Methicillin-resistant *Staphylococcus aureus* (MRSA) from poultry and food of poultry origin: molecular characterization and antimicrobial resistance

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Summary

Two studies, involving 22 MRSA from diseased turkeys and chickens as well as 32 MRSA from turkey and chicken meat/meat products, were conducted in Germany to gain insight in the MRSA types present and their antimicrobial resistance properties. MRSA isolates of the clonal complex (CC) 398 dominated in both studies but MRSA of CC5 and CC9 were also detected. All but two MRSA isolates were classified as multi-resistant by showing resistance to at least three classes of antimicrobial agents The molecular characteristics obtained by DNA microarray analysis and molecular typing represent helpful tools to trace back the dissemination of MRSA isolates within and beyond poultry flocks, but also along the food chain.

Introduction

In contrast to the wealth of data about methicillin-resistant *Staphylococcus aureus* (MRSA) from humans and other animals, especially pigs, comparatively little is known about the molecular characteristics of MRSA from poultry (Monecke *et al*., 2011). To gain insight into the MRSA types present in diseased poultry and food of poultry origin, two studies have recently been conducted in Germany in which **(a)** isolates from diseased turkeys and chickens (Monecke *et al*., 2012) and **(b)** isolates from fresh turkey and chicken meat as well as turkey and chicken meat products (Feßler *et al*., 2011) have been characterized by using molecular methods and investigated for their antimicrobial resistance geno- and phenotypes.

The results of both studies are presented and compared to what is known about MRSA from poultry and food of poultry origin in other parts of the world.

Material and Methods

A total of 22 MRSA isolates from clinically ill poultry (19 from turkeys and 3 from chickens) (Monecke *et al*., 2012) as well as 32 MRSA isolates from 86 samples of food of poultry origin (22 from turkey meat, 21 from turkey meat products, 24 from chicken meat and 19 from chicken meat products)

(Feßler *et al*., 2011) were included in these analyses. All isolates were identified as *S. aureus* by standard biochemical and molecular techniques (Feßler *et al*., 2011, Monecke *et al*., 2012). Methicillin resistance was assessed phenotypically by their oxacillin minimum inhibitory concentrations (MICs) and genotypically by the detection of the *mecA* gene (Feßler *et al*., 2011, Monecke *et al*., 2012). A previously described *S. aureus*-specific diagnostic DNA microarray (StaphyType, Alere Technologies, Jena, Germany) was used to characterize the MRSA isolates (Monecke *et al*., 2008, Monecke *et al*., 2011). This microarray-based assay can detect a total of 330 different sequences (~ 180 genes and alleles thereof) including species-specific genes, as well as virulence and resistance genes. Further characterization of the isolates included *spa* typing (http://*spa*server.ridom.de), dru typing (http://dru-typing.org), two CC398-specific PCR assays (van Wamel *et al*., 2010), SCCmec typing (Kondo *et al*. 2007) and multilocus sequence typing (MLST, http://saureus.mlst.net/).

All MRSA isolates were tested for their antimicrobial susceptibility by broth microdilution according to the recommendations given in document M31-A3 of the Clinical and Laboratory Standards Institute (CLSI 2008). For this, custom-made microtitre plates (MCS Diagnostics, Swalmen, The Netherlands) were used which included 30 antimicrobial agents in two-fold dilution series with 10–12 concentrations per antimicrobial agent. *S. aureus* ATCC®29213 served as quality control strain in the MIC determinations. Resistance genes were detected either by the aforementioned DNA microarray or by PCR as previously described (Feßler *et al*., 2010; Feßler *et al*., 2011; Hauschild *et al*., 2012; Monecke *et al*., 2012).

Results

(a) MRSA from diseased poultry

The 22 MRSA isolates from clinically ill poultry included 19 (22.6%) of the 84 isolates of turkey origin and 3 (6.4%) of the 47 isolates of chicken origin. Microarray analysis, SCC*mec* typing, CC398-specific PCRs and MLST identified 13 CC398-MRSA-V (10 from turkey and 3 from chickens), two CC398-MRSA-IV, one CC398-MRSA with an untypeable SCC*mec* element, four CC5-MRSA-III and two CC9-MRSA-IV (Monecke *et al*., 2012).

