Abundance of colistin-resistant *Escherichia coli* harbouring *mcr-1* and extended-spectrum β-lactamase-producing *E. coli* co-harbouring *bla*$_{CTX-M-55}$ or *bla*$_{CTX-M-65}$ with *bla*$_{TEM}$ isolates from chicken meat in Vietnam

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Abstract

Although the spread of plasmid-mediated antibiotic-resistant bacteria is a public health concern, food contamination with plasmid-mediated antibiotic-resistant *Escherichia coli* in Vietnam has not been well investigated. This study aimed to describe the prevalence of colistin-resistant, carbapenem-resistant, and endemic *bla*$_{CTX-M}$ in extended-spectrum β-lactamase (ESBL) producing *E. coli* isolates. Colistin and carbapenem-resistant ESBL-producing *E. coli* were isolated from chickens in Vietnam and Japan. Colistin-resistant and AmpC/ESBL-producing *E. coli* (52% and 93%, respectively) were detected in chickens from Vietnam, in comparison to 52.7%, AmpC/ESBL-producing *E. coli* found in chicken from Japan. Carbapenem-resistant *E. coli* has not been isolated in Vietnam and Japan. Genotyping revealed that colistin-resistant *E. coli* harboured *mcr-1*, and most of the AmpC/ESBL-related genes were *bla*$_{CTX-M-55}$ and *bla*$_{CTX-M-65}$ together with *bla*$_{TEM}$ in Vietnamese chickens and *bla*$_{CMY-2}$ in Japanese chickens. Multi-drug resistance analysis showed that ESBL-producing *E. coli* isolates had greater resistance to quinolones, streptomycin, and chloramphenicol than colistin-resistant *E. coli* isolates from Vietnam, suggesting the selection of multiple antibiotic resistance genes in ESBL-producing *E. coli*. In conclusion, colistin-resistant *E. coli* was detected in approximately half of the chicken samples, the majority of which harboured *mcr-1*. The high prevalence of ESBL-producing *E. coli* has remained constant in the last 5 years. The predominant *bla*$_{CTX-M}$ in ESBL-producing *E. coli* was *bla*$_{CTX-M-55}$ or *bla*$_{CTX-M-65}$, with the coexistence of *bla*$_{TEM}$ in Vietnam. These results can be implemented in monitoring systems to overcome the development of antimicrobial resistance.

Keywords *Mcr-1* · *Blac$_{CTX-M-55}$* · *Blac$_{CTX-M-65}$* · *Blac$_{CMY-2}$* · *Blac$_{TEM}$* · Plasmid-mediated antibiotic-resistant *Escherichia coli*

Introduction

The spread of antibiotic-resistant bacteria is a global public health concern (Giurazza et al. 2021). Plasmid-mediated antibiotic resistance is a critical issue that requires urgent attention owing to the development of resistance by horizontal gene transmission (Bevan et al. 2017).

In 2015, there was a report on the acquisition of colistin resistance by a new plasmid-encoded *mcr* gene (Liu et al. 2016). Colistin is expected to be a therapeutic agent for carbapenem-resistant bacteria. Therefore, the spread of
colistin-resistant bacteria in society is of great concern. In this study, we found that colistin is frequently used in agricultural and livestock farms in Vietnam (Nakayama et al. 2017). Yamamoto et al. (2019) found that approximately 70% of Vietnamese residents carried colistin-resistant bacteria. Although it is assumed that Vietnamese food can lead to human colonisation with colistin-resistant bacteria, the pathways of transmission are unclear. This is especially true in chickens, where plasmid-mediated antibiotic-resistant bacteria are frequently isolated.

Extended-spectrum β-lactamases (ESBL) and carbapenem-resistant bacteria are often associated with plasmid-mediated antibiotic resistance. Recent studies have focussed on ESBL-producing *Escherichia coli*, a bacterium that demonstrates plasmid-mediated antibiotic resistance (Bevan et al. 2017). Current knowledge suggests that ESBL-producing bacteria in food and humans are detected more frequently in Vietnam than in Japan (Nakayama et al. 2015; Le et al. 2015a, b). In an earlier study in Vietnam, it was found that ESBL-producing *E. coli* were frequently detected in chicken meat between 2013 and 2016. Most ESBL-producing *E. coli* isolates carried ESBL-related genes in the *bla*<sub>CTX-M-1</sub> and *M*-9 groups (Nakayama et al. 2015).

