Antimicrobial resistance of *Escherichia coli* isolated from retail foods in northern Xinjiang, China

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Abstract
To determine antimicrobial resistance, 431 samples of retail foods purchased at different supermarkets in Northern Xinjiang were examined in this study. There were 112 *Escherichia coli* strains that were isolated, with approximately 26% of the samples contaminated by *E. coli*. The detection rate of *E. coli* isolated from pork was the highest (59.6%), followed by mutton (52.6%), retail fresh milk (52.4%), duck (36.4%), beef (35.3%), chicken (33.3%), and ready-to-eat food (12.9%); the *E. coli* detection rate for fish and vegetables was <11%. The result showed that the 112 isolates were mostly resistant to tetracycline (52%), followed by ampicillin (42%), compound trimethoprim/sulfamethoxazole (37%), amoxicillin (33%), and nalidixic acid (32%); imipenem resistance was not detected. One hundred isolates carried at least one antimicrobial resistance gene. The detection rate of resistance genes of our study was as follows: *tetA* (38%), *tetB* (27%), *bla*<sub>OXA</sub> (40%), *bla*<sub>TEM</sub> (20%), *floR* (20%), *sul1* (16%), *sul2* (27%), *aad<sub>Ala</sub>* (19%), *aadB* (11%), *strA* (28%), and *strB* (24%); *tetC* and *bla*<sub>PSE</sub> were not detected. Virulence genes *fimC*, *agg*, *stx2*, *fimA*, *fyuA*, *papA*, *stx1*, and *eaeA* were found in 52, 34, 21, 19, 6, 3, 2, and 2 isolates, respectively; *papC* was not detected. There was a statistically significant association between *fimC* and resistance to ciprofloxacin (*p* = .001), gentamicin (*p* = .001), amikacin (*p* = .001), levofloxacin (*p* = .001), and streptomycin (*p* = .001); between *fimA* and resistance to tetracycline (*p* = .001), ampicillin (*p* = .001), compound trimethoprim/sulfamethoxazole (*p* = .001), and amoxicillin (*p* = .003); between *agg* and resistance to gentamicin (*p* = .001), tetracycline (*p* = .001), ciprofloxacin (*p* = .017), and levofloxacin (*p* = .001); and between *stx2* and resistance to ampicillin (*p* = .001), tetracycline (*p* = .001), compound trimethoprim/sulfamethoxazole (*p* = .002), and amoxicillin (*p* = .015).

**KEYWORDS**
*Escherichia coli*, multidrug resistance, resistance gene, virulence gene
1 | INTRODUCTION

It is well known that *Escherichia coli* mainly exists in the human and animal gastrointestinal tract. It also occurs in the natural environment, especially in soil, water, and plants (Katarzyna & Anna, 2016). Therefore, it is not surprising that some of the *E. coli* in the environment reinfects humans through vegetable- or animal-derived foods.

*Escherichia coli* is a highly diverse virulent species that is widely distributed in open systems, is easy to spread in the environment, and can be harmful to human health (Tenaillon, Skurnik, Picard, & Denamur, 2010). Drug resistance genes carried by *E. coli* can be transferred to other pathogenic bacteria, and, due to the excessive use of antibiotics, selection pressure is very high, resulting in bacterial strains resistant to a variety of drugs. Multi-drug-resistant strains are characterized by the presence of multiple genes conferring drug resistance, which results in insensitivity to many different drug groups (Hu, Yang, & Li, 2016; Rasheed, Thajuddin, Ahamed, Teklemariam, & Jamil, 2014).

Genetic mutations or genetic acquisition of antibiotic resistance genes (ARG) through horizontal gene transfer might also result in the occurrence of antibiotic-resistant bacteria (ARB) throughout the environment (Céline & David, 2015). This has resulted in the emergence of many different ARG, including the *drf* and *sul* genes related to trimethoprim and sulfamethoxazole resistance, respectively (Chang, Lin, Chang, & Lu, 2007; Ho, Wang, Chow, & Que, 2009), and other genes, such as *ampC*, *oxa2*, and *tetA*.

The ever-increasing threat of ARB may be associated with enhanced virulence (Guillard, Pons, Roux, Pier, & Skurnik, 2016; Roux et al., 2015), and with the increase in antibiotic resistance, an increase in virulence may naturally evolve. Therefore, when controlling the spread of antibiotic resistance, we must also control the spread of virulence (Meredith, Brooks, & Brooks, 2017). Although the profile of virulence and antimicrobial resistance genes of *E. coli* from foods has been reported (Luo, Ji, & Wang, 2016), the data elucidating the association between these two gene sets are lacking.

In Xinjiang, China, a previous study conducted antibiotic resistance research on foodborne *E. coli* based on samples from slaughterhouses, butcher shops, and farms (Xia, Xiang, & Guo, 2014; Yao, Long, Kuerbannaimu, Wang, & Xia, 2017). However, little is known about the resistance of those bacteria in retail foods.

There have been some reports describing the antimicrobial resistance and virulence of *E. coli*, such as Arisoy, Rad, Akin, and Akar (2008), who showed that the virulence genes *afaI*, *pap*, *hly*, *aer*, and *sfa* were increased in sensitive strains. However, detailed information on the relationship between antimicrobial resistance genes and virulence genes of *E. coli* isolated from retail foods in Xinjiang is scarce.

The purpose of this study was to evaluate the drug resistance of *E. coli* strains isolated from retail foods in northern Xinjiang, identify their virulence genes, and determine the possible relationship between the virulence genes and drug resistance.

2 | MATERIALS AND METHODS

2.1 | Sampling and *E. coli* isolation

A total of 431 food samples were purchased at supermarkets in Shihezi, Kuitun, and Urumqi, in northern Xinjiang, China, from 2014 to 2016, and each type of sample and its number are listed in Table 1. Each sample weighed 25 g and was placed in a sterile plastic bag containing 225 ml of sterilized sodium chloride solution (0.85%) and then homogenized for 90 s using a BagMixer 400 CC beating homogenizer. Lauryl Sulfate Tryptose (LST) broth was inoculated with 1 ml of homogenate and incubated for 48 hr at 37 ± 1°C. Gas-positive tubes were inoculated into 100 ml of *E. coli* (EC) broth and incubated at 44 ± 0.5°C for 48 hr (Wang, Sun, & Ji, 2014). After that, one loopful from each gas-positive tube was streaked onto eosin methylene blue agar. Presumptive *E. coli* colonies were streaked onto Luria–Bertani nutrient agar and incubated for 12–48 hr at 36 ± 1°C. Each culture was confirmed as *E. coli* through an IMViC test. *E. coli* ATCC 25922 was used as a positive control for polymerase chain reaction (PCR) of *UidA*. Template was prepared via the boiling method, for the amplification of selected *UidA* genes in *E. coli* using PCR (Heijnen & Medema, 2006). The oligonucleotide sequences used and the predicted sizes of PCR amplification products of genes are listed in Table 2.