The two CC9-MRSA-IV isolates shared *spa* type t1430 and *dru* type dt10a and exhibited the same resistance pheno- and genotypes. The four CC5-MRSA-III isolates did not differ in their *spa* (t002) and *dru* (dt9v) types. They showed the same resistance phenotype, but one of the four isolates differed in the resistance genotypes from the others by harboring an additional *erm*(B) gene. Fifteen of the 16 CC398 isolates showed either *spa* types t011 or t034 (one isolate proved to be non-typeable), but displayed seven different *dru* types – dt6j, dt10q, dt11a, dt11ap, dt7aa, dt11aw and dt12q (Monecke *et al*., 2012).

Thirteen different resistance phenotypes and sixteen different resistance genotypes were detected (Monecke *et al*., 2012) with all 22 MRSA isolates being considered as multi-resistant by their resistance to three or more classes of antimicrobial agents (Schwarz *et al*., 2010) (**Table 1**).

(b) MRSA from food of poultry origin

The 32 MRSA isolates from food of poultry origin included 11 isolates (50.0%) of 22 samples from turkey meat, 11 isolates (52.4%) of the 21 samples from turkey meat products, six (25.0%) of the 24 samples from chicken meat and four (21.1%) of the 19 samples from chicken meat products (Feßler *et al*., 2011).

Microarray analysis, SCCmec typing, CC398-specific PCRs and MLST identified 19 CC398-MRSA-V (five from turkey meat, six from turkey meat products, six from chicken meat and two from chicken meat products), nine CC398-MRSA-IV (four from turkey meat, five from turkey meat products), two CC5-MRSA-III (both from turkey meat) and two CC9-MRSA-IV (both from chicken meat products) (Feßler *et al*., 2011).

Both CC9-MRSA-IV isolates showed *spa* type t1430 and *dru* type dt10a while the two CC5-MRSA-III shared *spa* type t002 and *dru* type dt9v. The 28 CC398 isolates exhibited five different *spa* types: t011 (n = 16), t034 (n = 9), as well as t899, t2346 and t6574 (n = 1, each). The *dru* typing of the 28 CC398 isolates identified ten different *dru* types among which dt11a (n = 8), dt10q (n = 7) and dt6j (n = 6) were found most frequently while the remaining seven *dru* types dt2b, dt6m, dt10a, dt10as, dt10at, dt11ab and dt11v were present in single isolates (Feßler *et al*., 2011).

Twenty different resistance phenotypes and 25 different resistance genotypes were detected with all but two MRSA isolates being considered as multi-resistant by their resistance to at least three classes of antimicrobial agents (Schwarz *et al*.,

Table 1 - Characteristics of the 22 MRSA isolates from diseased turkeys and chickens