Monitoring of antibiotic-resistant bacteria is currently underway in many countries around the world. Therefore, it is of utmost importance to identify not only the presence of ESBL-producing *E. coli* but also the *bla*<sub>CTX-M</sub> genotype, which is widespread. Carbapenem-resistant *E. coli* are also well known as plasmid-mediated antibiotic-resistant *E. coli*; however, there is a lack of research on its importance and the degree of contamination in chicken. Hence, as with ESBL-producing *E. coli*, caution is required for the spread of carbapenem-resistant *E. coli*. In Japan, food contamination with AmpC/ESBL-producing *E. coli* has been reported in multiple studies (Kameyama et al. 2013; Hiroi et al. 2012). Reports indicate that *bla*<sub>CMY-2</sub> and *bla*<sub>CTX-M-2</sub> are the most abundant ESBL-producing *E. coli* in chickens. There are no reports of carbapenem-resistant and colistin-resistant *E. coli* isolated from chickens in Vietnam or Japan. Therefore, this study aimed to determine and compare the prevalence of colistin, carbapenem-resistant, and ESBL-producing *E. coli* in chickens from Vietnam and Japan.

**Materials and methods**

**Sampling locations and bacterial isolation**

A total of 134 chicken samples (60 meat samples from retailers/supermarkets, Ho Chi Minh City, Vietnam and 33 meat samples from supermarkets and 41 faecal samples from laying hens in Japan) were investigated. Chicken meat (25 g) was added to 225 mL of buffered peptone water (BPW), and 1 g of faeces was added to 9 mL of BPW. After gentle shaking, 100 µL of the solution was spread on MacConkey agar (Eiken Chemical, Tochigi, Japan) containing 2 µg mL<sup>−1</sup> of cefotaxime (CTX) for the isolation of AmpC/ESBL-producing *E. coli*. For the isolation of colistin-resistant and carbapenem-resistant *E. coli*, MacConkey agar (Eiken Chemical) containing either 2 µg mL<sup>−1</sup> colistin or 0.25 µg mL<sup>−1</sup> of meropenem (MEM), respectively, were used. The plates were incubated at 37 °C for 21 ± 3 h. After incubation, one to three colonies were selected for further analysis.

**Bacterial identification and DNA extraction**

Isolated bacteria were confirmed as *E. coli* using the following biochemical tests: the triple sugar iron (Eiken Chemical) and the lysin indole motility (Eiken Chemical) tests. Bacterial DNA was extracted by boiling suspensions of the isolates in tris (hydroxymethyl) aminomethane-EDTA buffer (Nakayama et al. 2015). Isolated bacteria were identified as *E. coli* using ECN amplification (Hoa et al. 2020).

**Multiplex PCR for phylogenetic group identification**

The phylogenetic groups of isolated bacteria were determined using multiplex PCR amplification of a combination of two genes, *chuA* and *yjaA*, and a DNA fragment, TspE4C2 (Le et al. 2015a, b). The extracted DNA was amplified using a multiplex PCR kit (Qiagen, Hilden, Germany). Primer sets used for multiplex PCR are listed in Table S1. PCR was conducted under the following conditions: 35 cycles of denaturation at 98 °C for 10 s, annealing at 57 °C for 30 s, and extension at 72 °C for 30 s. The PCR-amplified products were visualised using 1.5% agarose gel and stained with midori-green (Nippon Genetics, Tokyo, Japan).

**Antibiotic susceptibility testing**

After subculturing, the isolated bacteria were suspended in Mueller–Hinton (MH) broth (BD, Franklin Lakes, USA). The bacterial suspensions were adjusted to a McFarland standard (0.5) and spread on MH agar (BD, Franklin Lakes, USA) using a sterile cotton swab. *E. coli* isolates were tested for susceptibility to 14 antimicrobial agents: 30 µg tetracycline (TET), 10 µg ampicillin (AMP), 30 µg nalidixic acid (NAL), 30 µg kanamycin (KAN), 30 µg chloramphenicol (CHL), 10 µg streptomycin (STR), 23.75/1.25 µg sulfamethoxazole/trimethoprim (SXT), 10 µg gentamicin (GEN), 5 µg ciprofloxacin (CIP), 30 µg CTX, 30 µg ceftazidime (CAZ), 10 µg meropenem (MEM), and 30 µg cefoxitin (BD Japan, Tokyo, Japan). The disc diffusion assay was subsequently used to measure the zone of inhibition after bacterial incubation at 37 °C for 21 h, following the standard procedure of the Clinical
Laboratory Standards Institute (CLSI 2012) (Le et al. 2015a, b). The ESBL phenotype was determined by the double-disc synergy test using ceftazidime and CTX with and without clavulanic acid (BD), following the guidelines of the CLSI (2012). The AmpC phenotype was also determined using the cefoxitin disc, and MEM resistance was evaluated as carbapenem resistance.

