Surveillance on antimicrobial resistance in Escherichia coli and Salmonella isolates from poultry between 1993 and 1999*

Untersuchungen zur Resistenzentwicklung von Escherichia coli und Salmonella Isolaten aus Geflügel im Untersuchungszeitraum 1993 bis 1999

Silvia Jodas¹ and H. M. Hafez²

* Dedicated to Prof. Dr. Gerhard Monreal, on behalf of his seventy-fifth birthday

Introduction

The introduction of antibiotics in 1940's provided a means of treating bacterial diseases and infections in human and animals that were previously often lethal. Currently antimicrobials were used in poultry to treat clinical diseases, to prevent the spread of an infection in the flock and between farms and to enhance the digestion. With regard to the animal welfare aspects their use is necessary to reduce pain and suffering in cases where management and biosecurity fail to prevent the introduction of infectious microorganisms. Furthermore, using antibiotics to control and treat diseases in animals, improves the safety of the poultry production by reducing the contamination with zoonotic pathogens.

Generally, use of antimicrobials will tend to promote the development of antibiotic resistance in bacteria, either by non-transmissible chromosome mutation or by the acquisition of transmissible R-plasmids (SMITH and LEWIN, 1993; DAVIES, 1994). The resistance determinant may be transferred from a commensal reservoir to a pathogen: for instance, a multiresistant plasmid may spread from an E. coli to a Salmonella (CORPET, 1998). The development of resistance is influenced by environmental changes, the microorganism, the drug, the dose and the duration of use.

A large number of studies on antimicrobial resistance of E. coli and Salmonella has been published in many countries world-wide. Since the development of resistance is influenced by many factors, it is difficult to compare the results obtained from different countries, even from different regions within one country.

The present investigation was carried out to detect the development of antimicrobial resistance of E. coli and Salmonella isolated from commercial turkey in the State of Baden-Württemberg between 1993 and 1999 to neomycin, tetracycline, enrofloxacin as well as furazolidone and chloramphenicol. The use of last both antibiotics is not allowed in the EU since 1994 and 1995, respectively.

Materials and Methods

E. coli and Salmonella Isolates

During a period between 1993 and September 1999 in total 2097 E. coli and 568 Salmonella isolates were tested. All isolates were obtained from turkey, layer and broiler specimens attended by Poultry Health Service Stuttgart and adopted for the diagnostic purpose or surveillance in Chemical and Veterinary Laboratory, Stuttgart. About 85% of the E. coli isolates were from flocks with respiratory diseases and about 15% from flocks with enteric disorders. E. coli isolates were obtained by culturing of the internal organs of poultry submitted to post mortem examination. The Salmonella isolates originate from post mortem examination and faecal samples monitored and surveyed for coccidiosis and salmonella. All isolates were initially isolated on blood and gasner agar either direct or after enrichment in case of salmonella. Table 1 show the number of tested isolates each year.

Disc sensitivity testing by diffusion technique

The antimicrobial sensitivity test was done in an agar diffusion technique using Diagnostic Sensitivity Agar (DST-agar) (Oxoid, Wesel) and discs containing antimicrobials. The following discs were applied on DST-agar (Table 2).

A loop full of a pure culture of the isolated E. coli and Salmonella strains was suspended in a tube with 2ml buffered

<table>
<thead>
<tr>
<th>Year</th>
<th>E. coli</th>
<th>Salmonella</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Turkey</td>
<td>Broiler</td>
</tr>
<tr>
<td>1993</td>
<td>145</td>
<td>66</td>
</tr>
<tr>
<td>1994</td>
<td>146</td>
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<td>1996</td>
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<td>1997</td>
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<td>1998</td>
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<td>110</td>
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<td>Sep. 1999</td>
<td>186</td>
<td>101</td>
</tr>
<tr>
<td>Total</td>
<td>1152</td>
<td>574</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Turkey</th>
<th>Broiler</th>
<th>Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>2097</td>
<td>568</td>
<td></td>
</tr>
</tbody>
</table>

¹ Poultry Health Service, Stuttgart, Germany
² Institute of Poultry Health, Free University Berlin, Germany
peptone water and distributed on the DST-agar. After moistening of the whole surface the surplus was discarded and the closed plate allowed to dry for approximately 10–20 min. The antimicrobial discs were then placed on the DST-agar with an antibiotic disc dispenser (Oxoid, Wesel). After incubation for 18 h at 37 °C the agar plate was evaluated.