2.2 | Antimicrobial susceptibility testing

Antimicrobial susceptibility testing was performed utilizing the disk-diffusion method as recommended by the Clinical and Laboratory Standards Institute (CLSI, 2015). The following antibiotics were used: ampicillin (AMP: 10 μg/p), cefotaxime (CTX: 30 μg/p), ceftazidime (CAZ: 30 μg/p), gentamicin (GEN: 10 μg/p), imipenem (IPM: 10 μg/p), ciprofloxacin (CIP: 5 μg/p), levofloxacin (LEV: 5 μg/p), tetracycline (TET: 30 μg/p), chloramphenicol (CHL: 30 μg/p), amikacin (AMK: 30 μg/p), piperacillin (PIP: 100 μg/p), compound trimethoprim/sulfamethoxazole (T/S: 23.75 μg/1.25 μg/p), erythromycin (ERY: 15 μg/p), amoxicillin (AMX: 10 μg/p), streptomycin (STR: 10 μg/p), nalidixic acid (NAL: 30 μg/p), and polymyxin B (PB: 300 μg/p). Standard strain *E. coli* ATCC 25922 was used as a quality control. Strains were classified as either susceptible, intermediate, or resistant strains (CLSI, 2015).

2.3 | PCR amplification of antimicrobial resistance and virulence genes

Genomic DNA for PCR was extracted by the boiling method. Tables 2 and 3 list the oligonucleotide sequences of different antimicrobial and virulence genes in *E. coli* and the predicted sizes after PCR amplification.

The presence of genes associated with resistance to tetracycline (*tetA*, *tetB*, and *tetC*), β-lactams (*bla*<sub>TEM</sub>, *bla*<sub>PSE</sub>, and *bla*<sub>OXA</sub>), aminoglycosides (*aadA<sub>1</sub>*, *aadB*, *strA*, and *strB*), chloramphenicol (*floR*), and sulfonamide (*Sul1* and *Sul2*) and virulence-encoding genes were detected...
### TABLE 1 The original number of samples

| Number | Sampling number | Origin         | Number | Sampling number | Origin         | Number | Sampling number | Origin   |
|--------|-----------------|----------------|--------|-----------------|----------------|--------|-----------------|----------|
| 1      | K1              | Pig heart      | 145    | K3              | Celery         | 289    | K15             | Duck     |
| 2      | K2              | Pork           | 146    | K5              | Broccoli       | 290    | K16             | Duck     |
| 3      | K4              | Pork liver     | 147    | K7              | Lettuce        | 291    | K17             | Duck leg  |
| 4      | K6              | Pork           | 148    | K11             | Tomato         | 292    | K19             | Duck     |
| 5      | K8              | Pork           | 149    | K12             | Pepper         | 293    | K20             | Duck     |
| 6      | K9              | Pork           | 150    | K14             | Cabbage        | 294    | K24             | Duck     |
| 7      | K10             | Pork stuffing  | 151    | K21             | Ginger         | 295    | K25             | Duck     |
| 8      | K13             | Porcine blood  | 152    | K22             | Celery         | 296    | K27             | Duck     |
| 9      | K18             | Pork           | 153    | K23             | Pepper         | 297    | K35             | Duck     |
| 10     | K33             | Porcine blood  | 154    | K26             | Cabbage        | 298    | W7              | Duck     |
| 11     | K34             | Pork           | 155    | W1              | Broccoli       | 299    | W12             | Duck     |
| 12     | K40             | Pork liver     | 156    | W4              | Lettuce        | 300    | N4              | Fish     |
| 13     | W2              | Pork intestine | 157    | W5              | Pepper         | 301    | N5              | Fish     |
| 14     | W3              | Pork liver     | 158    | N1              | Ginger         | 302    | N8              | Fish     |
| 15     | W6              | Porcine blood  | 159    | N2              | Broccoli       | 303    | N14             | Fish     |
| 16     | W8              | Pigtail        | 160    | N3              | Eggplant       | 304    | N15             | Fish     |
| 17     | W9              | Pork           | 161    | S18             | Spinach        | 305    | N16             | Crustacean |
| 18     | W10             | Pork fillet    | 162    | S19             | Celery         | 306    | N17             | Fish     |
| 19     | W11             | Pork liver     | 163    | N6              | Shallot        | 307    | W17             | Fish     |
| 20     | W13             | Pork           | 164    | N7              | Tomato         | 308    | W18             | Fish     |
| 21     | W14             | Pork           | 165    | N9              | Lettuce        | 309    | W61             | Fish     |
| 22     | W15             | Pork           | 166    | W21             | Tomato         | 310    | W62             | Fish     |
| 23     | W16             | Pork           | 167    | H11             | Ginger         | 311    | W63             | Fish     |
| 24     | W19             | Pork           | 168    | N52             | Cowpea         | 312    | K36             | Fish     |
| 25     | W20             | Pork           | 169    | H14             | Spinach        | 313    | K37             | Fish     |
| 26     | W25             | Porcine blood  | 170    | H15             | Broccoli       | 314    | S1              | Fish     |
| 27     | W26             | Porcine blood  | 171    | H16             | Pepper         | 315    | S2              | Fish     |
| 28     | S5              | Pork           | 172    | H17             | Shallot        | 316    | S3              | Fish     |
| 29     | S8              | Pig heart      | 173    | Tomato          | 317             | S4      | Fish             |
| 30     | S9              | Pork stuffing  | 174    | W22             | Eggplant       | 318    | W64             | Fish     |
| 31     | S10             | Pork fillet    | 175    | W23             | Spinach        | 319    | W65             | Fish     |
| 32     | S12             | Pork liver     | 176    | W24             | Tomato         | 320    | W66             | Fish     |
| 33     | S14             | Pig hind leg   | 177    | W67             | Celery         | 321    | W69             | Fish     |
| 34     | S15             | Pork           | 178    | W68             | Ginger         | 322    | W72             | Fish     |
| 35     | S16             | Pork liver     | 179    | W70             | Shallot        | 323    | W73             | Fish     |
| 36     | S17             | Pork           | 180    | W71             | Cowpea         | 324    | W75             | Fish     |
| 37     | H2              | Pork intestine | 181    | W74             | Tomato         | 325    | W54             | Fish     |
| 38     | H4              | Pork           | 182    | W76             | Pepper         | 326    | W55             | Fish     |
| 39     | H5              | Pork           | 183    | K38             | Broccoli       | 327    | W56             | Fish     |
| 40     | H6              | Porcine blood  | 184    | K39             | Ginger         | 328    | S6              | Fish     |
| 41     | H7              | Pig trotters   | 185    | K41             | Shallot        | 329    | S7              | Fish     |
| 42     | H8              | Porcine blood  | 186    | W77             | Lettuce        | 330    | S11             | Brine shrimp |
| 43     | H9              | Pork           | 187    | W78             | Cowpea         | 331    | N10             | Bean curd skin |
| 44     | H12             | Porcine blood  | 188    | W79             | Spinach        | 332    | N11             | Marinated tofu |
| 45     | H13             | Pork           | 189    | W80             | Eggplant       | 333    | N12             | Stewed chicken leg |