**Multiplex PCR for mcr and AmpC/ESBL-related genes**

The genotype of AmpC/ESBL-producing *E. coli* was determined using multiplex PCR, as described previously (Le et al. 2015a, b; Perez-Perez and Hanson 2002). The extracted DNA was amplified using a multiplex PCR kit (Qiagen). Multiplex PCR was conducted under the following conditions: 25 cycles of denaturation at 95 °C for 30 s, annealing at 60 °C for 90 s, and extension at 72 °C for 90 s; for AmpC, 25 cycles of denaturation at 95 °C for 30 s, annealing at 64 °C for 90 s, and extension at 72 °C for 60 s. Primers for multiplex PCR of both AmpC and ESBL-related genes are described in Table S1. The PCR-amplified products were visualised using a 3% agarose gel and stained with midori-green (Nippon Genetics).

**Identification of blaCTX-M and blaCMY-2**

After determining the ESBL genotypes, the results from the *blaCTX-M-1*, *blaCTX-M-2*, and *blaCTX-M-9* groups were sequenced. We followed the protocol described in previous studies (Chanawong et al. 2002; Pitout et al. 2004; Imoto et al. 2014; Harada et al. 2017; Hoang et al. 2017). In the *blaCTX-M-1* group, the *blaCTX-M-1* sequence was amplified using the primer sets ctx-m15-168F and ctx-m3-1059R. The amplified gene was sequenced using the primer sets ctxm1-185F and ctxm3-492R. For the *blaCTX-M-2* and *blaCTX-M-9* groups, the gene was amplified using the primer sets ctx-m2s-1f and ctx-m2-869F, and toho2-48F and ctxm14-903R, respectively. The amplified gene was sequenced using the primer sets toho1-1R, ctx-m2-316f, toho2-411F, and ctxm9-490R, respectively. To identify *blaCMY-2*, the *blaCMY-2* gene was amplified using cmy-F and cmy-R primers (Zhao et al. 2003), and the amplified gene was sequenced using CMY2-outF and CMY2-outR (Noda et al. 2015). Primer information is described in Table S1. Each assembled gene sequence was identified using a BLAST search (https://blast.ncbi.nlm.nih.gov/Blast.cgi).

![Table 1](https://example.com/tables.png)

**Table 1** Prevalence of *Escherichia coli* harbouring *mcr*, AmpC/ESBL, and carbapenemase-related genes in chickens

| Location | Number of chicken samples | Number of chicken samples contaminated with *E. coli* harbouring antibiotic resistance genes | Number of colistin-resistant *E. coli* isolates and tested | Number of *E. coli* harbouring *mcr* genes | Number of CTX-resistant *E. coli* isolates and tested | Number of *CTX-M*-resistant *E. coli* isolates | Number of *CTX-M*-resistant *E. coli* tested | Number of *AmpC/ESBL*-related genes |
|-----------|--------------------------|---------------------------------------------------------------------------------|------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------------------------|
| Vietnam   | 60 (chicken meat)        | 43.3% (26/60)                                                                  | 0                                               | 43                              | 135                             | 122                             | 14                              | 57                            |
| Japan     | 33 (chicken meat)        | 36.4% (12/33)                                                                  | 0                                               | 0                               | 23                              | 14                              | 43                              | 57                            |
| Japan     | 41 (faeces in laying hens)| 65.9% (27/41)                                                                  | 0                                               | 0                               | 70                              | 43                              | 43                              | 57                            |
| Total     | 74                       | 52.7% (39/74)                                                                  | 0                                               | 0                               | 93                              | 57                              | 57                              | 57                            |

*Significant difference between chicken meat from Vietnam and Japan (p < 0.01).*
Statistical analysis

Statistical analysis was performed using Fisher’s exact test (Tables 1, 2, 4, and Fig. 2).

