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Investigation of antimicrobial resistance of ESβL, Amp-C, and carbapenemase-producing *E. coli* strains in retail poultry meats

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Abstract: Antimicrobial agents are used for suppressing some bacterial infections during the rearing of poultry. In this study; the antibiotic resistance properties of Extended Spectrum βeta-lactamase (ESβL), Amp-C, carbapenemase-producing *Escherichia coli* (*E. coli*) strains isolated from chicken breast meat were determined by disc diffusion and E-test methods. Additionally, it is aimed to determine antibiotic resistance genes by classical polymerase chain reaction (PCR). In this context, *E. coli* strains were isolated from 7 of 100 chicken breast meat (fillets) and identified by a rapid identification system (BBL Crystal). Disc diffusion test results of the isolates were evaluated and 100% to tetracycline; ampicillin, ciprofloxacin, cefoxitin, nalidixic acid, oxytetracycline 85.7%; ceftazidime, cefotaxime and meropenem 28.5%; chloramphenicol 71.4%, trimethoprim/sulfamethoxazole 42.8%; 14.2% resistance to gentamicin was observed. Test results of the isolates were evaluated and ESβL activity was found in 2 isolates in the disc diffusion test. Amp-C and carbapenemase activity was detected in 6 isolates in disc diffusion, in all isolates in E-test; 2 isolates in disc diffusion were detected carbapenemase activity, while carbapenemase activity was not detected in E-test, respectively. Classical PCR was performed after the DNAs were isolated for the detection of antibiotic resistance genes. According to classical PCR results; ESβL activity was detected in all isolates; carbapenemase activity was positive in only 1 isolate, while Amp-C activity was positive in 4 isolates. *CTXM-1* (71%) and *SHV1* (71%), *OXA-1* (42.8%), *CTXM-9* (28.5%), and *TEM* (14.2%) were detected by classical PCR, respectively. It has been concluded that *E. coli* isolated from poultry meat collected from the market may pose a risk in terms of ESβL, Amp-C, and carbapenemase genes, and continuous monitoring is required in this regard.

Key words: Antimicrobial resistance, Amp-C, carbapenemase, *E. coli*, ESβL

1. Introduction

Escherichia coli (E. coli) infections are one of the common infections in poultry farming. In poultry, *E. coli* causes various diseases such as colisepticemia, hemorrhagic septicemia, coligranuloma, air sac inflammation, coligranuloma, swollen head syndrome, and enteritis [1]. Excessive and unconscious use of antibiotics creates antimicrobial resistance in both humans and animals. Antimicrobial resistance creates negative consequences for the animal and the treating physician [2]. However, it may not provide the success required for it to be frozen. Antimicrobial resistance in patients is as important as the least disease factor and causes high mortality and morbidity [3]. Multi-drug resistance emerges when the microorganism that becomes resistant to any antibiotic develops resistance to many antimicrobial agents in the process, and this adversely affects the treatment time and cost [4,5].

ESβL, Amp-C, and carbapenemase enzymes produced by some *E. coli* strains pose a great risk to public health [6,7]. Beta-lactamase enzymes that can be produced by *E. coli* and other Gram-negative bacteria are defined as beta-lactamases capable of hydrolyzing penicillins, broad-spectrum cephalosporins and monobactams and are inhibited by clavulanic acid. These features distinguish ESβLs from Amp-C-type β-lactamase which is another group of enzyme isolated from broad-spectrum cephalosporin-resistant Gram-negative bacteria [8]. ESβL genes are mostly associated with plasmids and, thanks to this feature, they can also transfer genes to other bacteria. For this reason, antimicrobial resistance can spread and the carrier bacteria do not need to be pathogenic for this. The most known ESβL enzyme genes are *TEM*, *SHV*, and *CTX-M* [9,10].

Carbapenems are a member of the beta-lactam class [1]. In recent years, it has been used against infections caused by bacteria that produce ESβL and Amp-C, and it brings along the development of resistance. Carbapenems are a powerful group of antibiotics that can be used if

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ESβL-producing *Enterobacteriaceae* species have not improved after trying other options, especially in multi-drug resistant (MDR) *Enterobacteriaceae* [11].