(Continues)
TABLE 1 (Continued)

| Number | Sampling number | Origin          | Number | Sampling number | Origin | Number | Sampling number | Origin          |
|--------|----------------|-----------------|--------|----------------|--------|--------|----------------|----------------|
| 46     | H23            | Porcine blood   | 190    | S13            | Tomato | 334    | N13            | Stewed beef    |
| 47     | H24            | Pork liver      | 191    | H1             | Shallot| 335    | N51            | Red oil chicken gizzards |
| 48     | H27            | Pork            | 192    | H3             | Celery | 336    | K42            | Hot and sour gluten |
| 49     | H28            | Pork            | 193    | H10            | Ginger | 337    | K43            | Marinated chicken leg |
| 50     | H30            | Pork            | 194    | W28            | Pepper | 338    | K45            | Cold bamboo shoots |
| 51     | H33            | Pork            | 195    | W29            | Broccoli| 339   | K74            | Soy sauce pickles |
| 52     | H34            | Pork            | 196    | W34            | Tomato | 340    | K75            | Spiced gizzard |
| 53     | K28            | Celery          | 197    | H66            | Lettuce| 341    | K76            | Beef salad     |
| 54     | K29            | Shallot         | 198    | H67            | Shallot| 342    | K77            | Beef tendon in cold sauce |
| 55     | K30            | Spinach         | 199    | H68            | Eggplant| 343   | K78            | Cold bamboo shoots |
| 56     | N46            | Potato          | 200    | H69            | Ginger | 344    | K79            | Bean salad     |
| 57     | N47            | Eggplant        | 201    | H70            | Spinach| 345    | S22            | Fungus salad   |
| 58     | N48            | Spinach         | 202    | H71            | Cowpea | 346    | S23            | Kelp salad     |
| 59     | N49            | Shallot         | 203    | H72            | Tomato | 347    | K80            | Bean curd skin in cold sauce |
| 60     | W52            | Cowpea          | 204    | H73            | Coriander| 348   | K81            | Kelp salad     |
| 61     | W53            | Bitter gourd    | 205    | H74            | Snow pea| 349   | W32            | Shredded lotus root slice |
| 62     | W57            | Eggplant        | 206    | H75            | Lettuce | 350   | W33            | Spiced gizzard |
| 63     | S20            | Flammulina velutipes mushroom | 207 | N18 | Drumsticks | 351   | H18            | Pea noodles |
| 64     | S21            | Celery          | 208    | N19            | Chicken wings | 352   | H19            | Dried bean curd |
| 65     | S24            | Zhaer root      | 209    | N20            | Drumsticks | 353   | H20            | Bean curd     |
| 66     | S25            | Lettuce         | 210    | N21            | Chicken gizzard | 354   | H26            | Red ear silk |
| 67     | S26            | Chinese cabbage | 211    | N22            | Chicken | 355   | H29            | Chicken salad |
| 68     | S27            | Bok choy        | 212    | H21            | Drumsticks | 356   | H30            | Sweet potato |
| 69     | S28            | Ginger          | 213    | H22            | Chicken wings | 357   | S95            | Chinese wolfberries |
| 70     | S47            | Tomato          | 214    | K44            | Chicken gizzard | 358   | S96            | Cold bean curd |
| 71     | S48            | Bitter gourd    | 215    | K46            | Chicken | 359   | S97            | Bean curd skin |
| 72     | S49            | Black fungus    | 216    | H23            | Chicken wing | 360   | S98            | Gluten        |
| 73     | S50            | Garlic sprouts  | 217    | S53            | Drumsticks | 361   | S99            | Cold pig ears |
| 74     | S51            | Chive           | 218    | N53            | Chicken | 362   | S100           | Peanut salad  |
| 75     | S52            | Coriander       | 219    | N54            | Chicken wing | 363   | H76            | Cold bamboo shoots |
| 76     | N55            | Broccoli        | 220    | S64            | Drumsticks | 364   | H77            | Marinated tofu |
| 77     | N56            | Celery          | 221    | S65            | Chicken gizzard | 365   | H78            | Spicy dried tofu |
| 78     | S61            | Pepper          | 222    | S66            | Chicken | 366   | K47            | Spicy dried tofu |
| 79     | S62            | Coriander       | 223    | S67            | Drumsticks | 367   | K64            | Red oil ear silk |
| 80     | S63            | Green Chinese onion | 224 | S68 | Chicken wings | 368   | K65            | Cold bean curd stick |
| 81     | H24            | Bitter gourd    | 225    | W25            | Drumsticks | 369   | K66            | Dried vegetables |
| 82     | H25            | Lentinus edodes mushroom | 226 | W38 | Chicken wings | 370   | K67            | Brine shrimp |
| 83     | H27            | Pepper          | 227    | S69            | Drumsticks | 371   | K71            | Bean curd skin |
| 84     | H28            | Kelp            | 228    | S70            | Chicken gizzard | 372   | K72            | Chicken skewer |

(Continues)
| Number | Sampling number | Origin     | Number | Sampling number | Origin     | Number | Sampling number | Origin                  |
|--------|-----------------|------------|--------|-----------------|------------|--------|-----------------|--------------------------|
| 85     | H31 Pepper      | 229        | S71    | Chicken         | 373        | K73    | Hot and sour gluten |                          |
| 86     | S72 Bean sprouts| 230        | S29    | Chicken wings   | 374        | W36    | Marinated tofu   |                          |
| 87     | S73 Coprinus comatus mushroom | 231 | S30    | Chicken         | 375        | W37    | Stewed pork liver |                          |
| 88     | S74 Romaine lettuce | 232 | H41    | Chicken wings   | 376        | S34    | Stewed beef      |                          |
| 89     | S75 Coriander   | 233        | H42    | Drumsticks      | 377        | S35    | Stewed chicken leg |                          |
| 90     | S76 Tomatoes    | 234        | H43    | Drumsticks      | 378        | S36    | Marinated tofu   |                          |
| 91     | S77 Pepper      | 235        | H44    | Chicken wings   | 379        | S54    | Brine shrimp      |                          |
| 92     | S78 Celery      | 236        | H60    | Chicken gizzard | 380        | S55    | Bean curd skin   |                          |
| 93     | S79 Lotus root  | 237        | S81    | Drumsticks      | 381        | S56    | Chicken skewer   |                          |
| 94     | S80 Cabbage     | 238        | S82    | Chicken         | 382        | S57    | Marinated chicken leg |                        |
| 95     | S89 Cucumber    | 239        | S83    | Chicken gizzard | 383        | N34    | Marinated tofu   |                          |
| 96     | S90 Celery      | 240        | S84    | Chicken wings   | 384        | N35    | Stewed beef      |                          |
| 97     | S91 Garlic sprouts | 241 | S85    | Chicken gizzard | 385        | N36    | Stewed beef      |                          |
| 98     | S92 Spinach     | 242        | S86    | Drumsticks      | 386        | N37    | Hot and sour gluten |                      |
| 99     | S93 Towel gourd | 243        | S87    | Drumsticks      | 387        | N38    | Marinated chicken leg |                     |
| 100    | S94 Peas        | 244        | S88    | Drumsticks      | 388        | N45    | Stewed chicken leg |                          |
| 101    | K48 Chives      | 245        | K32    | Chicken wings   | 389        | N50    | Stewed pork liver |                          |
| 102    | K49 Garlic sprouts | 246 | W27    | Chicken         | 390        | K61    | Marinated tofu   |                          |
| 103    | K52 Lettuce     | 247        | W30    | Drumsticks      | 391        | K62    | Stewed pork liver |                          |
| 104    | K68 Pepper      | 248        | W31    | Chicken wings   | 392        | K63    | Lamb tripe       |                          |
| 105    | K69 Cucumber    | 249        | K53    | Chicken         | 393        | K31    | Mutton            |                          |
| 106    | K70 Lettuce     | 250        | K54    | Chicken         | 394        | W39    | Mutton            |                          |
| 107    | H40 Cucumber    | 251        | K59    | Drumsticks      | 395        | W46    | Mutton            |                          |
| 108    | H45 Pepper      | 252        | K60    | Chicken gizzard | 396        | W51    | Sheep heart       |                          |
| 109    | H48 Peas        | 253        | W47    | Chicken gizzard | 397        | W63    | Mutton            |                          |
| 110    | H50 Cucumber    | 254        | W48    | Drumsticks      | 398        | W64    | Mutton            |                          |
| 111    | H56 Lettuce     | 255        | K50    | Beef            | 399        | W65    | Mutton            |                          |
| 112    | H57 Towel gourd | 256        | K51    | Beef            | 400        | W66    | Mutton            |                          |
| 113    | H58 Pepper      | 257        | W47    | Beef            | 401        | S39    | Mutton            |                          |
| 114    | H59 Peas        | 258        | W48    | Beef stuffing   | 402        | S40    | Mutton            |                          |
| 115    | W40 Chives      | 259        | N23    | Beef            | 403        | S41    | Mutton            |                          |
| 116    | W43 Spinach     | 260        | N24    | Beef            | 404        | S44    | Mutton            |                          |
| 117    | W45 Pepper      | 261        | N25    | Beef            | 405        | S58    | Mutton            |                          |
| 118    | W60 Towel gourd | 262        | N26    | Beef            | 406        | S59    | Mutton            |                          |
| 119    | W61 Spinach     | 263        | N27    | Beef            | 407        | S60    | Mutton            |                          |
| 120    | W62 Cucumber    | 264        | H32    | Beef            | 408        | N31    | Mutton            |                          |
| 121    | S42 Celery      | 265        | H33    | Beef            | 409        | N32    | Mutton            |                          |
| 122    | S43 Chives      | 266        | H34    | Beef            | 410        | N33    | Mutton            |                          |
| 123    | N28 Peas        | 267        | H61    | Beef            | 411        | R1     | Retail fresh milk |                          |
| 124    | N29 Lettuce     | 268        | H62    | Beef            | 412        | R2     | Retail fresh milk |                          |
by PCR. The PCR products were electrophoresed for 40 min at 90 V in 1% agarose gel containing 0.5 µg/ml of ethidium bromide, and then, the gels were visualized on a Gel Doc 2000 transmittance apparatus (Kerrn, Klemmensen, Frimodt-Møller, & Espersen, 2002). Target fluorescent bands were removed from the gel with a razor blade. The DNA fragments were purified with a MIDI gel purification kit and then sequenced. The DNA sequence data were compared with the data in the GenBank database.