Origin	Isolate	CC-SCCmec type	spa type	dru type	Resistance phenotype[1,2]	Resistance genes in addition to mecA
Turkey	Tur-001	CC5-III	t002	dt9v	BLA, TET, MLSB, SPC, ENR	blaZ/I/R, tet(M), erm(A)+erm(B), spc
	Tur-022	CC5-III	t002	dt9v	BLA, TET, MLSB, SPC, ENR	blaZ/I/R, tet(M), erm(A), spc
	Tur-025	CC5-III	t002	dt9v	BLA, TET, MLSB, SPC, ENR	blaZ/I/R, tet(M), erm(A), spc
	Tur-038	CC5-III	t002	dt9v	BLA, TET, MLSB, SPC, ENR	blaZ/I/R, tet(M), erm(A), spc
	Tur-067	CC9-IV	t1430	dt10a	BLA, TET, MLSB, TMP, (KAN), ENR	blaZ/I/R, tet(L), erm(B), dfrK, aadD
	Tur-075	CC9-IV	t1430	dt10a	BLA, TET, MLSB, TMP, (KAN), ENR	blaZ/I/R, tet(L), erm(B), dfrK, aadD
	Tur-006	CC398- n.t.4	n.t.4	dt11a	BLA, TET, MLSB, TMP, SPC, TIA, SXT	blaZ/I/R, tet(M)+tet(L), erm(A)+erm(B)+erm(C), dfrK, aadD
	Tur-003	CC398-IV	t011	dt10q	BLA, TET, MLSB, TMP, GEN, KAN	blaZ/I/R, tet(M), erm(C), dfrK, aacA/aphD, aadD
	Tur-005	CC398-IV	t011	dt10q	BLA, TET, MLSB, TMP, GEN, KAN	blaZ/I/R, tet(M)+tet(K)+tet(L), erm(B), dfrK, aacA/aphD, aadD
	Tur-002	CC398-V	t034	dt7aa	BLA, TET, MLSB, SPC	blaZ/I/R, tet(M), erm(A), spc
	Tur-004	CC398-V	t011	dt11aw	BLA, TET, MLSB, TIA, (ENR)	blaZ/I/R, tet(M)+tet(K), erm(C), vga(A)3
	Tur-026	CC398-V	t011	dt11aw	BLA, TET, MLSB, TMP, KAN, TIA, (ENR)	blaZ/I/R, tet(M)+tet(K)+tet(L), erm(C)+erm(T), dfrK, aadD, vga(A)3
	Tur-028	CC398-V	t011	dt11aw	BLA, TET, MLSB, TMP, SPC, (KAN), TIA, (ENR)	blaZ/I/R, tet(M)+tet(K)+tet(L), erm(B)+erm(C), dfrK, aadD, vga(A)3
	Tur-034	CC398-V	t011	dt11aw	BLA, TET, MLSB, TIA, (ENR)	blaZ/I/R, tet(M)+tet(K), erm(C), vga(A)3
	Tur-039	CC398-V	t011	dt11a	BLA, TET, MLSB, TMP, SPC, GEN, KAN, TIA	blaZ/I/R, tet(M)+tet(L), erm(A)+erm(B), lnu(A), dfrK, spc, aacA/aphD, aadD, vga(E)
	Tur-106	CC398-V	t011	dt11ap	BLA, TET, MLSB, TMP, GEN, KAN	blaZ/I/R, tet(M)+tet(L), erm(T), dfrK, aacA/aphD
	Tur-119	CC398-V	t011	dt11ap	BLA, TET, MLSB, TMP, GEN, KAN, SXT	blaZ/I/R, tet(M)+tet(L), erm(T), dfrK, aacA/aphD
	Tur-134	CC398-V	t011	dt12q	BLA, TET, MLSB	blaZ/I/R, tet(M)+tet(K), erm(C)
	Tur-135	CC398-V	t034	dt6j	BLA, TET, MLSB, TMP, SPC, TIA	blaZ/I/R, tet(M)+tet(K), erm(A), dfrK, spc
Chicken	Chi-90	CC398-V	t011	dt11ap	BLA, TET, MLSB, TMP, GEN, KAN, SXT	blaZ/I/R, tet(M)+tet(L), erm(T), dfrK, aacA/aphD
	Chi-79	CC398-V	t011	dt11ap	BLA, TET, MLSB, TMP, GEN, KAN	blaZ/I/R, tet(M)+tet(L), erm(T), dfrK, aacA/aphD
	Chi-133	CC398-V	t011	dt11ap	BLA, TET, MLSB, TMP, SPC, GEN, KAN, SXT	blaZ/I/R, tet(M)+tet(L), erm(T), dfrK, spc, aacA/aphD

1 - Abbreviations of the antimicrobial agents: BLA (-lactam antibiotics), ENR (enrofloxacin), GEN (gentamicin), KAN (kanamycin), MLSB (macrolides/lincosamides/ streptogramin B), Q/D (quinupristin/dalfopristin), SPC (spectinomycin), SXT (sulfamethoxazole/trimethoprim, 19:1), TET (tetracyclines), TIA (tiamulin), TMP (trimethoprim); brackets indicate an intermediate status. 2 - Despite the lack of CLSI-approved breakpoints, isolates that showed high MIC values of TMP (256 mg/L), SPC (512 mg/L) and TIA (16 mg/L) were considered as resistant. 3 - vga(A) variant from strain *S. aureus* BM3327 (GenBank accession no. AF186237). 4 - non-typeable.

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2010). One of these two isolates showed β-lactam and enrofloxacin resistance and was from a chicken meat product while the other exhibited β-lactam and tetracycline resistance and was from a turkey meat product (**Table 2**).