Results

Antimicrobial sensitivity of E. coli isolates from turkeys

The average of E. coli resistant isolates to neomycin was 24%, to tetracycline 76%, to enrofloxacin 21%, to furazolidone 10% and to chloramphenicol 36%.

The percentage of E. coli isolates resistant to neomycin show a slight gradual decrease from 30 in 1993 to 16 in year 1999. On the other hand resistance to tetracycline in 1993 was at a very high level (67%) and increased to 78%–83% in year 1999 and 1998 respectively. There was some fluctuation in the resistance to enrofloxacin. In year 1993 14% of tested isolates were resistant and reached 32% in year 1996 followed by decrease in 1997 and then started to increase again in years 1998 and 1999. Similar fluctuations were also detected for furazolidone and chloramphenicol (Table 3).

Antimicrobial sensitivity of E. coli isolates from layers

The E. coli isolates from layers showed in general a lower resistance patterns in comparison to the turkey isolates. However, the resistance to tetracycline was again at a very high level and ranged between 44% and 80%.

The average of E. coli resistant isolates to neomycin was 10%, to tetracycline 60%, to enrofloxacin 5%, to furazolidone 4% and to chloramphenicol 19% (Table 4).

Antimicrobial sensitivity of E. coli isolates from broilers

The average of E. coli resistant isolates to neomycin was 19, to tetracycline 74%, to enrofloxacin 22%, to furazolidone 10% and to chloramphenicol 36%.

Table 2. Used antimicrobial discs

Verwendete Resistenztest-Plättchen

<table>
<thead>
<tr>
<th>Antimicrobials</th>
<th>Code</th>
<th>Concentration of active substance</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neomycin</td>
<td>N</td>
<td>30 µg</td>
<td>Oxoid, Wesel</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>TE</td>
<td>30 µg</td>
<td>Oxoid, Wesel</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>ENR</td>
<td>5 µg</td>
<td>Oxoid, Wesel</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>C</td>
<td>50 µg</td>
<td>Oxoid, Wesel</td>
</tr>
<tr>
<td>Furazolidone</td>
<td>FR</td>
<td>50 µg</td>
<td>Oxoid, Wesel</td>
</tr>
</tbody>
</table>

Table 3. Antimicrobial sensitivity and resistance in % of E. coli isolates from turkeys

Antimikrobielle Sensitivität und Resistenz in % der E. coli – Isolate von Puten

<table>
<thead>
<tr>
<th>Years</th>
<th>% of tested strains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>1993</td>
<td>70</td>
</tr>
<tr>
<td>1994</td>
<td>63</td>
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<td>1995</td>
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<td>80</td>
</tr>
<tr>
<td>1998</td>
<td>81</td>
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<tr>
<td>Total</td>
<td>76</td>
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</tbody>
</table>

s = sensitive in %

r = resistance in %

* in 1998 FR: n = 178

** in 1998 C: n = 186

Table 4. Antimicrobial sensitivity and resistance of E. coli isolates from layers

Antimikrobielle Sensitivität und Resistenz in % der E. coli – Isolate von Legehennen

<table>
<thead>
<tr>
<th>Years</th>
<th>% of tested strains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>1993</td>
<td>81</td>
</tr>
<tr>
<td>1994</td>
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<td>1997</td>
<td>94</td>
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<tr>
<td>1998</td>
<td>96</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
</tr>
</tbody>
</table>

s = sensitive in %

r = resistance in %

* in 1998 FR: n = 178

** in 1998 C: n = 186
The percentage of resistant \emph{E. coli} strains from broilers to neomycin decreased from 24% to 8%. Resistance to tetracycline was at a very high level with an average during the entire investigation period. Resistance to enrofloxacin decreased from 35% in 1993 to 12% in 1999 but showed again some fluctuations. Similar fluctuations were observed for furazolidone and chloramphenicol (Table 5).