Amp-C beta-lactamases are cephalosporins found in many *Enterobacteriaceae* such as *E. coli*. It also suppresses cefazolin, cefoxitin, cephalothin, and beta-lactams; it is resistant to beta-lactam-beta-lactamase inhibitory combinations and many penicillin derivatives [12]. Amp-C is of chromosomal and plasmid origin; the plasmid-derived group does not show inducibility [13]. Amp-C and beta-lactamase genes in plasmids are divided into 6 families: they are encoded as *ACC, CIT, DHA, EBC, FOX*, and *MOX* [14]. Plasmid-derived Amp-C-type beta-lactamases are particularly associated with ESβLs [15,16].

In this study; the antibiotic resistance properties of ESβL, Amp-c, and Carbapenemase-producing *E. coli* strains isolated from chicken breast meat of different brands sold in the markets were determined by disc diffusion and E test. It is aimed to determine antibiotic resistance genes by PCR.

2. Material and methods

2.1. Samples

A hundred samples of chicken fillets, which are known to be grown in different flocks, belonging to two different brands offered for retail sale in Ankara and Kırıkkale provinces, were taken and sent to the laboratory for examination by the cold chain.

2.2. Isolation and identification

Twenty-five g sample, at a ratio of 1/10, was taken into 225 mL Buffered Pepton Water (BPW) in the stomacher bag under aseptic conditions and incubated at 37 °C for 18–22 h. The preenriched samples were inoculated on Mac Conkey Agar containing meropenem to observe the carbapenemase activity at 0.5 µg/mL. Petri dishes were incubated for 18–22 h at 44 °C. Likewise, Mac Conkey Agar containing cefotaxime (CTX) was incubated at 44 °C for 18–22 h. It was then passaged 3 times on Mac Conkey Agar as suggested by the method until colonies of *E. coli* were seen; according to the most recent version of the "Protocol for Selective Isolation of Presumptive ESBL-, Ampc- and Carbapenemase-Producing *E. coli* from Meat and Caecal Samples" by European Union Reference Laboratory-Antimicrobial Resistance (EURL-AR) [17]. With the BBL Crystal Rapid Identification System, 16 suspicious isolates with typical *E. coli* characteristics were identified. It was incubated for 18–22 h at 37 °C and identified with a kit suitable for Enteric-Non fermentative bacteria.

2.3. Disc diffusion and E-test

Isolates were passaged into Nutrient Agar; a disc diffusion test for antimicrobial resistance testing and E-test to determine the minimal inhibition concentration (MIC) were used. For the disc diffusion test, the agars were incubated at 37 °C for 18–22 h; the resulting zone diameters were measured and evaluated according to EUCAST and CLSI [18,19]. *E. coli* ATCC 25922 strain was used as the positive control. Tetracycline, chloramphenicol, oxytetracycline , ceftazidime, ceftazidime/clavulanic acid, cefotaxime, cefotaxime/clavulanic acid, gentamicin, meropenem, ciprofloxacin, cefoxitin, ampicillin, nalidixic acid, trimethoprim/sulfamethoxazole antibiotic discs were used for disk diffusion test; meropenem, cefotaxime, cefotaxime/clavulanic acid, ceftazidime, ceftazidime/clavulanic acid, imipenem, colistin, cefoxitin E-test strips were used for E-test. In the disc diffusion test, ESβL is considered positive if the zone difference between CTX and CTX-CLA and CAZ and CAZ-CLA combinations is 5 mm or more. The resistance to FOX shows the positivity of Amp-C activity; the resistance to meropenem or imipenem shows the positivity of carbapenemase activity. The resulting MIC was measured and evaluated to ECOFF values (mg/L) according to EUCAST [18].