Discussion

So far, comparatively little information is available for MRSA from poultry in general and in particular for MRSA from poultry in Germany. The national resistance monitoring program of veterinary pathogens in Germany, GERM-Vet, did not identify MRSA among *S. aureus* from poultry (Wallmann *et al*., 2007). Studies conducted in neighboring countries, such as Belgium and The Netherlands, identified MRSA at distinctly lower frequencies in poultry than in pigs. Nemati *et al*. (2008) investigated comparatively 90 *S. aureus* isolates from diseased breeder chickens and from healthy broiler breeders obtained during the period 1970–1972 and 81 *S. aureus* isolates from healthy broiler chickens collected in 2006 in Belgium. Only ten of the recent isolates were classified as MRSA. They were non-typeable by SmaI PFGE analysis, exhibited *spa* types t011 (n = 8) and t567 (n = 2) and belonged to the clonal complex CC398. Another study from Belgium (Persoons *et al*., 2009) investigated 50 healthy laying hens and 75 healthy broiler chickens for the presence of MRSA. While none of the laying hens was MRSA-positive, eight broilers from different farms carried MRSA. The respective isolates all showed the CC398-associated *spa* type t1456. In The Netherlands, Mulders *et al*. (2010) investigated a total of 405 broilers upon their arrival at the slaughterhouse and found that 6.9% of them were positive for MRSA. Moreover, they found that MRSA contamination in the different compartments of slaughterhouses increased during the production day. They found mainly livestock-associated MRSA CC398, but also CC9 isolates with *spa* type t1430. In contrast to the aforementioned studies from Belgium and the Netherlands, in which mainly healthy broilers were investigated, the study by Monecke *et al*. (2012) focused on diseased chickens and turkeys from Germany. It showed that MRSA isolates of three clonal complexes were detected with CC398 being the most predominant CC, and CC5 as well as CC9 being present only at lower frequencies.

Various MRSA isolates were detected at different frequencies in food of poultry origin in different parts of the world. A study from The Netherlands identified MRSA isolates in 11.9% of 2217 food samples tested (de Boer *et al*., 2009). MRSA were most prevalent in turkey (35.3%), followed by chicken (16.0%), veal (15.2%), pork (10.7%) and beef (10.6%). About 85% of the MRSA isolates were assigned to CC398. MRSA was not identified in a study conducted in Switzerland examining 100 pooled neck skin swabs from chicken carcasses and 460 food samples of animal origin (Huber *et al*., 2010). In *Spa*in, Lozano *et al*. (2009) identified only five MRSA isolates in 318 raw food samples, among them an ST125 (CC5) isolate in a single chicken sample. In addition to livestock-associated MRSA, MRSA isolates that corresponded to types commonly found in humans were also detected in food of animal origin. This observation suggested that there is potential for contamination of food either at the slaughterhouse or during food processing, with humans being a likely source of contamination. In a Canadian study, Weese *et al*. (2010) found 32 MRSA isolates in 678 food samples (9.6% of pork, 5.6% of beef and 1.2% of chicken samples) purchased at retail outlets. All 32 isolates were classified as Canadian epidemic MRSA-2 [= CC5-MRSA-II], a human MRSA recognized as the most common cause of healthcare-associated infections in Canada. Two MRSA isolates, which displayed characteristics of community-associated MRSA isolates, were also detected among 444 retail raw chicken meat samples in Japan (Kitai *et al*., 2005). In addition, MRSA ST5 has also been identified from retail chicken in Korea (Kwon *et al*., 2006).

The study by Feßler *et al*. (2011) identified MRSA isolates of CC398, CC5 and CC9 among fresh turkey and chicken meat and associated meat products obtained from retail stores in Germany. Again, CC398 isolates were the most predominant MRSA. A comparison of both studies from Germany revealed that MRSA CC398 from diseased turkeys and chickens as well as those from turkey and chicken meat/meat products displayed very similar characteristics. The same is also true for the corresponding CC9 and CC5 isolates. This observation suggests that closely related – if not the same – MRSA isolates are present not only in turkeys and chickens, where they can cause diseases, but also in meat and meat products obtained from turkeys and chickens. Moreover, the MRSA CC398 isolates from poultry and poultry products showed similar characteristics as isolates from pigs and cattle (Kadlec *et al*., 2009; Feßler *et al*., 2010). In addition, the CC9 and CC5 isolates corresponded closely in their microarray patterns to human strains of CC9 and CC5, respectively (Monecke *et al*., 2011). Almost all MRSA isolates from diseased poultry

Table 2 - Characteristics of the 32 MRSA isolates from food of poultry origin.