Results

Prevalence of contamination in chicken with E. coli harbouring mcr, AmpC/ESBL, and carbapenemase-related genes

AmpC/ESBL-producing E. coli was isolated from 90% (54/60) of the chicken samples from Vietnam, and 52% (26/50) of the chicken meat samples were found to have colistin-resistant E. coli, whereas carbapenem-resistant E. coli was not detected (Table 1). AmpC/ESBL-producing E. coli was isolated from 36.4% (12/33) of chicken meat from Japan. Neither colistin- nor carbapenem-resistant E. coli were detected (Table 1).

Phylogenetic grouping of E. coli

Among the AmpC/ESBL-producing E. coli isolated from Vietnamese chicken, type B2 was the least common (7.7%), whereas the other types showed similar results (21.1–26.3%). Type B2 was not detected in colistin-resistant E. coli, and the other types showed similar results to ESBL-producing E. coli (22.9–25.9%) (Table 2). In Japanese chickens, significantly high rates of B1 (43.9%) and D (31.6%) types of ESBL-producing E. coli were isolated. Type B2 (3.5%) had a low detection rate, similar to that of the E. coli strains in Vietnamese chickens (Table 2).

E. coli harbouring the mcr gene

Isolated E. coli were used to detect mcr using multiplex primers. The results showed that one strain was undetectable, and mcr-1 was detected in all the remaining E. coli isolates (Table 3).

ESBL-producing E. coli co-harbouring bla_CTX-M and bla_TEM

In 115 ESBL-producing E. coli isolates from Vietnamese chickens, bla_CTX-M-1 (67%) tended to be more prevalent than the bla_CTX-M-9 (28.7%), which was also the case in the 39 Japanese isolates (bla_CTX-M-1 = 53.8%, bla_CTX-M-9 = 23.1%). The results of bla_CTX-M identification showed that bla_CTX-M-55 (58.3% [67/115]) of the bla_CTX-M-1 group was the most common bla_CTX-M in Vietnamese samples, followed by bla_CTX-M-65 (18.2% [21/115]) of the bla_CTX-M-9 group (Fig. 1a). bla_CTX-M-1 (23.1% [9/39]) of the bla_CTX-M-1 group and bla_CTX-M-2 (23.1% [9/39]) were common in Japanese samples, followed by bla_CTX-M-2 of the bla_CTX-M-2 group (12.8% [5/39]) (Fig. 1b). Multiple ESBL-related genes were detected in Vietnamese samples. In particular, the combination of bla_CTX-M and bla_TEM was present in more than 70% of the strains (Table 4). This result was significantly different between ESBL-producing E. coli harbouring CTX-M and TEM isolates in Vietnam and Japan (p < 0.01).

Antibiotic susceptibility and multidrug-resistant E. coli

The susceptibility assay showed that colistin-resistant E. coli harbouring mcr differed significantly from the ESBL strains derived from Vietnamese chicken in third-generation cephalosporins and quinolones (Fig. 2a, b), and the result of multidrug resistance showed that the highest numbers of drug resistance were 4 and 6, with an average of 6.7 (Fig. 3).

Compared to strains detected in Japanese chickens, ESBL-producing E. coli isolates from Vietnamese chickens had a significantly higher percentage of resistance to all...
treatments except β-lactams ($p < 0.01$) (Fig. 2b, c). The percentage of resistance to quinolones, SXT, and chloramphenicol was particularly high in ESBL-producing $E. coli$ isolates from Vietnam ($p < 0.01$). ESBL-producing $E. coli$ (8) showed the highest number of drug-resistant strains (average number of drug-resistant strains was 9.1), followed by 11 drug-resistant strains. In comparison, in ESBL-producing $E. coli$ isolates from Japanese chickens, four and three kinds of drug resistance were the most common, with an average drug resistance of 4.7 (Fig. 3).

**Discussion**

The contamination of Vietnamese food with colistin-resistant bacteria has not been adequately studied. Nguyen et al. (2021) investigated colistin resistance in ESBL-producing $E. coli$ isolated from chickens. They found that 53.2% of ESBL-producing $E. coli$ isolates were colistin-resistant, and all of these colistin-resistant isolates harboured mcr-1 (Le et al., 2021). In this study, 43.3% of the food products contained colistin-resistant $E. coli$, and almost all of them harboured mcr-1, suggesting that mcr-1 may be spreading between chickens in Vietnam.