2.4. Molecular methods

For PCR, DNA extraction was performed from positive samples. For extraction; one colony from 7 positive isolates was taken and suspended in 100 µL sterile distilled water. The tubes were kept at 95 °C for 10 min and then centrifuged at 10,000 rpm for 2 min. Supernatants were taken into sterile Eppendorf tubes. The amounts of DNA obtained by nano-drop spectrophotometer were measured as ng/mL. Genes used to determine ESβL activity: *CTXM-9*, *CTXM-1*, *SHV*, *TEM*, *OXA-1*; genes used for Amp-C: *FOX* and genes used for carbapenemases: *OXA-48*, *IMP*, *VIM*, *KPC*, *NDM-1*. For classical PCR; 12.5 µL master mix, 1 µL DNA, 5 µL primer, and 6.5 µL sterile distilled water were prepared in an Eppendorf tube with a total volume of 25 µL. In conventional PCR: 10 min at 94 °C; 30 cycles at 94 °C for 40 s, at 60 °C for 40 s, at 72 °C for 1 min; 7 min at 72 °C protocol was applied [20].

After PCR amplification, 1% agarose was prepared for the agarose gel. DNAs were run at 100 Volts for 1 h. The formed bands were evaluated for ESβL, Amp-C and carbapenemase activity under UV light [20].

3. Results

3.1. Isolation and identification results

In our study, resistant 7 isolates from 100 chicken breasts were identified as *E. coli* by the method recommended by EURL-AR. Samples positive for *E. coli* are S78, S68, S49, S42, S9, B6, B8.

3.2. Disc diffusion test results

Multidrug resistance (MDR) was also observed in all isolates. Mostly, multiple resistance is in the form of S42 and S78 (10 antibiotics). Disc diffusion test results of the

isolates were evaluated and 100% resistance to tetracycline; 85.7% to ampicillin, ciprofloxacin, cefoxitin, nalidixic acid and oxytetracycline; 28.5% to ceftazidime, cefotaxime and meropenem; 71.4% to chloramphenicol; 42.8% to trimethoprim/ sulfamethoxazole; 14.2% to gentamicin was observed. There is resistance to tetracycline in all 7 strains. Two of the 7 *E. coli* isolates were positive for ESβL. Six isolates were resistant to cefoxitin and they were evaluated for Amp-C actitivies; two isolates (S42 and S78) were resistant to meropenem and they were evaluated as positive for carbapenemase activity. Disc diffusion distributions for *E. coli* (ECOFF) according to EUCAST 2022 (R or S/ESβL/Amp-C/Carbapenemase activity) are given in Table 1.

3.3. E-test results

Among 7 *E. coli* isolates, 1 was positive for ESβL and all were positive for Amp-C activity. Since all isolates were sensitive to meropenem, they were evaluated as negative of carbapenemase activity. When we evaluated the TZ-CLA and CAZ-CLA combinations, only the S68 isolate was ESβL positive. MIC distributions for *E. coli* (ECOFF) according to EUCAST (MIC/R or S/ ESβL/Amp-C/ Carbapenemase activity) are given in Table 2.

3.4. PCR Results

All 7 isolates were observed as positive for ESβL genes in classical PCR. In classical PCR, ESβL genes were used as *SHV*, *OXA-1*, *CTXM-9*, *CTXM-1* and *TEM* genes; *SHV*, *OXA-1*, *CTXM-9* and *CTXM-1* genes were positive in the S9 isolate; *CTXM-1* and *OXA-1* genes were positive in the B6 isolate; All ESβL genes were evaluated as positive in the S68 isolate. The genes *CTXM-1* for the S42, *SHV* for S78, and *SHV* and *CTXM-1* for S49 were observed as positive. *CTXM-1* and *OXA-1* genes in isolate B6; *SHV* genes in B8 isolate were observed positive. *CTXM-1* (71%) and *SHV1* (71%), *OXA-1* (42.8%), *CTXM-9* (28.5%), and *TEM* (14.2%) were detected most, respectively. ESβL activity was detected in all isolates; S68, S78, S9, and B6 isolates (57.1%) were positive for Amp-C activity. No positivity was observed in S68, S78, S42, S9, B6, B8 isolates against carbapenemase genes. In the S49 isolate, positivity is observed in all *NDM*, *OXA-48*, *IMP*, *VIM* and *KPC* genes, respectively, placed in carbapenemase activity. Evaluation of ESβL, Amp-C and carbapenemase genes with PCR, are given in Table 3.