Origin	Isolate	CC-SCCmec type	spa type	dru type	Resistance phenotype[1,2]	Resistance genes in addition to mecA
Turkey meat	Tur-2	CC5-III	t002	dt9v	BLA, TET, MLSB, SPC, ENR	blaZ/I/R, tet(M), erm(A), spc
	Tur-10	CC398-V	t034	dt6j	BLA, TET, TMP, MLSB, SPC, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), dfrK, erm(A)+erm(B), spc, vga(E)
	Tur-11	CC398-V	t034	dt11a	BLA, TET, TMP, MLSB, SPC, KAN, TIA, (Q/D)	blaZ/I/R, tet(L)+tet(M), dfrK, erm(A), spc, aadD, vga(C)
	Tur-13	CC398-IV	t011	dt10q	BLA, TET, TMP,MLSB, GEN, KAN	blaZ/I/R, tet(L)+tet(M), dfrK, erm(T), aacA-aphD, aadD
	Tur-14	CC5-III	t002	dt9v	BLA, TET, MLSB, SPC, ENR	tet(M), erm(A), spc
	Tur-16	CC398-IV	t899	dt10as	BLA, TET, TMP, MLSB, TIA, (Q/D)	blaZ/I/R, tet(L)+tet(M), dfrS1, erm(B), vga(A)
	Tur-18	CC398-V	t6574	dt11ab	BLA, TET, GEN, KAN, TIA	blaZ/I/R, tet(M), aacA-aphD, vga(A)
	Tur-19	CC398-IV	t011	dt10q	BLA, TET, TMP, MLSB, SPC, TIA, Q/D	blaZ/I/R, tet(K)+tet(M), dfrS1+dfrK, erm(A)+erm(C), spc, vga(E)
	Tur-20	CC398-V	t034	dt11v	BLA, TET, TMP, MLSB, SPC, KAN, TIA, (Q/D)	blaZ/I/R, tet(L)+tet(M), dfrK, erm(A), spc, aadD, vga(C)
	Tur-21	CC398-IV	t011	dt10q	BLA, TET, TMP, MLSB, SPC, (GEN), KAN	blaZ/I/R, tet(L)+tet(M), dfrK, erm(C), aacA-aphD
	Tur-22	CC398-V	t034	dt6m	BLA, TET, TMP, MLSB, SPC, TIA, Q/D	blaZ/I/R, tet(M), dfrK, erm(A)+erm(C), spc, vga(E)
Turkey product	Tur-1	CC398-IV	t011	dt10q	BLA, TET, TMP, MLSB, SPC, GEN, KAN	blaZ/I/R, tet(L)+tet(M), dfrK, erm(T), aacA-aphD, aadD
	Tur-3	CC398-V	t011	dt11a	BLA, TET	blaZ/I/R, tet(K)+tet(M)
	Tur-4	CC398-IV	t011	dt10q	BLA, TET, TMP,MLSB, GEN, KAN	blaZ/I/R, tet(L)+tet(M), dfrK, erm(T), aacA-aphD
	Tur-5	CC398-IV	t011	dt10q	BLA, TET, TMP, MLSB, SPC, (GEN), KAN, ENR	blaZ/I/R, tet(L)+tet(M), dfrK, erm(C)+erm(T), aacA-aphD, aadD
	Tur-6	CC398-V	t034	dt6j	BLA, TET, TMP, MLSB, SPC, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), dfrK, erm(A), spc, vga(E)
	Tur-7	CC398-IV	t011	dt10q	BLA, TET, TMP, MLSB, SPC, GEN, KAN	blaZ/I/R, tet(L)+tet(M), dfrK, erm(C), aacA-aphD
	Tur-8	CC398-V	t034	dt6j	BLA, TET, TMP, MLSB, SPC, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), dfrK, erm(A)+erm(B), spc, vga(E)

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Table 2 - Characteristics of the 32 MRSA isolates from food of poultry origin.