Table 5. Antimicrobial sensitivity and resistance of \emph{E. coli} isolates from broilers
\begin{tabular}{cccccccccc}
Years & \% of tested strains & & & & & & & & & \\
& N & T & ENR & FR & C & & & & \\
& s & r & s & r & s & r & s & r & s & r \\
1993 n = 66 & 76 & 24 & 15 & 85 & 65 & 35 & 77 & 23 & 35 & 65 \\
1994 n = 54 & 76 & 24 & 37 & 63 & 76 & 24 & 94 & 6 & 98 & 2 \\
1995 n = 65 & 69 & 31 & 18 & 82 & 77 & 23 & 83 & 17 & 45 & 55 \\
1996 n = 86 & 84 & 16 & 20 & 80 & 83 & 17 & 95 & 5 & 59 & 41 \\
1997 n = 97 & 79 & 21 & 29 & 71 & 82 & 18 & 96 & 4 & 70 & 30 \\
1998 n = 110 & 93 & 7 & 34 & 66 & 75 & 25 & 95 & 5 & 76 & 24 \\
Total n = 574 & 81 & 19 & 26 & 74 & 78 & 22 & 90 & 10 & 64 & 36 \\
\end{tabular}

s = sensitive in % & r = resistance in %

\* in 1998 FR: n = 178 & ** in 1998 C: n = 186

The percentage of resistant \emph{E. coli} strains from broilers to tetracycline was at a very high level with an average during the entire investigation period. Resistance to enrofloxacin decreased from 35% in 1993 to 12% in 1999 but showed again some fluctuations. Similar fluctuations were observed for furazolidone and chloramphenicol (Table 5).

Antimicrobial sensitivity of Salmonella isolates from turkey

Sixteen percent of tested Salmonella isolates from turkeys were resistant to neomycin, 31% to tetracycline, 2% to enrofloxacin, 9% to furazolidone and 20% to chloramphenicol. The percentage of Salmonella isolates resistant to neomycin decreased from 19% in 1993 to 5% in 1997 and increased to 42% in 1998 then started to decrease again.

Table 6. Antimicrobial sensitivity and resistance of Salmonella isolates from turkeys
\begin{tabular}{cccccc}
Years & \% of tested strains & & & & \\
& N & T & ENR & FR & C & \\
& s & r & s & r & s & r & s & r \\
1993 n = 21 & 81 & 19 & 71 & 29 & 100 & 0 & 90 & 10 & 76 & 24 \\
1994 n = 35 & 83 & 17 & 74 & 26 & 97 & 3 & 91 & 9 & 86 & 14 \\
1995 n = 37 & 89 & 11 & 65 & 35 & 100 & 0 & 95 & 5 & 84 & 16 \\
1996 n = 52 & 92 & 8 & 69 & 31 & 100 & 0 & 92 & 8 & 83 & 17 \\
1997 n = 59 & 95 & 5 & 81 & 19 & 100 & 0 & 88 & 12 & 71 & 29 \\
Total n = 294 & 84 & 16 & 69 & 31 & 98 & 2 & 91 & 9 & 80 & 20 \\
\end{tabular}

1 1998 FR: n = 77 & 2 Total ENR: n = 293 & 3 Total FR: n = 216 & 4 Total C: n = 204

Table 7. Antimicrobial sensitivity and resistance of Salmonella isolates from layers
\begin{tabular}{cccccc}
Years & \% of tested strains & & & & \\
& N & T & ENR & FR & C & \\
& s & r & s & r & s & r & s & r \\
1993 n = 35 & 100 & 0 & 94 & 6 & 100 & 0 & 91 & 9 & 100 & 0 \\
1994 n = 15 & 100 & 0 & 93 & 7 & 97 & 3 & 80 & 20 & 100 & 0 \\
1995 n = 26 & 100 & 0 & 96 & 4 & 100 & 0 & 100 & 0 & 100 & 0 \\
1996 n = 29 & 93 & 7 & 97 & 3 & 100 & 0 & 93 & 7 & 97 & 3 \\
1997 n = 29 & 100 & 0 & 66 & 34 & 97 & 3 & 93 & 7 & 90 & 10 \\
1998 n = 21 & 100 & 0 & 95 & 5 & 95 & 5 & 95 & 5 & 100 & 0 \\
Total n = 177 & 98 & 2 & 90 & 10 & 98 & 2 & 92 & 8 & 98 & 2 \\
\end{tabular}