When three different methods used in this study were compared for antimicrobial resistance, generally different results were obtained. The Amp-C activity was detected in partially close results. A comparison of three methods of antimicrobial resistance properties is given in Table 4.

4. Discussion

Food-borne antimicrobial resistance is increasing in many countries and is an important problem. Countries follow

Table 1. Disc diffusion distributions for *E. coli* (ECOFF) according to EUCAST 2022 (R or S/ESβL/Amp-C/carbapenemase activity).

E.coli isolates	TE*	C*	OT*	TAZ	T/C	FOT	F/C	GM	MP	CIP	FOX	AM	NA	SXT
S9	R	R	R	S	S	S	S	R	S	R	R Amp-C	R	R	R
S42	R	R	R	R ESβL	S	R	S	S	R Carba	R	R Amp-C	R	R	S
S49	R	S	R	S	S	S	S	S	S	R	R Amp-C	R	R	R
S68	R	R	R	S	S	S	S	S	S	R	S	R	R	S
S78	R	R	R	R ESβL	S	R	S	S	R Carba	R	R Amp-C	R	R	S
B6	R	R	R	S	S	S	S	S	S	R	R Amp-C	R	R	R
B8	R	S	S	S	S	S	S	S	S	S	R Amp-C	S	S	S

*CLSI, R: Resistance, S: Sensitive, TE: Tetracycline, C: Chloramphenicol, OT: Oxytetracycline, T/C: Ceftazidime-clavulanic Acid, TAZ: Ceftazidime, FOT: Cefotaxime, F/C: Cefotaxime-clavulanic acid, GM: Gentamicin, MEM: Meropenem, CIP: Ciprofloxacin, FOX: Cefoxitin, AM: Ampicillin, NA: Nalidixic acid, SXT: Trimethoprim/sulfamethoxazole, Amp-C: AmpC βeta lactamases activity, Carba: Carbapenemase activity, ESβL: Extended Spectrum Beta-lactamase activity.

Table 2. MIC distributions for *E. coli* (ECOFF) according to EUCAST (MIC/R or S/ ESβL/Amp-C/Carba).

***E. coli* Isolates**	**E-test results (MIC/R or S/ ESβL/Amp-C/Carba**							
	FOT >0.25	**F/C >0.25**	**TAZ >0.5**	**T/C >0.5**	**FOX >0.125**	**MERO >0.125**	**IMI >0.5**	**CO >2**
S9	0.19/S	-	0.38/S	-	8/R Amp-C	0.064/S	0.19/S	0/S
S42	0/S	-	0/S	-	12/R Amp-C	0.047/S	0.125/S	0/S
S49	0.125/S	-	0.38/S	-	24/R Amp-C	0.064/S	0.19/S	0/S
S68	25/R	25/0.23 ESBL	50/R	50/0.64 ESBL	8/R Amp-C	0.064/S	0.125/S	0/S
S78	0/S	-	0/S	-	32/R Amp-C	0.094/S	0.19/S	0/S
B6	0/S	-	0/S	-	128/R Amp-C	0.064/S	0.19/S	0/S
B8	0.19/S	-	0.5/S	-	1.5/R Amp-C	0.032/S	1.9/R	0/S

R: Resistance, S: Sensitive, MP: Meropenem, FOT: Cefotaxime, TAZ: Ceftazidime, IPM: Imipenem, CO: Colistin, FOX: Cefoxitine, F/C: Cefotaxime-clavulanic acid, T/C: Ceftazidime-clavulanic acid, ESβL: Extended Spectrum βeta-lactamase activity, Amp-C: AmpC βeta lactamases activity, Carba: Carbapenemase activity.