To easily isolate colistin-resistant $E. coli$, we analysed chicken faeces from Japan, however, there was no trace of the bacteria. Therefore, colistin-resistant $E. coli$ did not increase in Japanese chickens. In this study, carbapenem-resistant $E. coli$ strains were not isolated from either Vietnamese or Japanese chickens. Although it can be isolated in hospitals and the environment (Mathys et al., 2019; Zhong et al., 2021), carbapenem-resistant $E. coli$ is not generally transmitted to foods in Vietnam or Japan.

In this study, the phylogenetic group was determined for colistin-resistant and ESBL-producing $E. coli$ isolates. Colistin-resistant $E. coli$ showed a pattern similar to that of the ESBL-producing Vietnamese strains. The prevalence of B2 type $E. coli$ was much lower than that of the other types. Although there are no studies that have investigated the pattern of phylogenetic grouping of $E. coli$ isolates from chickens, the absolute number of $E. coli$ type B2 bacteria contamination may be low. The phylogenetic grouping of ESBL-producing $E. coli$ in Japanese strains showed that B1 and D types were very high. This result may be due to regional differences.

To monitor antibiotic resistance, it is necessary to clarify the actual conditions of antibiotic resistance genes in chicken meat that are frequently contaminated. In Vietnam, the $bla_{CTX-M}$ gene in ESBL-producing $E. coli$ is the most prevalent plasmid antibiotic resistance gene. In this study, ESBL-producing $E. coli$ was detected in 90% (54/60) of chicken meat samples from Vietnam. Similar to our study, Le et al. (2015a, b) and Nguyen (2016) found ESBL-producing $E. coli$ isolates in 88.3% (Le et al. 2015b), 58.7% (Le et al. 2015a), and 92.7% (Nguyen et al. 2016) of Vietnamese chicken samples. The Vietnamese government is motivated to research antibiotic resistance and plans to limit the use of antibiotics in chicken farms. However, the prevalence of ESBL-producing $E. coli$ has not changed, 5 years later, and is considered to have become chronic due to its prevalence.

Previous studies by Le et al. (2015a, b) and Nguyen et al. (2016) examined the CTX-M sub-group and found that $bla_{CTX-M-1}$ group was the most common, followed by $bla_{CTX-M-9}$ group. No actual identification was performed. In this study, the $bla_{CTX-M-1}$ group was the most common, followed by $bla_{CTX-M-9}$. Among the $bla_{CTX-M-1}$ group, $bla_{CTX-M-55}$ was the most common, and among the $bla_{CTX-M-9}$
group, \( \text{bla}_{\text{CTX-M-65}} \) was the most common. The results of a previous study of ESBL-producing \( \text{E. coli} \) from pork in Vietnam showed that \( \text{bla}_{\text{CTX-M-55}} \) was abundant, and the plasmid carrying \( \text{bla}_{\text{CTX-M-55}} \) was also found in workers and patients with urinary tract infection (Hoang et al. 2017), suggesting plasmid transmission within the community. Based on these findings, \( \text{bla}_{\text{CTX-M-55}} \) is abundant in pork and chicken.

Multiple studies have reported the genotyping of AmpC/ESBL-producing \( \text{E. coli} \) isolated from Japanese chickens. Kameyama et al. (2013) reported that the AmpC \( \beta \)-lactamase gene \( \text{bla}_{\text{CMY-2}} \) (66%) was most prevalent, followed by \( \text{bla}_{\text{CTX-M-1}} \) (26%) and \( \text{bla}_{\text{CTX-M-55}} \) (26%). Hiroi et al. (2012) reported that ESBL-producing \( \text{E. coli} \) harbouring \( \text{bla}_{\text{CTX-M-2}} \) were most prevalent in chickens. Nahar et al. (2018) also reported that the \( \text{bla}_{\text{CTX-M-2}} \) and \( \text{bla}_{\text{CTX-M-1}} \) groups represented 45% and 34% of ESBL-producing \( \text{E. coli} \), respectively. Our study found clear differences in the prevalence of \( \text{bla}_{\text{CTX-M}} \) in Vietnamese and Japanese chicken samples. Hence, the pattern of \( \text{bla}_{\text{CTX-M}} \) varied between the regions. In Vietnam, the co-harbouring genes \( \text{bla}_{\text{CTX-M-55}} \) or \( \text{bla}_{\text{CTX-M-65}} \)