2.4 | Statistical analysis

SPSS v.17.0 software was used to analyze the data. Logistical regression analysis was used to analyze the correlation between variables. $p < .05$ was considered statistically significant.

3 | RESULTS AND CONCLUSIONS

3.1 | E. coli isolated from retail foods

A total of 112 strains of E. coli were isolated from 431 random samples, with 26% of the samples testing positive for contamination. The overall incidence was higher than 14.7% reported elsewhere (Rasheed et al., 2014). As shown in Table 4, pork was most frequently contaminated with E. coli (59.6%). The detection rates of E. coli were 52.6%, 52.4%, 36.4%, 35.3%, and 33.3% in mutton, retail fresh milk, duck, beef, and chicken, respectively, followed by ready-to-eat food (12.9%), vegetables (11%), and fish (10%).

Several studies have documented antibiotic-resistant E. coli and other coliforms in raw meat (Srinivasa, Gill, Ravi, & Sandeep, 2011), poultry (Nuno et al., 2016), eggs (Arathy, Vanpee, Belot, DeAllie, & Sharma, 2011), milk (Alharbi & Khaled, 2018), and vegetables (Rasheed et al., 2014). Whether there is a link between high contamination rates and high antibiotic resistance rates for E. coli in food remains to be determined.

In both developed and developing countries, antibiotic resistance has been recognized as a problem in the field of human and veterinary medicine (Bottacini et al., 2018; Zhang et al., 2017). There is ample evidence that the widespread use of antibiotics in agriculture and medicine is the main reason for the high resistance rate of Gram-negative bacteria (Bothyna & Randa, 2018). Various food and environmental sources contain bacteria resistant to one or more antimicrobial agents used in human or veterinary medicine and animal food production (Hinthong, Pumipuntu, & Santajit, 2017).

3.2 | Antimicrobial resistance profiles of E. coli isolates

Antibiotic resistance in E. coli is of particular concern because it is the most common Gram-negative pathogen in humans, the most

| Number | Sampling number | Origin  | Number | Sampling number | Origin  | Number | Sampling number | Origin  |
|--------|----------------|---------|--------|----------------|---------|--------|----------------|---------|
| 125    | N30            | Pepper  | 269    | H63           | Beef    | 413    | R3             | Retail fresh milk |
| 126    | S31            | Towel gourd | 270    | H64           | Beef    | 414    | R4             | Retail fresh milk |
| 127    | S32            | Pepper  | 271    | H65           | Beef    | 415    | R5             | Retail fresh milk |
| 128    | S33            | Lettuce | 272    | W44           | Beef stuffing | 416    | R6            | Retail fresh milk |
| 129    | W41            | Cucumber | 273    | S37           | Beef stuffing | 417    | R7            | Retail fresh milk |
| 130    | W42            | Peas    | 274    | S38           | Beef    | 418    | R8             | Retail fresh milk |
| 131    | N39            | Lettuce | 275    | S45           | Beef    | 419    | R9             | Retail fresh milk |
| 132    | N40            | Lettuce | 276    | S46           | Beef    | 420    | R10            | Retail fresh milk |
| 133    | K55            | Pepper  | 277    | S50           | Beef    | 421    | R11            | Retail fresh milk |
| 134    | K57            | Chives  | 278    | S51           | Beef    | 422    | R12            | Retail fresh milk |
| 135    | S47            | Towel gourd | 279    | S53           | Beef    | 423    | R13            | Retail fresh milk |
| 136    | S48            | Lettuce | 280    | K56           | Beef    | 424    | R14            | Retail fresh milk |
| 137    | S52            | Cucumber | 281    | K58           | Beef    | 425    | R15            | Retail fresh milk |
| 138    | N41            | Spinach | 282    | S49           | Beef    | 426    | R19            | Retail fresh milk |
| 139    | N42            | Pepper  | 283    | H36           | Beef    | 427    | R20            | Retail fresh milk |
| 140    | N43            | Cucumber | 284    | H37           | Beef    | 428    | R21            | Retail fresh milk |
| 141    | N44            | Cucumber | 285    | W59           | Beef    | 429    | R23            | Retail fresh milk |
| 142    | W49            | Chives  | 286    | W60           | Beef    | 430    | R26            | Retail fresh milk |
| 143    | W50            | Spinach | 287    | H38           | Beef    | 431    | R31            | Retail fresh milk |
| 144    | H35            | Towel gourd | 288    | H39           | Beef    | 432    |                |          |

Note: H, supermarket sampling in Shihezi; K, samples collected from Kuitun; N, sampling in cooperation with Inspection Institute; R, retail fresh milk collected from Shihezi; S, samples collected from Shihezi; W, samples collected from Urumqi.
common cause of urinary tract infections, and a frequent cause of community and hospital-acquired bacteremia (Bothyna & Randa, 2018) and diarrhea (Jessica, Lashaunda, & Levens, 2016).

Worldwide data have shown that resistance to traditional drugs is increasing, and resistance is also being encountered against newer and more effective antibiotics (Sara, Mohammad, & Sadegh, 2014). As in this study, the most frequent resistance was seen for third-generation cephalosporin–ceftazidime (22%) and tetracyclines (52%; Table 5). A comparative study by Dominguez et al. (2018) showed that high resistance rates (76.5%–79.4%) were observed in oxyimino-cephalosporins (cefotaxime, ceftriaxone, and ceftiofur) and ceftepime (70.6%). This phenomenon requires additional study and sustained data support.