Table 3. Classical PCR, ESβL, Amp-C, and carbapenemase genes in terms of isolates evaluation.

***E. coli* Isolates**	ESβL genes					Amp-C gene	Carbapenemase genes				
	CTX M1	CTX M9	SHV	TEM	OXA1	FOX	NDM	OXA 48	IMP	VIM	KPC
S9	+	+	+	-	+	+	-	-	-	-	-
S42	+	-	-	-	-	-	-	-	-	-	-
S49	+	-	+	-	-	-	+	+	+	+	+
S68	+	+	+	+	+	+	-	-	-	-	-
S78	-	-	+	-	-	+	-	-	-	-	-
B6	+	-	-	-	+	+	-	-	-	-	-
B8	-	-	+	-	-	-	-	-	-	-	-

ESβL: Extended Spectrum βeta-lactamase, Amp-C: AmpC βeta lactamases, +: Positive, -: Negative.

antimicrobial resistance by making their own monitoring programs. For this purpose, many studies are carried out in poultry meat.

In a study conducted in Germany, chicken cecum and carcass samples were taken from two different farms. The *CTX-M* gene was found to be 87% positive, the *TEM* gene 27%, and the *SHV* gene 47% positive. As a result, ESβL was positive in 88% of 70 carcasses and Amp-C was positive in 52.9% [21]. In our study, ESβL genes in all isolates; CTX-M genes found to be 50% that was less than the study in Germany, and Amp-C genes were detected to be 57% which was similar.

In addition, antimicrobial resistance genes of Asian, African and Latin American countries have been stated to

Table 4. Comparison of three methods of antimicrobial resistance properties.

E. coli isolates names	DD	E-TEST	PCR
S9	Amp-C	Amp-C	ESβL +Amp-C
S42	ESβL+Amp-C	Amp-C	ESβL
S49	Amp-C	Amp-C	ESβL
S68		ESβL+ Amp-C	ESβL +Amp-C
S78	ESβL+Amp-C	Amp-C	ESβL +Amp-C
B6	Amp-C	Amp-C	ESβL +Amp-C
B8	Amp-C	Amp-C	ESβL

ESβL: Extended Spectrum βeta-lactamase activity, Amp-C: AmpC βeta lactamases activity, Carba: Carbapenemase activity, DD: Disc diffusion , PCR: Polymerase chain reaction

act as a reservoir for the spread of resistant genes around the world. It has been reported that the rate of strains developing MDR among *E. coli* strains producing ESβL is more than 80%. When carbapenem resistance was reviewed in Europe, resistance was found ranging from 3% to 50% in the region from the Netherlands to Greece [22]. In our study, MDR was detected in all of the isolates and the carbapenemase genes were detected only one isolate. A study conducted in the Netherlands in 2012, it was aimed to determine the incidence of *E. coli* and *Klebsiella pneumoniae* (*K. pneumoniae*) from ESβL and Amp-C producing bacteria in chicken meat, vegetables, fruits, meat, and seafood from other countries. Of the 200 samples, 14 were positive for *E. coli* and *K. pneumoniae* producing ESβL and Amp-C [23]. Our results of *E. coli* producing ESβL and Amp-C were consistent with the work in the Netherlands. A different study conducted in the Netherlands found that the rate of *E. coli* producing ESβL in 68 chicken meat is 76.8%; had the highest prevalence [24]. In our study, *E. coli* producing ESβL was found in all isolates.

According to a study conducted in Sakarya and İstanbul, ESβL was found positive in 75 isolates and *E. coli* was the most common *Enterobacteriaceae* agent with 68.8%. ESβL and Amp-C were found positive in 10 isolates, and 7 of them were reported to belong to *E. coli*. The number of samples positive for Amp-C was 5; no positivity of *E. coli* was detected. It was also emphasized that these results were similar to Belgium, Germany, China, Netherlands, Denmark, and Poland worldwide [2]. In our study, the rate of *E. coli* producing ESβL and Amp-C were found to be higher.