1 Total FR and C: n = 155 & 2 n.d.: not done
Tetracycline resistance increased markedly from 29% in 1993 to 50% in 1998 and started to decrease again. The resistance to enrofloxacin remained at a very low level ranging between 1% and 8%. Resistance to furazolidone fluctuated slightly between 5% and 12%. The percentage of resistant salmonella strains to chloramphenicol varies between 14% and 29%. Since 1998 chloramphenicol was not tested anymore (Table 6).

**Antimicrobial sensitivity of Salmonella isolates from layers**

The resistance of 177 Salmonella isolates from layers to neomycin, enrofloxacin and chloramphenicol stay during the investigation period at a very low level. Resistance to tetracycline and furazolidone fluctuated between 3% and 34% and from 0% and 20%, respectively (Table 7).

**Antimicrobial sensitivity of Salmonella isolates from broilers**

The resistance of 97 Salmonella isolates from broilers to neomycin and chloramphenicol increased slightly during the investigation period. Resistance to enrofloxacin stay at a very low level. Resistance to tetracycline and furazolidone fluctuated during the entire investigation period (Table 8).

**Discussion**

There have been many reports on increasing resistance to antimicrobial drugs in animal and man especially a decrease in efficacy against *E. coli* and Salmonella (Anon, 1980; Linton, 1977; Threlfall et al., 1998). On the other hand, some authors in different countries reported on no increase of antibiotic resistance. Murray et al. (1986) found in Australia from 1975 to 1982 in Salmonella isolates from bovine, porcine and avian sources no change of the overall level of antimicrobial resistance. Furthermore, no increase of antibiotic resistance in *E. coli* isolates of agriculture animals from UK during 1971–1977 could be observed (Jackson, 1981).

In central Europe (Germany, Austria, Switzerland) Kerksen and Wiedemann (1986) investigated the development of resistance in human bacterial isolates collected between 1975 and 1984. They observed in none of the bacterial species tested an increase in the number of resistant strains including *E. coli* and *Salmonella* spp. Also Atkinson and Lorian (1984) investigated the antimicrobial susceptibility of 242 bacterial strains isolated in U.S. hospitals. Throughout the 12-year period from 1971–1982 *E. coli* strains as well as *Staphylococcus aureus*, *Haemophilus influenzae* and *Pseudomonas aeruginosa* had the same susceptibilities to antibiotics.

With regard to the continuing discussion about resistance of antimicrobials in humans influenced of antimicrobials used in animals, in the U.K. the application of antibiotics in animals was very early regulated by the Swann report (Anon, 1969) with the aim not to lose sensitivity of antimicrobials in humans. Nevertheless there is continuing concern that excessive use of chemotherapy agents will inevitably lead to the development of resistance, especially where zoonotic organisms are concerned and where related agents are used for treatment in human infections. However, prohibition of an antimicrobial agent does not necessarily lead to a dramatic reduction in the prevalence of resistance to that drug (Wooley et al., 1996). A survey in the U.K. conducted in 1980 from Smith and Lovell (1984) indicates that table chickens were still a large reservoir of tetracycline-resistant *E. coli* although the use of tetracyclines as feed additive was prohibited in the U.K. in 1977.