As shown in Table 5, our study revealed that 87 (77.7%) isolates (n = 112) were resistant to one or more antimicrobials, including tetracycline (52%), ampicillin (42%), compound trimethoprim/sulfamethoxazole (37%), amoxicillin (33%), and nalidixic acid (32%). No resistance to imipenem was observed. Among those isolates, two strains (E24 and E53) isolated from chicken and one strain (E56) from mutton were resistant to 13 antimicrobial agents. There were two strains (E36, E37) isolated from chicken and one strain (E38) isolated from mutton were resistant to 11 antimicrobials, including tetracycline (52%), ampicillin (42%), compound trimethoprim/sulfamethoxazole (37%), amoxicillin (33%), and nalidixic acid (32%). No resistance to imipenem was observed. Among those isolates, two strains (E24 and E53) isolated from chicken and one strain (E56) isolated from fish resistant to 11 antimicrobial agents. The specific
multiple drug resistance rate is shown in Table 6, and the pattern of antibiotic resistance in those isolates is shown in Table 7.

The incidence of multidrug resistance is a compelling issue, as there is a repository of antimicrobial resistance genes in the community, and drug resistance genes and plasmids can easily be transferred to other strains. The high resistance to tetracycline and ampicillin may be due to the easy availability and low cost of those medications. Although these antibiotics have been banned, the bans have not been effectively implemented by the relevant regulatory bodies. Another explanation for a strain’s high resistance rate is its contact with environmental microorganisms that produce natural antibiotics, or with soil contaminated by wildlife feces carrying antibiotic-resistant microorganisms.

### TABLE 3 Primers used for detection of genes encoding resistance to different virulence

| Gene | Primer | DNA sequence (5’ → 3’) | Size (bp) | Thermocycling conditions | References |
|------|--------|-------------------------|-----------|--------------------------|------------|
| stx1 | stx1-F | 5’-ACACTGGATGATCCTCAGTG-3’ | 244 | 95°C for 5 min, 35 cycles of 94°C for 1 min, 60°C for 1 min, 72°C for 1 min, final extension at 72°C for 10 min | Moses, Garbati, and Egwu (2006) |
|     | stx1-R | 5’-CTGATCCCACACCTGCTATTG-3’ | | | |
| stx2 | stx2-F | 5’-CCATGACACCCAGACAGATT-3’ | 255 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Moses et al. (2006) |
|     | stx2-R | 5’-CCTGTCAACTGAGACCGTATG-3’ | | | |
| agg  | agg-F | 5’-AAGAAAAGAAGTAGACAAA-3’ | 400 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Pass, Odedra, and Batt (2000) |
|     | agg-R | 5’-AAACGGCAAGGAAAGATAA-3’ | | | |
| eaeA | eae-F | 5’-AACCGACTGAGGTCACT-3’ | 384 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Lopez et al. (2003) |
|     | eae-R | 5’-ACGCTGCTACTAGATG-3’ | | | |
| fyuA | fyu-F | 5’-ACACGGCTTATATCTTGGGC-3’ | 235 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Viktoria, Lionel, and Per (2008) |
|     | fyu-R | 5’-GGCATATTGACGATTAACGA-3’ | | | |
| fimA | fimA-F | 5’-CTGTGACGGTCTCGGACTAC-3’ | 352 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Rawool et al. (2015) |
|     | fimA-R | 5’-GCTGTGGATATGATTAAC-3’ | | | |
| papC | papC-F | 5’-GACGGCTGCTACTGAGGTCGCGG-3’ | 234 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Xia et al. (2011) |
|     | papC-R | 5’-ATATCCTTCTGTGACGATTCG-3’ | | | |
| papA | papA-F | 5’-GGAACGCAAGCAGACGGCCG-3’ | 374 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Xia et al. (2011) |
|     | papA-R | 5’-CGCAATGGCTCTGCTAAACGG-3’ | | | |
| fimC | fimC-F | 5’-TAAGGAAATCGCAGGACAGG-3’ | 337 | 95°C for 5 min, 30 cycles of 94°C for 30 s, 52°C for 30 s, 72°C for 45 s, and final extension at 72°C for 10 min | Antonio et al. (2007) |
|     | fimC-R | 5’-GCTGTGGATATGATTAAC-3’ | | | |

### TABLE 4 Samples and isolates from different food origins

| Products       | No. of samples | No. of samples positive for E. coli | Positive rate (%) |
|----------------|---------------|------------------------------------|-------------------|
| Pork           | 52            | 31                                 | 59.6              |
| Chicken        | 48            | 16                                 | 33.3              |
| Duck           | 11            | 4                                  | 36.4              |
| Fish           | 30            | 3                                  | 10.0              |
| Retail fresh milk | 21        | 11                                 | 52.4              |
| Beef           | 34            | 12                                 | 35.3              |
| Mutton         | 19            | 10                                 | 52.6              |
| Vegetables     | 154           | 17                                 | 11.0              |
| Ready-to-eat food | 62        | 8                                  | 12.9              |
| Total          | 431           | 112                                | 26.0              |

Note: n = 112: No. of samples positive for E. coli.

### TABLE 5 The reactions of E. coli to 17 antibacterial agents

| Antimicrobials | Resistant (n = 112) | Susceptible (n = 112, %) |
|----------------|---------------------|--------------------------|
| AMP            | 47 (42%)            | 23 (20)                  |
| CTX            | 12 (11%)            | 34 (30)                  |
| CAZ            | 25 (22%)            | 38 (34)                  |
| IPM            | 0                   | 112 (100)                |
| PIP            | 31 (28%)            | 40 (36)                  |
| AMX            | 37 (33%)            | 35 (31)                  |
| PB             | 2 (2%)              | 72 (64)                  |
| CIP            | 18 (16%)            | 48 (43)                  |
| LEV            | 12 (11%)            | 50 (45)                  |
| NAL            | 36 (32%)            | 34 (30)                  |
| GEN            | 12 (11%)            | 50 (45)                  |
| AMK            | 10 (9%)             | 55 (49)                  |
| STR            | 24 (21%)            | 44 (39)                  |
| TET            | 58 (52%)            | 22 (20)                  |
| CHL            | 30 (27%)            | 38 (34)                  |
| T/S            | 41 (37%)            | 32 (29)                  |
| ERY            | 12 (11%)            | 38 (34)                  |
| Resistance type | The number of multi-drug-resistant strain | The rate of multi-drug-resistant strains (%) | n = 112 |
|-----------------|------------------------------------------|-------------------------------------------|--------|
| AMP CTX GEN CIP LEV TET CHL AMK PIP T/S AMX STR NAL | E36 | 3 (2.7) |
| AMP CTX CAZ GEN CIP LEV TET CHL AMK PIP T/S AMX NAL | E37 | 5 (4.5) |
| AMP CTX CAZ CIP LEV TET CHL AMK PIP T/S AMX NAL | E38 | 1 (0.9) |
| AMP CTX CAZ CIP TET CHL T/S ERY NAL | E48 | 6 (5.4) |
| AMP CAZ TET CHL PIP T/S AMX CIP | E28 | 12 (11) |
| AMP CAZ TET CHL AMK T/S ERY AMX | E31 | 11 (10) |
| AMP TET T/S CAZ CHL AMX STR NAL | E47 | 1 (0.9) |
| AMP CIP LEV TET T/S AMX STR NAL | F38 | 3 (2.7) |
| AMP TET PIP T/S ERY AMX NAL | E9 | 5 (4.5) |
| AMP CAZ GEN PIP T/S AMX AMK | E23 | 1 (0.9) |
| AMP CAZ TET PIP AMX CIP LEV | E41 | 6 (5.4) |
| CAZ TET CHL T/S AMX STR NAL | E46 | 1 (0.9) |
| CAZ TET PIP T/S AMX STR NAL | E49 | 1 (0.9) |
| TET NAL T/S AMP PIP AMX CHL | F21 | 1 (0.9) |
| TET CHL T/S NAL CIP | E5 | 11 (10) |
| AMP TET CHL T/S STR | E8 | 1 (0.9) |
| AMP TET PIP AMX NAL | E43 | 6 (5.4) |
| GEN TET CHL T/S AMX | E51 | 5 (4.5) |
| NAL T/S AMP LEV CHL | F10 | 1 (0.9) |
| TET NAL AMP PIP LEV | F18 | 1 (0.9) |
| TET AMP PIP AMX CHL | F19 | 1 (0.9) |
| TET NAL T/S AMP LEV | F24 | 1 (0.9) |
| AMP PIP AMX CHL STR | F30 | 1 (0.9) |
| TET NAL T/S GEN STR | F32 | 1 (0.9) |
| NAL PIP AMX STR ERY | F56 | 1 (0.9) |

