococcal isolates encodes PBP2a. The *mecA* gene is therefore considered a useful molecular marker of methicillin resistance in *Staphylococcus* strains (Lencastre et al., 1996; Jaffe et al., 2000; Yasuda et al., 2002).

Phenotypic methicillin resistance may appear in staphylococci which harbour no *mecA,* because they produce large amounts of β-lactamase or a novel methicillinase. These types of resistance usually appear as low-level or borderline resistance and addition of β-lactamase inhibitors such as sulbactam or clavulanate may help overcome methicillin resistance (McDougal and Thornsberry, 1986; Konkoly Thege et al., 1988). According to the result of PCR examinations none of our phenotypic methicillin-resistant staphylococcal strains had *mecA* gene but they were susceptible to amoxicillin/clavulanic acid and cephalosporins.

Penicillin resistance, mediated by penicillinase production, was the most frequent among *S. aureus* strains from humans (96%) (Tables 5 and 6), from bovine mastitis (55%), from food (45%) (Tables 3 and 6) and from dogs (Tables 4 and 6).

Table 6

Comparison of resistance among staphylococci isolated from humans, food animals and foods

Antibiotic	Staphylococci from humans		Staphylococci from foods		Staphylococci from food animals	
	Intermediate %	Resistance %	Intermediate %	Resistance %	Intermediate %	Resistance %
Penicillin	0	91	0	45	0	30
Oxacillin	0.4	17	0.3*	0.3*	1.2*	0.9*
Erythromycin	0.7	26	3	2	7	7
Clinda-/lincomycin	0.7	18	0.3	4	6	17
Tetracycline	1	27	1	14	2	13
Cipro-/marbofloxacin	2	12	0.3	0.3	0.5	3
Gentamicin	2	14	0	0	0	0
Sulph./trim.	2	31	0.6	1	0.5	4

**mecA* gene negative

Among CNS from bovine clinical or subclinical mastitis, strains with decreased susceptibility to lincomycin were the most prevalent (8% intermediate susceptible and 22% resistant) while in pigs (80%) and in poultry (71%) strains with decreased susceptibility to tetracycline were the most common (Table 3).

Table 7

Resistance patterns of strains isolated from two or more tested groups

	Mastitis		Milk industry	Swine	Meat industry	Poultry		Noodle	Dog		Horse
	CNS	*S. aureus*				Herd	Industry		*S. intermedius*	*S. aureus*	
Li/Ery	9	–	–	–	–	1	2	–	–	–	–
Li/Te	–	–	–	1	1	1	–	–	–	–	–
P/Novo	5	–	–	–	1	–	–	–	–	–	–
P/Li	3	7	1	–	1	–	–	–	5	1	–
P/Te	3	–	–	–	31	1	1	1	1	–	2
P/SXT	2	1	–	–	4	–	–	–	–	–	–
P/Neo	2	–	–	–	1	–	–	1	–	–	–
P/Ery	1	4	–	–	5	1	–	–	–	–	–
Te/Mar	–	–	–	–	–	4	1	–	–	–	–
Ery/Te	–	1	–	–	–	3	–	–	–	–	1
P/Li/Ery	–	2	–	–	1	–	–	–	–	–	–
P/Ery/Te	–	–	1	–	–	–	–	1	–	–	–
P/Te/Novo	2	–	–	–	2	–	–	–	–	–	–
P/Li/Te	1	1	2	1	1	1	–	–	–	–	–
P/Li/Ery/Te	–	4	–	–	–	1	–	–	–	–	–
P/Li/Ery/Te/Neo	–	–	–	–	–	–	–	–	1	1	–
P/Li/Te/Novo/Vi	1	–	–	–	1	–	–	–	–	–	–

In staphylococci that were isolated from animals, very low resistance percentages to aminoglycosides were found (0–2%) (Tables 3 and 6) but in humans these percentages are higher (1–14%) (Tables 5 and 6). Comparing the susceptibility results to fluoroquinolones and sulphonamides there are noticeable differences among strains from humans (2–12%) and animals (0.5–3%) (Table 6).

The results show that there are similarities and differences in the prevalence of resistance to antimicrobial drugs among the isolates of staphylococci from humans and from animal species. These similarities and differences may reflect therapeutic use or the availability of certain antimicrobial agents for the treatment of infections (Konkoly Thege et al., 1988; Milch et al., 2001) in humans, cattle, pig, poultry, dog and horse as well as exchange of drug resistance genes among the farm microbiota.

The antibiotic group with beta-lactam ring (penicillin, amino-penicillins, cloxacillin, cephalosporins), lincomycin, and novobiocin are commonly used to treat mastitis both in the lactational and, except lincomycin, in the dry period. The high prevalence of novobiocin-resistant strains among CNS could be due to the intrinsic resistance of some species (*S. sciuri, S. lentus, S. xylosus, S. cohnii,* and *S. saprophyticus*) which are relatively common (except the last) in farm animals (Devriese, 1990). The same may apply to the lincomycin resistance of *S. xylosus*. Tetracyclines and amino-penicillins are widely used in swine and poul-

try production for the treatment and prevention of disease; therefore, a high rate of resistance to drugs in these antimicrobial classes was not unexpected. Surprisingly, such relationship could not be detected for beta-lactamase-resistant penicillins (cloxacillin, nafcillin). Namely, these drugs are used frequently as dry cow treatment in mastitis therapy but resistance to the closely related antibiotic, methicillin, is rare not only in poultry, swine, horse and dog but also in cow.

As the resistance pattern of bacteria, especially in the case of multiresistant strains, can be a useful tool to distinguish between different populations of resistant strains we compared the phenotypes of staphylococci isolated from different animal species and food. Table 7 contains the numbers of resistance patterns that were isolated from more than one group. The most frequent antibiotic susceptibility profiles were P/Te, P/Li, and P/Li/Te. P/Te resistance was exhibited by strains from mastitis (3), samples from the meat industry (31), a poultry flock (1), the poultry industry (1), noodle (1) and horses (2). P/Li resistance was found in 10 *Staphylococcus* strains from mastitis, 1 from the milk industry, 1 from the meat industry and 6 from dogs. Isolates from mastitis (2), from the milk industry (2), from pig (1), from the meat industry (1) and from poultry (1) harboured P/Li/Te pattern. The relatively common occurrence of penicillin-, lincomycin- and tetracycline-resistant strains in animal species could be related to the widespread use of these drugs (or intrinsic resistance to lincomycin) rather than transfer of the strains among the different animal species.

Multiresistant strains were usually isolated only from one and sometimes from two animal species, which does not provide evidence of the spread of the same strains among different species. This is consistent with earlier statements that the transfer of staphylococci between humans and different animal species is rare and various animal ecovars colonising humans and animals other than their host species are scarce (Devriese, 1984, 1990; Aarestrup et al., 2000; Zadoks et al., 2000). The results of Southern blot analysis indicate that the *ScpA* gene encoding a cysteine (thiol) protease of *S. aureus* strain was found only in the high protease-producing *S. aureus* strains from chicken and not from cattle and pig (Takeuchi et al., 2002).

Even so staphylococci from animals may present difficulties in humans because resistance genes might in some instances change between staphylococci occurring in humans and staphylococci present in animal species and thereby compromise antimicrobial treatment.

Monitoring of resistance to antibiotics is a useful tool to provide accurate information on the prevalence of antibiotic resistance in both human and animal pathogens. Staphylococcal resistance phenotypes should be taken into account to improve strategies of antimicrobial use. This information may help to select the appropriate antimicrobial drug for empirical therapy.

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