In the present survey the resistance of *E. coli* strains to individual antibiotics differ markedly from resistance of Salmonella strains. The results are in agreement with those described by Soika and Hudson (1976). However, it is difficult to compare the results of in vitro antimicrobial sensitivity tests obtained from different countries and different regions within one country because patterns of antibiotic resistance vary regional and are variable depending on therapeutic medication and have been related to the usage of a particular drug. For instance, in countries where neomycin is widely used in the treatment of calves the frequency of occurrence of resistant strains of *E. coli* to this drug is high (Loken et al., 1971) compared with other countries, e.g. Sweden, where the drug is used much less (Wierup, 1975). Furthermore available monitoring and statistics are based on mixed evaluation of antimicrobial resistance of isolates from clinical cases and from animal food products. Laboratory methods used for the detection of resistance are disc diffusion test and minimal inhibitory concentration. Disc methods are widely used, however, there are great variations in the antimicrobial concentrations and the bacterial counts between laboratories. Nevertheless comparison of the antimicrobial resistance of *E. coli* strains isolated from turkeys in 1993 and 1994 in

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**Table 8. Antimicrobial sensitivity and resistance of Salmonella isolates from broilers**

*Antimikrobielle Sensitivität und Resistenz in % der Salmonellen Isolate von Masthähnchen*

<table>
<thead>
<tr>
<th>Years</th>
<th>% of tested Strains</th>
<th>N</th>
<th>T</th>
<th>ENR</th>
<th>FR</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>s</td>
<td>r</td>
<td>s</td>
<td>r</td>
<td>s</td>
<td>r</td>
</tr>
<tr>
<td>1993 n = 11</td>
<td>100</td>
<td>0</td>
<td>91</td>
<td>9</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>1994 n = 9</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>89</td>
<td>11</td>
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<td>1995 n = 20</td>
<td>100</td>
<td>0</td>
<td>45</td>
<td>55</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>1996 n = 28</td>
<td>89</td>
<td>11</td>
<td>68</td>
<td>32</td>
<td>96</td>
<td>4</td>
</tr>
<tr>
<td>1997 n = 16</td>
<td>88</td>
<td>12</td>
<td>88</td>
<td>12</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>1998 n = 9</td>
<td>78</td>
<td>22</td>
<td>78</td>
<td>22</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>1999 n = 4</td>
<td>75</td>
<td>25</td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Total n = 97</td>
<td>90</td>
<td>10</td>
<td>74</td>
<td>26</td>
<td>98</td>
<td>2</td>
</tr>
</tbody>
</table>

1 Total FR and C: n = 93
2 n.d.: not done
this study was in agreement with the results of Trolle-Deni er (1996). The results of the National Laboratory (NL), Berlin, and the Chemical and Veterinary Laboratory (CVUA), Stuttgart, show nearly the same percentage of resistance to neomycin, tetracycline, enrofloxacin and chloramphenicol (Table 9). Notwithstanding to correctly estimate the development of the antimicrobial resistance in an area, the comparison of the results within one lab seem to be, currently the most suitable method. However, for comparison between laboratories quality assurance and ring-trials are necessary.

In this investigation the resistance of Salmonella strains to antimicrobials is at a very low level and show no trend to increase except for tetracycline. However, recently several reports on the significant increase of antimicrobial resistance of Salmonella isolated from turkeys in U.K. were published (Wray et al., 1990). In 1997 Salmonella isolated from turkeys in Great Britain showed a high level of resistance to nalidixic acid. 31.1% salmonella isolates other than Salmonella typhimurium (S. typhimurium), 72.7% of S. typhimurium other than DT 104 and 78.3% of S typhimurium DT 104 were resistant to nalidixic acid (Davies et al., 1999).

Although the use of furazolidone and chloramphenicol in the European Union is not allowed since 1994 and 1995 respectively, some resistant E. coli and Salmonella strains could be observed. Nevertheless resistance of E. coli and Salmonella to furazolidone decrease gradually. On the other hand, the resistance to enrofloxacin remained mostly at the same level. The resistance to quinolones which is determined chromosomally by a mutation in the gyrA gene (Griggs et al., 1994) and to furazolidone which resistance is also encoded in the chromosome and is therefore non-transmissible. The chromosomally-encoded resistance is more stable than plasmid-mediated resistance and so is likely to persist even if selective pressure is withdrawn (Threlfall et al., 1994).