(Continues)
### 3.3 Antimicrobial resistance genotypes of *E. coli* isolates

We detected 11 of the 13 resistance genes (tetA, tetB, *bla*<sub>TEM</sub>, *bla*<sub>OXA</sub>, *floR*, *aad<sub>Ala</sub>*, *aadB*, sul1, sul2, strA, and strB), and one hundred isolates carried one or more antimicrobial genes. Resistance genes were not detected in twelve strains of *E. coli*. The resistance genotypes of *E. coli* isolates are shown in Table 7.

| Resistance type | The number of multi-drug-resistant strain | The rate of multi-drug-resistant strains (%; n = 112) |
|-----------------|------------------------------------------|-----------------------------------------------|
| GEN CIP TET AMX| E3                                       | 9 (8)                                         |
| AMP TET CHL T/S| E12                                      |                                               |
| CAZ TET AMX STR| E19                                      |                                               |
| CIP ERY AMX NAL| E20                                      |                                               |
| TET NAL PIP AMK| E26                                      |                                               |
| CAZ TET AMX NAL| E27                                      |                                               |
| TET T/S CIP AMK| E33                                      |                                               |
| TET AMP PIP STR| F45                                      |                                               |
| TET NAL AMP STR| F47                                      |                                               |
| CAZ TET CIP    | E18                                      | 10 (9)                                        |
| CTX CAZ CHL    | E39                                      |                                               |
| TET AMX CHL    | E40                                      |                                               |
| AMP CTX CAZ    | E45                                      |                                               |
| TET T/S AMP    | F9                                       |                                               |
| CHL STR ERY    | F23                                      |                                               |
| TET NAL AMP    | F35                                      |                                               |
| T/S AMX STR    | F49                                      |                                               |
| CHL ERY STR    | F53                                      |                                               |
| CHL GEN STR    | F55                                      |                                               |
| TET T/S        | E1                                       | 16 (14)                                       |
| AMP CAZ        | E15                                      |                                               |
| AMP CIP        | E16                                      |                                               |
| CAZ NAL        | E17                                      |                                               |
| AMP TET        | E21                                      |                                               |
| PB CIP         | E25                                      |                                               |
| AMP AMX        | F4                                       |                                               |
| AMP PIP        | F6                                       |                                               |
| AMP PIP        | F15                                      |                                               |
| AMP STR        | F17                                      |                                               |
| TET STR        | F28                                      |                                               |
| TET NAL        | F29                                      |                                               |
| NAL T/S        | F31                                      |                                               |
| AMP GEN        | F39                                      |                                               |
| GEN STR        | F42                                      |                                               |
| TET STR        | F44                                      |                                               |

Among 58 tetracycline-resistant *E. coli* isolates, tetA was found in 43 isolates and tetB in 30 isolates, although tetC was not detected in any. One of the beta-lactam resistance genes, *bla*<sub>TEM</sub>, was detected in 23 *E. coli* isolates, *bla*<sub>OXA</sub> was detected in 45, and *bla*<sub>PSE</sub> was not detected. Other resistance genes such as *floR*, sul1, sul2, *aad<sub>Ala</sub>*, *aadB*, strA, and strB were detected in 22, 18, 30, 21, 12, 31, and 27 isolates, respectively. The detection rate of resistance genes of our study was as follows: tetA (38%, 43/112), tetB (27%, 30/112),
| Sampling number | Origin          | Strain number | Resistance to antimicrobial agent | Resistance gene(s) |
|-----------------|-----------------|---------------|-----------------------------------|--------------------|
| K2              | Pork            | E1            | TET-T/S                           | tetA, bla\text{oxa}, bla\text{TEM} |
| K13             | Pork tenderloin | E2            | AMP-CIP-TET-CHL-PIP-T/S           | tetA, floR         |
| N19             | Chicken wings   | E3            | GEN-CIP-TET-AMX                   | tetA               |
| K50             | Beef            | E4            | –                                 | –                  |
| K34             | Pork            | E5            | TET-CHL-T/S-NAL-CIP               | tetA, bla\text{oxa}, floR, ada\text{TEM}, Sul1 |
| K46             | Chicken         | E6            | AMP-TET-CHL-PIP-T/S-AMX           | blao\text{oxa}, blao\text{TEM}, Sul1, sul2, strB |
| K51             | Beef            | E7            | –                                 | adaB               |
| K17             | Duck leg        | E8            | AMP-TET-CHL-T/S-STR               | floR, Sul1, sul2, strA, strB |
| S24             | Zhaer root leaf vegetable | E9 | AMP-TET-PIP-T/S-ERY-AMX-NAL | tetA, floR, Sul1, strA |
| S99             | Cold pig ears   | E10           | –                                 | –                  |
| S100            | Peanut salad    | E11           | –                                 | –                  |
| H8              | Porcine blood   | E12           | AMP-TET-CHL-T/S                   | adaB, strA         |
| H22             | Chicken wings   | E13           | –                                 | –                  |
| W41             | Mutton          | E14           | –                                 | strA               |
| N23             | Beef            | E15           | AMP-CAZ                           | –                  |
| S25             | Lettuce         | E16           | AMX-CIP                           | strA               |
| K14             | Chinese cabbage | E17           | CAZ-NAL                           | tetA               |
| H23             | Chicken wings   | E18           | CAZ-TET-CIP                       | tetA               |
| H76             | Cold bamboo shoots | E19 | CAZ-TET-AMX-STR                  | tetB, Sul1, sul2, strA, strB |
| S65             | Chicken breast  | E20           | CIP-ERY-AMX-NAL                   | strA               |
| S49             | Black fungus    | E21           | AMP-TET                           | tetA               |
| H32             | Beef            | E22           | AMP-CTX-CAZ-PIP-NAL-PB            | tetA, blao\text{oxa}, blao\text{TEM} |
| W9              | Pork            | E23           | AMP-CAZ-GEN-PIP-T/S-AMX-AMK       | tetB, blao\text{oxa}, ada\text{TEM} |
| S55             | Chicken wings   | E24           | CAZ-CIP-LEV-TET-CHL-PIP-T/S-ERY-AMX-STR-NAL | floR, Sul1, sul2, ada\text{TEM}, strA, strB |
| H33             | Beef            | E25           | PB-CIP                            | tetA, blao\text{oxa}, strA |
| W39             | Mutton          | E26           | TET-NAL-PIP-AMK                   | tetA, tetB, adaB   |
| W46             | Mutton          | E27           | TET-CHL-NAL-PIP-AMK               | blao\text{TEM}, strA |
| K4              | Pork liver      | E28           | AMP-CAZ-TET-CHL-PIP-T/S-AMX-CIP   | tetA, blao\text{oxa}, floR, sul2, ada\text{TEM}, strA, strB |
| H65             | Beef hind legs  | E29           | AMX                               | –                  |
| H61             | Dried beef      | E30           | –                                 | blao\text{TEM}    |
| H13             | Pork            | E31           | AMP-CAZ-TET-CHL-AMK-T/S-ERY-AMX   | blao\text{oxa}, floR, ada\text{TEM} |
| N11             | Marinated tofu  | E32           | AMP-CTX-CAZ-TET-PIP-T/S           | blao\text{TEM}    |
| S66             | Chicken         | E33           | TET-T/S-CIP-AMK                   | tetA, ada\text{TEM} |
| H27             | Pork            | E34           | AMP-CAZ-TET-PIP-NAL-CHL           | floR, blao\text{oxa} |
| K47             | Spicy dried tofu| E35           | TET                               | tetA, tetB         |
| W38             | Chicken wings   | E36           | AMP-CTX-GEN-CIP-LEV-TET-CHL-AMK-PIP-T/S-AMX-STR-NAL | blao\text{oxa}, blao\text{TEM}, floR, sul2, strA, strB, tetA |
| S70             | Chicken gizzard | E37           | AMP-CTX-CAZ-GEN-CIP-LEV-TET-CHL-AMK-PIP-T/S-AMX-STR-NAL | tetA, tetB, floR, sul2, strA, strB |
| S39             | Mutton          | E38           | AMP-CTX-CAZ-GEN-CIP-LEV-TET-CHL-AMK-PIP-T/S-AMX-STR-NAL | adaB, tetA, tetB |
| K40             | Pork liver      | E39           | CTX-CAZ-CHL                       | blao\text{oxa}    |
| W2              | Pork            | E40           | TET-AMK-CHL                       | tetA, blao\text{TEM} |
| S71             | Chicken         | E41           | AMP-CAZ-TET-PIP-AMX-CIP-LEV       | tetB, blao\text{oxa}, sul2, adaB, strA, strB |
| H24             | Pork liver      | E42           | AMP-CAZ-TET-CHL-PIP-T/S-ERY-LEV   | tetA, tetB, blao\text{oxa} |
| H60             | Chicken gizzard | E43           | AMP-TET-PIP-AMX-STR               | tetA, tetB, blao\text{TEM} |
| K33             | Porcine blood   | E44           | AMP-CAZ-TET-CHL-T/S-AMX           | tetA, blao\text{TEM}, floR |
| H78             | Spicy dried tofu| E45           | AMP-CTX-CAZ                       | tetA               |