When we look at the studies conducted in other countries, in a study conducted in the Netherlands, *E. coli* producing ESβL was detected to be 76.8% in chicken meat samples [24]. In addition, the most common ESβL gene was *CTXM-1* with 58%. Again in the Netherlands, at least one type of *E. coli* producing ESβL was detected in 92% of the samples; while the prevalence of the *CTXM-1* gene is 56% in chicken meat produced [25]. In our study, *E. coli* producing ESβL was seen in 7 isolates (71%) according to PCR test results, and the most common genes were the *CTXM-1* gene which was parallel with both studies, and *SHV* gene that was aside from the studies.

In the study conducted with humans and poultry materials, the rate of *E. coli* producing ESβL found to be 29% in broilers [26]; in our study, this rate was determined as 7%. *CTXM-1* was detected as a common gene in both human and avian rectal samples and showed parallel results with many studies.

Among the 283 isolates collected from Bolu Province and its surroundings in Turkey, 135 samples belonged to chicken meat, and the presence of ESβL producing *E. coli* was investigated. As a result of the analysis, the *TEM* gene was found as the *E. coli* gene that produces ESβL in 114 (84.4%) of 135 samples. In the mentioned study, the *CTXM* gene was not detected in any isolate, which is inconsistent with our study. In our study, we detected *CTXM-1* and *SHV* genes the most [27].

In a study, *E.coli* was isolated from a total of 55 isolates, including 29 from chicken meat, 24 from raw milk, and 2 from cheese. In these isolated *E. coli* strains, the most dominant gene was determined as *CTXM*, which was not in parallel with our study, and *TEM* was the following gene, which was consistent with this study [28].

In a study conducted to test the presence of ESβL producing *E. coli*, 100 chicken meat and 100 beef samples were collected from the markets as frozen or chilled. It was determined that 82 of 100 chicken meat samples were *E. coli* resistant to cefotaxime and produced ESβL. In terms of ESβL genes, 81 of 82 isolates were positive.

It has been reported that there is a positive correlation between the *CTX-M* gene and the presence of ESβL. In this study, all isolates were susceptible to imipenem; in our study, the sensitivity of all isolates to meropenem is also an indication that the isolates are negative for carbapenemase activity. On the other hand, with the presence of *CTXM-1* or *CTXM-9* genes in ESβL positive isolates, detected by classical PCR in our study, it has been confirmed that the isolates can be evaluated positively of ESβL, in other words, there is a positive correlation between them [29].

Internal organs were removed from 135 broilers with colibacillosis aged 16-41 days in a commercial poultry farm disease diagnostic laboratory. It was confirmed by molecular methods that 112 materials contained *E.coli*. The isolates were subjected to the disk diffusion test against 7 different antibiotics. In the study, 64.3% of the isolates showed multidrug resistance [30]. In our study, all isolates had multidrug resistance.

In the study of Önen et al. (2015) on poultry meat in Turkey, the resistance of tetracycline and nalidixic was found to be very close to our study results; they reported that retail raw chicken meat has a high rate of ESβL producing *E. coli*, which poses a risk to human health in Turkey [31].

Poultry meat, which is preferred as an easily accessible protein source, carries antimicrobial resistance genes and poses a risk in terms of public health as these genes can transfer to humans. As in the world, there is a high rate of multiple resistance in poultry meat in our country. In addition to multiple resistance, *E. coli* isolates with ESβL, Amp-C, and carbapenemase activities phenotypically and genotypically were also detected. When the resistance genes were examined alone, it was determined that the highest prevalence belonged to the *CTXM-1* and *SHV* genes, in line with other countries. In this study, when disc diffusion, E-test, and PCR results were compared, inconsistent results were obtained. Monitoring of poultry meat in terms of ESβL, Amp-C and carbapenemase activity and implementation of control programs are necessary for monitoring antibiotic resistance.