| Table 4: \( \text{Escherichia coli} \) co-harbouring \( \text{bla}_{\text{CTX-M}} \) and \( \text{bla}_{\text{TEM}} \) genes in Vietnam |
|---------------------------------------------------------------|
| **CTX-M sub-group** | **CTX-M or CMY-2** | **Number of AmpC/ESBL-producing \( \text{E. coli} \)** |
| **ESBL-related genes** | **CTX-M-1 group** | **Vietnam** | **Japan** |
| M-1 | 9 |
| M-15 | 1 |
| M-55 | 22 |
| M-1/TEM | 2 |
| M-15/TEM | 3 |
| M-15/TEM/SHV | 1 |
| M-55/TEM | 45 |
| M-24/TEM | 1 |
| M-79/TEM | 1 |
| M-114/TEM | 1 |
| CTX-M 1 group | 67% (77/115) | 53.8% (21/39) |
| **CTX-M-9 group** | M-14 | 2 |
| M-27 | 2 |
| M-65 | 4 |
| M-125 | 1 |
| M-14/TEM | 4 |
| M-24/TEM | 1 |
| M-27/TEM | 2 |
| M-65/TEM | 17 |
| M-125/TEM | 1 |
| M-129/TEM | 1 |
| CTX-M 9 group | 28.7% (33/115) | 23.1% (9/39) |
| **CTX-M-1 and 9 group** | M-1, 65 | 1 |
| M-1,129/TEM | 1 |
| M-55, 65/TEM | 3 |
| **CTX-M-2 groups** | M-2 | 5 |
| CTX-M-2/TEM | 2 |
| **SHV group** | SHV | 2 |
| **CTX-M group with TEM** | CMY-2 | 13 |
| CMY-2/TEM | 2 |
| Other CITg | 1 |
| Other CITg/TEM | 2 |
| **CIT group** | CIT group | 15.7% (18/115) | 13.9% (16/115) |
| **CIT group with TEM** | CIT group | 22.2% (4/18) | 0 |

*Significance difference between ESBL-producing \( \text{E. coli} \) harbouring CTX-M group with TEM isolates in Vietnam and Japan (p<0.01)
Fig. 2 Antibiotic-resistance pattern of *Escherichia coli* isolates. 

**a** *E. coli* harboring *mcr*-1, **b** ESBL-producing *E. coli* isolates from Vietnam and **c** Japan. Fisher’s exact test was conducted. 1: Significant difference in the percentage of antibiotic resistance between ESBL-producing *E. coli* and *E. coli* harboring *mcr*-1 gene. 2: Significant difference in the percentage of antibiotic resistance between ESBL-producing *E. coli* isolated from Vietnam and Japan. R: resistant, I: intermediate, S: susceptible
with blaTEM were most prevalent in ESBL-producing E. coli. These blaCTX-M genes could be used to monitor antibiotic resistance genes to improve healthcare in Vietnam.

The prevalence of antibiotic resistance genes is known to change annually (Bevan et al. 2017). The blaCTX-M types of ESBL-producing E. coli isolated from humans are identified as blaCTX-M-15 (blaCTX-M-1 group) and blaCTX-M-14 (blaCTX-M-9 group), which are prevalent in many parts of the world. Accounting for prominent global trends in blaCTX-M epidemiology, there is increasing evidence suggesting that blaCTX-M-27 has started outcompeting other blaCTX-M genotypes (Bevan et al. 2017). In Vietnam, a study of ESBL-producing E. coli isolates from healthy Vietnamese people from 2013 to 2015 reported that blaCTX-M-27 was the most common type, followed by blaCTX-M-55, blaCTX-M-15, and blaCTX-M-65 (Hoang et al. 2017). Our results show that in 2019, the overwhelming majority of blaCTX-M isolates from chickens had ESBL-producing E. coli harbouring blaCTX-M-55 and blaCTX-M-65. It has not been verified whether the blaCTX-M gene is transferred from chickens to humans, however, it is possible that blaCTX-M-55 or blaCTX-M-65 will be predominant in human carriers in the future. Therefore, it is necessary to carefully monitor the presence of blaCTX-M-27 in ESBL-producing E. coli in the future.

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Declarations

Conflict of interest None of the authors declares a conflict of interest.

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