(Continues)
| Sampling number | Origin                | Strain number | Resistance to antimicrobial agent | Resistance gene(s) |
|----------------|-----------------------|---------------|----------------------------------|--------------------|
| H28            | Pork liver            | E46           | CAZ-TET-CHL/T/S-AMX-STR-NAL      | tetA, bla_TEM, sul1, sul2, aadB, strA, strB |
| H30            | Pork                  | E47           | AMP-TET/T/S-CAZ-CHL-AMX-STR-NAL  | tetA, tetB, sul1, sul2, strB |
| H34            | Pork liver            | E48           | AMP-CTX-CAZ-CIP-TET-CHL/T/S-ERY-NAL | tetA, tetB, sul1, sul2, strA, strB |
| S10            | Pork fillet           | E49           | CAZ-TET-PIP-T/S-AMX-STR-NAL      | tetA, sul1, sul2, strA, strB |
| N31            | Mutton                | E50           | –                                | bla_TEM |
| K10            | Pork stuffing         | E51           | GEN-TET-CHL/T/S-AMX              | tetA, bla_TEM |
| W3             | Pork                  | E52           | AMP-CTX-PIP-T/S-AMX              | tetA, tetB, bla_TEM, aadA |
| S30            | Chicken               | E53           | CTX-GEN-TET-CHL-AMK-PIP-T/S-ERY-AMX-STR-NAL | tetA, tetB, sul1, sul2, strA, strB |
| H64            | Beef hind legs        | E54           | AMP-CTX-TET-T/S-NAL              | tetA, tetB, strA, strB |
| K64            | Red oil ear silk      | E55           | AMP-TET-CHL-AMK-T/S-NAL          | sul2 |
| N5             | Fish                  | E56           | AMP-CTX-CAZ-CIP-LEV-TET-T/S-ERY-AMX-STR-NAL | tetA, sul1, sul2, strB |
| N16            | Crustacean            | F1            | TET-NAL/T/S-AMP-PIP-AMX          | strA, strB, bla_OKA, tetA, floR, Sul1, sul2 |
| R1             | Retail fresh milk     | F2            | –                                | tetB |
| S27            | Bok choy              | F3            | TET-NAL-T/S-AMP-PIP-AMX          | strA, strB, sul2, bla_OKA, tetA, bla_TEM, aadA, floR |
| S56            | Broccoli              | F4            | AMP-AMX                          | tetB |
| S96            | Cold bean curd stick  | F5            | –                                | – |
| W51            | Sheep heart           | F6            | AMP-PIP                          | strA, strB, bla_TEM, aadA, floR, Sul1, sul2 |
| S72            | Bean sprouts          | F7            | TET                              | bla_OKA |
| H4             | Pork                  | F8            | TET                              | strA, strB, sul2, bla_OKA, tetA, bla_TEM |
| H9             | Pork                  | F9            | TET-T/S-AMP                       | tetA |
| N22            | Chicken               | F10           | NAL-T/S-AMP-LEV-CHL              | strB, aadA1a, floR, Sul1, sul2 |
| R2             | Retail fresh milk     | F11           | TET-NAL-T/S-AMP-PIP-AMX          | bla_OKA |
| N30            | Pepper                | F12           | –                                | – |
| W8             | Pig tail              | F13           | T/S                              | bla_OKA, tetB, aadA |
| R5             | Retail fresh milk     | F14           | T/S                              | tetB |
| R7             | Retail fresh milk     | F15           | AMP-PIP                          | floR |
| R8             | Retail fresh milk     | F16           | –                                | bla_OKA, aadB |
| S38            | Beef                  | F17           | AMP-STR                          | strB, sul2, bla_OKA |
| K44            | Chicken gizzard       | F18           | TET-NAL-AMP-PIP-LEV              | bla_OKA |
| W47            | Beef                  | F19           | TET-AMP-PIP-AMX-CHL              | strA, strB, sul2, bla_OKA, aadA |
| R8             | Retail fresh milk     | F20           | –                                | bla_OKA |
| H9             | Pork                  | F21           | TET-NAL-T/S-AMP-PIP-AMX-CHL      | strA, strB, sul2, bla_OKA, tetA, tetB, bla_TEM, floR, aadB |
| K28            | Celery                | F22           | –                                | bla_OKA |
| H33            | Pork                  | F23           | CHL-STR-ERY                      | strA, strB, bla_OKA, aadA, sul1, sul2, aadB |
| S68            | Chicken wings         | F24           | TET-NAL-T/S-AMP-LEV              | strA, strB, Sul1, sul2, tetA, bla_TEM, aadA |
| S79            | Lotus root            | F25           | ERY                              | tetB |
| S80            | Cabbage               | F26           | –                                | bla_OKA |
| S89            | Cucumber              | F27           | TET                              | bla_OKA, tetA, tetB |
| S58            | Sheep fat             | F28           | TET-STR                          | bla_OKA, tetB, aadA |
| K60            | Chicken gizzard       | F29           | TET-NAL                          | tetB |
| S8             | Pig heart             | F30           | AMP-PIP-AMX-CHL-STR              | strA, strB, bla_OKA, tetA, bla_TEM, aadA, Sul1 |
| W13            | Pork                  | F31           | NAL-T/S                          | bla_OKA |
| W14            | Pork                  | F32           | TET-NAL-T/S-GEN-STR              | bla_TEM, aadA, aadB |
| K26            | Carrot                | F33           | –                                | – |
| R9             | Retail fresh milk     | F34           | –                                | sul2, bla_OKA |
| S60            | Mutton                | F35           | TET-NAL-AMP                      | tetA, tetB, bla_OKA |