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References

1. Başaran S, Korten V. Doripenem: A new carbapenem in clinical practice. A review. Klimik Journal 2010; 23 (1): 2-5. doi: 10.5152/kd.2010.02
2. Özpınar H, Tekiner IH, Sarıcı B, Çakmak B, Gökalp F et al. Phenotypic characterization of ESBL and AmpC- type betalactamases in Enterobacteriaceae from chicken meat and dairy products. Veterinary Journal of Ankara University, 2017; 64 (4): 267- 272. doi: 10.1501/Vetfak_0000002809
3. Owens RC. Antimicrobial stewardship: concepts and strategies in the 21st century, Diagnostic Microbiology and Infectious Disease 2008; 61 (1): 110-128. doi: 10.1016/j.diagmicrobio.2008.02.012
4. Rowe B, Ward LR, Threlfall EJ. Multidrug-resistant Salmonella typhi: a worldwide epidemic. Clinical Infectious Diseases 1997; 24 (Suppl 1): 106-109. doi: 10.1093/clinids/24.supplement_1. s. 106
5. Levin BR, Lipsitch M, Perrot V, Schrag S, Antia R et al. The population genetics of antibiotic resistance. Clinical Infectious Diseases 24 (Suppl 1) 1997; 24 Suppl 1: 9-16. doi: 10.1093/clinids/24.supplement_1. s. 9
6. European Food Safety Authority. Scientific Opinion on the public health risks of bacterial strains producing extended-spectrum β lactamases and/or Amp-C β-lactamases in food and food-producing animals in 2011. EFSA Journal 2011; 9 (8): 2322. doi: 10.2903/j.efsa.2011.2322
7. European Food Safety Authority. Scientific Opinion on Carbapenem resistance in food animal ecosystems in 2013. EFSA Journal 2013; 11 (12): 3501. doi: 10.2903/j.efsa.2013.3501
8. Rupp M, Fey P. Extended Spectrum β-Lactamase (ESBL)-Producing Enterobacteriaceae. Drugs 2003; 63 (4): 353-365. doi: 10.2165/00003495-200363040-00002
9. Paterson DL, Bonomo RA. Extended spectrum beta-lactamases: A clinical update. Clinical Microbiology Reviews 2005; 18 (4): 657-686. doi: 10.1128/CMR.18.4.657-686.2005
10. Cantón R, Coque TM. The CTX-M beta-lactamase pandemic. Current Opinion Microbiology 2006; 9: 466-475. doi: 10.1016/j.mib.2006.08.011
11. Nordmann P, Naas T, Poirel L. Global spread of carbapenemase-producing Enterobacteriaceae. Emerging Infectious Diseases 2011; 17: 1791-1798. doi: 10.3201/eid1710.110655
12. Jacoby GA. Amp-c β Laktamases. Clinical Microbiology Reviews 2009; 22 (1): 161-82. doi: 10.1128/CMR.00036-08
13. Mezzatesta ML, Gona F, Stefani S. Enterobacter cloacae complex: clinical impact and emerging antibiotic resistance. Future Microbiology 2012; 7: 887- 902. doi: 10.2217/fmb.12.61
14. Pehlivanoğlu, F. Gram Negatif Bakterilerin Beta-Laktamaz Enzim Çeşitliliği ve Türkiye'deki Hayvan Orjinli Bakterilerdeki Durum. Fırat Üniversitesi Sağlık Bilimleri Veteriner Dergisi 2019; 33 (2): 113-122.

15. Fadare FT, Adefisoye MA, Okoh AI. Occurrence, identification and antibiogram signatures of selected Enterobacteriaceae from Tsomo and Tyhume rivers in the Eastern Cape Province, Republic of South Africa. PLoS One. 2020; 15 (12): 1-27. doi: 10.1371/journal.pone.0238084

16. Thomson KS. Extended-spectrum-beta-lactamase, AmpC, and Carbapenemase issues. Journal of Clinical Microbiology 2010; 48 (4): 1019-1025. doi: 10.1128/JCM.00219-10

17. Protocol for selective isolation of presumptive ESBL-, Amp-C and carbapenemase-producing Escherichia coli from meat and caecal samples.