Origin	Isolate	CC-SCCmec type	spa type	dru type	Resistance phenotype[1,2]	Resistance genes in addition to mecA
Turkey product	Tur-9	CC398-V	t2346	dt11a	BLA, TET, MLSB, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), erm(C), vga(A)
	Tur-12	CC398-V	t011	dt11a	BLA, TET, MLSB	blaZ/I/R, tet(K)+tet(M), erm(C)
	Tur-15	CC398-V	t034	dt6j	BLA, TET, TMP, MLSB, SPC, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), dfrK, erm(A), spc, vga(C)
	Tur-17	CC398-IV	t011	dt10at	BLA, TET, TMP, GEN, KAN	blaZ/I/R, tet(L)+tet(M), dfrK, aacA-aphD
Chicken meat	Chi-1	CC398-V	t011	dt10a	BLA, TET, TMP, MLSB, GEN, KAN, APR	blaZ/I/R, tet(K)+tet(L)+tet(M), dfrK, erm(B), aadD, apmA
	Chi-2	CC398-V	t011	dt11a	BLA, TET, TMP, MLSB, SPC	blaZ/I/R, tet(K)+tet(L)+ tet(M), dfrK, erm(A)+erm(C), spc
	Chi-3	CC398-V	t034	dt6j	BLA, TET, TMP, MLSB, SPC, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), dfrK, erm(A), spc, vga(E)
	Chi-4	CC398-V	t011	dt11a	BLA, TET, TMP, MLSB, KAN, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(L)+tet(M), dfrK, erm(C), aadD, vga(A)
	Chi-5	CC398-V	t011	dt2b	BLA, TET, MLSB, TIA, Q/D	blaZ/I/R, tet(K)+tet(M), erm(C), vga(A)
	Chi-10	CC398-V	t011	dt11a	BLA, TET, TMP, MLSB, SPC	blaZ/I/R, tet(K)+tet(L)+tet(M), dfrK, erm(A)+erm(C), spc
Chicken product	Chi-6	CC9-IV	t1430	dt10a	BLA, TET, TMP, MLSB, (KAN), ENR	blaZ/I/R, tet(L), dfrK, erm(B), aadD
	Chi-7	CC398-V	t011	dt11a	BLA, TET, TMP, MLSB, SPC, TIA, Q/D	blaZ/I/R, tet(K)+tet(L)+tet(M), dfrK, erm(A)+erm(C), spc, vga(C)
	Chi-8	CC398-V	t034	dt6j	BLA, TET, TMP, MLSB, SPC, TIA, (Q/D)	blaZ/I/R, tet(K)+tet(M), dfrK, erm(A)+erm(B), spc, vga(C)
	Chi-9	CC9-IV	t1430	dt10a	BLA, ENR	blaZ/I/R

1 - Abbreviations of the antimicrobial agents: APR (apramycin), BLA (-lactam antibiotics), ENR (enrofloxacin), GEN (gentamicin), KAN (kanamycin), MLSB (macrolides/lincosamides/streptogramin B), Q/D (quinupristin/dalfopristin), SPC (spectinomycin), TET (tetracyclines), TIA (tiamulin), TMP (trimethoprim); brackets indicate an intermediate status. 2 - Despite the lack of CLSI-approved breakpoints, isolates that showed high MIC values of TMP (256 mg/L), SPC (512 mg/L), TIA (16 mg/L) and APR (64 mg/L) were considered as resistant.

and food of poultry origin tested were classified as multi-resistant. However, none of them proved to be resistant to antimicrobial agents of last resort, such as vancomycin or linezolid. Nevertheless, the in part rather expanded antimicrobial resistance patterns of the isolates from diseased poultry may represent a therapeutic challenge.

As previously stated by Weese *et al*. (2010), the relevance of MRSA contamination of retail meat is unknown and is discussed controversially (Kluytmans, 2010). Different screening studies resulted in strikingly different MRSA prevalences. This may be due to differences in the sampling plans and the MRSA detection procedures applied, but may also reflect country-specific or food-specific true differences in the MRSA prevalence. The studies by Monecke *et al*. (2012) and Feßler *et al*. (2011) presented only time-limited snapshots of the presence of MRSA in diseased turkeys and chickens as well as in fresh chicken and turkey meat and in the corresponding products sold in Germany. Actually, it is uncertain in how far these results can be extrapolated to Germany in general. Nevertheless, the study by Monecke *et al*. (2012) showed that MRSA CC398 and to a lesser degree MRSA CC5 and CC9 isolates occur in diseased poultry and account for a non-negligible proportion (16.8%) of the *S. aureus* isolates tested. Moreover, the observation that 37.2% of the samples of food of poultry origin tested were MRSA-positive is alarming and needs further investigation. Longitudinal studies in a farm-to-fork approach are needed to identify the sources of contamination and to clarify whether isolates found as commensals or pathogens in poultry are indistinguishable in their genotypic characteristics from those found in fresh poultry meat and poultry meat products.

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