(Continues)
We found that the detection rate of pork was more than that of chicken, duck, and beef, but there are fewer resistance genes in pork as compared to chicken. Ayoyi, Bii, and Okemo (2008) showed that multi-drug resistance is closely related to different farm management treatments, and statistical significance ($p \leq .001$) was found between them.
Chickens are more likely to get sick than pigs, and in large-scale chicken breeding operations, farmers will use a large number of antibiotic and antiviral drugs for the prevention and treatment of chicken diseases. The antibiotics used include enrofloxacin, amikacin, colistin, ciprofloxacin, azithromycin, doxycycline hydrochloride, levofloxacin, lincomycin, doxycycline, gentamicin, gentamicin, levofloxacin, neomycin sulfate, ceftriaxone sodium, cefotaxime sodium, penicillin, sulfachloropyridine, and sulfquinoloxide sodium.

3.4 | Virulence genes of E. coli isolates

Table 8 shows that among the nine tested virulence genes, fimC, agg, stx2, fimA, fyuA, papA, stx1, and eaeA were found in 52, 34, 21, 19, 6, 3, 2, and 2 isolates, respectively, papC was not detected. Two strains (F6, F52) carried five virulence genes, and six strains (F5, F11, F12, F14, F50, and F51) also carried four virulence genes. Detailed results are shown in Table 9.
The emergence of virulence is mainly due to the presence of multiple virulence genes in E. coli pathogenicity islands. \textit{fyuA} is highly pathogenic and is often used as an indication of the presence or absence of high pathogenicity islands (HPI; Paniagua et al., 2017). We detected \textit{fyuA} virulence genes in six isolates (5.4%), compared to 83.3% found by Laupland, Gregson, Church, Ross, and Pitout (2008).

Bacterial pili and fimbriae are important structures for bacterial pathogenicity, and it has been suggested that type I fimbriae function primarily in the initial pathogenic phase of avian pathogenic \textit{E. coli} (APEC) infection. P-type fimbriae are also thought to contribute to bacterial pathogenicity (Paniagua et al., 2017). The \textit{fimC} virulence gene encodes a protein necessary for the biosynthesis of type I fimbriae. The \textit{papA} virulence gene encodes the main protein component of P-type fimbriae, and P-type fimbriae are encoded by the nine-gene \textit{pap} operon, which includes \textit{papA}, \textit{papB}, \textit{papC}, \textit{papD}, \textit{papE}, \textit{papF}, \textit{papG}, \textit{papH}, and \textit{papI}. Sequence analysis showed that there is sufficient homology between P fimbriae in humans and chickens to indicate that they share some common antigen (Laupland, Kibsey, & Gregson, 2013). We detected the \textit{fimC} gene in 46.4% of isolates, and the \textit{papA} gene was detected in 2.7%; \textit{papC} was not detected. This suggests that APEC in the Xinjiang region is mainly caused by a type I fimbriae.

In the current study, strong associations were found between the presence of \textit{fimC} and resistance to ciprofloxacin, gentamicin, amikacin, levofloxacin, and streptomycin; between the presence of \textit{fimA} and resistance to tetracycline, ampicillin, compound trimethoprim/sulfamethoxazole, and amoxicillin; between the presence of \textit{agg} resistance to gentamicin, tetracycline, ciprofloxacin, and levofloxacin; and between the presence of \textit{stx2} and resistance to ampicillin, tetracycline, compound trimethoprim/sulfamethoxazole, and amoxicillin.

Based on statistical analysis, the following correlations were identified: (a) expression of the \textit{fimC} gene and resistance to ciprofloxacin (\(p = .001\)), gentamicin (\(p = .001\)), amikacin (\(p = .001\)), levofloxacin (\(p = .001\)), and streptomycin (\(p = .001\)); (b) expression of the \textit{fimA} gene and resistance to tetracycline (\(p = .001\)), ampicillin (\(p = .001\)), compound trimethoprim/sulfamethoxazole (\(p = .001\)), and amoxicillin (\(p = .003\)); (c) expression of the \textit{agg} gene and resistance to gentamicin (\(p = .001\)), tetracycline (\(p = .001\)), ciprofloxacin (\(p = .017\)), and levofloxacin (\(p = .001\)); and (d) expression of the \textit{stx2} gene and resistance to ampicillin (\(p = .001\)), tetracycline (\(p = .001\)), compound trimethoprim/sulfamethoxazole (\(p = .002\)), and amoxicillin (\(p = .015\); Table 10).

### 3.5 The relationship between virulence genes and antibiotic resistance

Arisoy et al. (2008) showed that there was a correlation between antibiotic sensitivity and virulence factors (VFs) of \textit{E. coli} isolates causing pyelonephritis. They reported an increased presence of virulence genes \textit{pap}, \textit{sfa}, \textit{afai}, \textit{hly}, and \textit{aer} in sensitive strains. Horcajada et al. (2005) showed that a significant correlation was found between nalidixic acid resistance and the decreased prevalence of three VFs: \textit{sfa}, \textit{hly}, and \textit{cnf-1}.

### 4 CONCLUSIONS

Differences in the pathogenicity of \textit{E. coli} and its susceptibility to antimicrobial agents were detected in different retail foods. This must be taken into account in developing guidelines for retail food management. Periodic review and formulation of antibiotic consumption policies are required to control the spread and acquisition of antibiotic resistance. Because most isolates express several types of VFs at the same time, it is necessary to further study the interaction between different VFs at the molecular level.
In conclusion, *E. coli* has become a potential source of foodborne illness due to the possibility of horizontal transfer of drug-resistant genes, high drug resistance rate, and the correlation between the resistance to some antibiotics and several virulence factors. As those problems become more and more serious, we need to strengthen the supervision of veterinary drugs used in the raising of livestock. At the same time, the detection and monitoring of antimicrobial agents in animal foods can help to reveal the ongoing use of prohibited animal husbandry practices.

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CONFLICT OF INTEREST
The authors declare that they do not have any conflicts of interest.

ETHICAL STATEMENTS
This study did not involve any human or animal testing.

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