Resistance of gram-negative bacteria to chloramphenicol and tetracycline is mostly encoded in transmissible R-plasmids. Antibiotics which promote plasmid mediated resistance lead to a very gradual reduction in incidence of resistance if their use is ceased (Smith and Lovell, 1981), since antibiotics encoding resistance in plasmids can confer resistance to all the antibiotics encoded in that plasmid. For example exposure to chlorotetracycline can confer resistance to other antibiotics including chloramphenicol (Anon, 1980). In this investigation turkey E. coli and Salmonella isolates indicated a very high level of resistance to tetracycline.

In conclusion the results of this study show that the resistance of E. coli and Salmonella strains to tetracycline is at a high level and tends to increase. Consequently the use of tetracycline should be only applied for therapeutic purposes after an accurate diagnosis and after testing of resistance in vitro. Furthermore tetracycline should be used at accurate dose level and for sufficient duration.

Fighting the problem of antibiotic resistance will require a better, more co-ordinated system of surveillance, as well as an increased effort to prolong the effectiveness of existing antibiotics and to develop new classes of antibiotics for both the medical and veterinary communities. According to Wise and Soulsby (2002) surveillance must be the basis of action and not, as is so often the case, an expensive end in itself. Such surveillance need to be constructed to answer specific questions. Finally, it will never be possible to stop the development of resistance entirely, but limiting the problem is realistic. In addition, forbid the use of antimicrobial in farm animals will result in increasing the incident of infectious diseases, which could increase public health risks and lead to higher demand for antibiotics to treat sick animals. In addition, prevention methods including vaccines and improvement of the management in poultry houses should be paid continuous attention.

Summary

The present investigation was carried out to detect the development of antimicrobial resistance of E. coli and Salmonella isolated from commercial turkeys, layers and broilers in the State of Baden-Württemberg between 1993 and 1999 to neomycin, tetracycline, enrofloxacin as well as furazolidone and chloramphenicol. The use of last both antibiotics is not allowed in EU since 1994 and 1995, respectively. Totally 2097 E. coli and 568 Salmonella isolates were tested in vitro using disc diffusion technique.

The results obtained by testing E. coli strains revealed that there is some gradual decrease in the resistance to neomycin from 1993 to 1999. Similar decrease could also be observed with furazolidone and chloramphenicol. On the other hand the percentage of resistant isolates to tetracycline was high increased in turkeys from 1993 till 1998. In turkeys the resistance of E. coli to enrofloxacin showed a slight increase from 14% in 1993 to 32% in 1995 and 1996 and a decrease in 1998 to 17%. In total the percentage of resistant isolates was in turkeys 21%, in broilers 22% and in layers 5%.

Nearly all of the examined salmonella isolates were sensitive to enrofloxacin (98%). On the other hand there is a gradual increase in the resistance to neomycin and tetracycline. The percentage of resistant isolates from turkeys to chloramphenicol was 20%, from layers 2% and from broilers 6%. The resistance to furazolidone remained at the same level ranged between 8 and 10%.

Keywords
E. coli, Salmonella, antimicrobial resistance, Poultry

Zusammenfassung

Untersuchungen zur der Resistenzentwicklung von Escherichia coli und Salmonella Isolaten aus Geflügel im Untersuchungszeitraum 1993 bis 1999

Ziel der in der Zeit von 1993 bis 1999 durchgeführten Untersuchung ist die Entwicklung der Resistenzsituation bei E. coli und Salmonella Isolaten von Mastputen, Legehennen und Broilern in Baden-Württemberg gegenüber 5 gebräuchlichen Antibiotika (Neomycin, Tetracyklin, Enrofloxacin, Chloramphenicol und Furazolidon) festzustellen. Der Einsatz von Furazolidon und Chlo-

<table>
<thead>
<tr>
<th>Drug</th>
<th>1993</th>
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<tbody>
<tr>
<td></td>
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<td>CVUA</td>
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<tr>
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</tr>
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</tbody>
</table>

Table 9. Comparison of the results of antimicrobial resistance (\%) of E. coli


Stichworte

E. coli, Salmonella, Resistenzenentwicklung, Geflügel

References


JODAS and HAFEZ, Surveillance on antimicrobial resistance in Escherichia coli and Salmonella isolates 21

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