18. The European Committee on Antimicrobial Susceptibility Testing (EUCAST) European Society Clinical Microbiology and Infectious Diseases. MIC and zone diameter distributions and ECOFFs. 2022.

19. Clinical and Laboratory Srandards Instıtute. M100 Performance Standards for Antimicrobial Susceptibility Testing, 32nd Edition.

20. Dallenne C, Costa A, Decre D, Favier C, Arlet G. Development of a set of multiplex PCR assays for the detection of genes encoding important b-lactamases in Enterobacteriaceae Journal Antimicrobial Chemotherapy 2010; 65: 490- 495. doi: 10.1093/jac/dkp498

21. Reich F, Atanassova V, Klein G. Extended-Spectrum ß-Lactamase– and Amp-C-Producing Enterobacteria in Healthy Broiler Chickens, Germany. Emerging Infectious Diseases 2013; 19 (8): 1253- 1259. doi: 10.3201/eid1908.120879

22. Theuretzbacher U. Global antibacterial resistance: The never-ending story. A review. Journal of Global Antibacterial Resistance 2013; 1 (2): 63-69. doi: 10.1016/j.jgar.2013.03.010.

23. Kurittu P, Khakipoor B, Jalava J, Karhukorpi J, Heikinheimo A. Whole-genome sequencing of Extended-Spectrum Beta-Lactamase-Producing *Escherichia coli* from human infections in Finland revealed isolates belonging to international successful ST131-C1-M27 subclade but distinct from non-human sources. Frontiers in Microbiology 2022; 12: 1-16. doi: 10.3389/fmicb.2021.789280

24. Overdevest I, Willemsen I, Eustace MA, Xu L, Hawkey P et al. Extended-Spectrum β-Lactamase Genes of *Escherichia coli* in Chicken Meat and Humans, the Netherlands. Emerging Infectious Disease 2011; 17 (7): 1216-1222. doi: 10.3201/eid1707.110209.

25. Cohen Stuart J, Van Den Munckhof T, Voets G, Scharringa J, Fluit A et al. Comparison of ESBL contamination in organic and convantional retail chicken meat. International Journal of Food Microbiology 1992; 154 (3): 212-214. doi: 10.1016/j.ijfoodmicro.2011.12.034

26. Falgenhauer L, Imirzalıoğlu C, Oppong K, Akenten CW, Hogan B et al. Detection and characterization of ESBL-producing Escherichia coli from humans and poultry in Ghana. Frontiers in Microbiology 2019; 9: 1-8. doi: 10.3389/fmicb.2018.03358

27. Keskin H. Kıyma, et, tavuk ve peynir örneklerinden izole edilen Escherichia coli'nin bazı antimikrobiyal direnç ve virülans genlerinin pcr ile tespiti. MSc, Kırıkkale University, Kırıkkale, Turkey, 2019 (in Turkish).

28. Tekiner IH. Gıdalardan izole edilen enterobacterıaceae suşlarında genişlemiş spektrumlu beta-laktamazların moleküler yöntemle araştırılması. PhD, İstanbul Aydın Üniversity, İstanbul, Turkey, 2016 (in Turkish).

29. Önen SP, Aslantaş Ö, Yılmaz EŞ, Kürekci C. Prevalence of β-Lactamase Producing Escherichia coli from Retail Meat in Turkey. Journal of Food Science 2015; 80 (9): M2023- M2029. doi: 10.1111/1750-3841.12984

30. Eğilmez T, Türkyılmaz S. Investigation of Antimicrobial Resistance and Integron Profiles of Poultry Pathogenic Escherichia coli. Israel Journal of Veterinary Medicine 2021; 76 (1): 19-26.

31. Önen SP, Aslantaş Ö, Yılmaz EŞ, Kürekçi C. Prevalance of B-Lactamase producing Escherichia coli from retail meat in Türkiye. Journal of Food Science 2015; 80 (9): M2023- 2029. doi: 10.1111/1750-3841.12984