SEROTYPES, TOXINS AND ANTIBIOTIC RESISTANCE OF *Escherichia coli* (E.COLI) STRAINS ISOLATED FROM DIARRHEIC RABBITS IN PHU VANG, THUA THIEN HUE

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ABSTRACT

This study was conducted to determine the prevalence of *E. coli* in rabbits, their biochemical and serological characteristics, common virulence genes, and antibiotic resistance. The diarrhea rabbit feces were collected from households and rabbit farms in Phu Vang - Thua Thien Hue with a total of 250 samples for testing. The results showed that rabbits age from 31 to 45 days old had the highest incidence of diarrhea disease caused by *E.coli* (92.0%) and the lowest infection rate was observed in rabbits over 60 days old with an infection rate of 30%. Further, the isolated *E.coli* strains tested biochemical characteristics showed 100% motile, positive for indole and methyl red, fermenting glucose and lactose. Simultaneously these strains were detected belong to 7 serotypes O103, O157, O158, O169, O44, O125, O153 and susceptible to cefuroxime (95.45%), amikacin (86.37%), streptomycin (81.82%), amoxicillin (81.82%), tetracycline (68.18%), colistin (68.18%), ampicillin (63.63%), gentamycin (59.10%) and levofloxacin (50.0%), whilst resistant to doxycycline (100%), sulfamethoxazole-bactrim (95.46%), and neomycin (86.37%). By using PCR assay for detection of virulence genes of the isolated *E. coli* strains, there were 7 strains carried virulence genes, of which 4/7 *E. coli* strains carried *eaeA* and *tsh* genes (57.14%), 2/7 strains carried *stx2* gene (28.57%); 1/7 *E. coli* strains carried *stx1* gene (14.28%) and the F4, F5 and F6 genes were not found in all serotypes in this study.

KEYWORDS

Antibiotic susceptibility
Diarrhea
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1 Introduction

Rabbit farming in recent years has increased for various purposes including medical and educational laboratory animals. Rabbit meat is efficiently converted from vegetable protein into high-quality animal protein. However, the large-scale production of rabbit meat is severely affected by the high mortality of rabbits, which hinders mass production (Okerman, 1994). Gastrointestinal syndrome in young rabbits often has a clinical manifestation of diarrhea and leads to secondary infections, which is the cause of reduced resistance and increased mortality in rabbits, and serious economic impacts for the rabbit industry (Yang et al., 2017). E. coli is a very common bacteria in the gastrointestinal tract and it does not directly disease in rabbits, but stress or exposure to other pathogens can lead to its growth in the gut which results in death (Milon., 1996). Enteropathogenic E. coli (EPEC) is the main causative agent of acute intestinal disease in rabbits, characterized by intestinal lesions (Licois, 2004). Highly virulent E. coli strains causing diarrhea in rabbits were identified as belonging to 12 different O serotypes (Pisoni et al., 2004). Intestinal infections in rabbits caused by serotypes of O are known as diarrheal E. coli strains, so their pathogenicity is related to several virulence properties (Xia, 2010). In addition, the majority of E. coli isolates were resistant to different antibiotics (Wang, 2021). Currently, there is a lack of information on the incidence of diarrheagenic E. coli in rabbits in Vietnam. Therefore, in this study, we collected fecal samples from rabbit farms to identify the prevalence of E. coli in rabbits, biochemically, serologically, common virulence genes, and analyze their drug resistance characteristics to provide information to determine reasonable use of antibiotics.

2 Materials and Methods

2.1 Collection of samples

A total of 250 fecal samples were collected from 1 to 60 and over 60 days old New Zealand white rabbits with diarrhea from households and farms in Phu Vang–Thua Thien Hue, Vietnam. Collected samples were directly transferred to the Laboratory of immunology and vaccine, Institute of Biotechnology, Hue University for E. coli isolation and identification without any delay.

2.2 Isolation and biochemical identification of E. coli

The nutrient broth was used to enrich the collected samples and incubated for 20-24 hours at 37°C. Then inoculated separately from each sample onto Mac Conkey agar and further incubated for 24 hours at 37°C. Suspect colonies were selected for gram staining; morphological and biochemical characteristics of the isolated bacterial strains were determined according to Cruickshank et al. (1975).

2.3 Serological identification of isolated E. coli strains

The serotypes of isolated E. coli strains were determined by slide agglutination assay for detection of O antigen using E. coli antiserum (Edwards & Ewing, 1972).

2.4 Antibiotic Sensitivity Test

The antibiotic susceptibility of isolated E. coli strains were determined by using the disk diffusion method as suggested by Bauer et al. (1966). Antibiotics used in this study including ampicillin (AM-10 µg), amoxicillin (AX-10 µg), colistin (Co-10 µg), gentamycin (GE-10 µg), amikacin (AK-30 µg), streptomycin (SM-10 µg), tetracycline (TE-30 µg), doxycycline (DX-30 µg), sulfamethoxazole-bacitracin (BT-23.75 µg), cefuroxime (CU-30 µg), levofloxacin (LV-5 µg) and neomycine (NM-30 µg). The diameter of the zone of inhibition of E. coli bacteria by antibiotics on the diffusion disk was determined according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI, 2015).

2.5 Detection of common virulence genes of isolated E. coli

Genomic DNA of E. coli bacteria was extracted using the QIAamp DNA Mini Kit following the manufacturer’s instructions. PCR conditions and primer sequences are shown in Table 1. The volume of the reaction was carried out in 25μl including (DNA template, primers of each, dNTP, PCR buffer, and Taq DNA polymerase). PCR products were separated by electrophoresis in 1.0% agarose gel with TAE buffer at 80V.

2.6 Statistical analysis

The data were analyzed using the Minitab statistical package version 14.0. The results were compared by X² test (Chi-square test) and analysis of variance (ANOVA), p-value < 0.05 was considered statistically significant.

3 Results

3.1 Prevalence of E. coli in rabbit samples

The prevalence of E. Coli isolated from rabbits with diarrhea in Thua Thien Hue is presented in Table 2. The results showed that an overall infection rate of 55.2%. Rabbits with the age group of 31-45 days old had the highest incidence of diarrhea caused by E. coli (92.0%), followed by rabbits of age between 16-30 days old, 46-60 days old, and 1-15 days old with an infection rate of 74.0 %, 48.0 %, and 32.0%, respectively. The lowest infection rate was observed in rabbits over 60 days old with an infection rate of 30%.

3.2 Results of isolation and biochemical identification of E. coli

The morphological characters of E. coli showed that all isolates were Gram-negative, rod-shaped, non-sporulated bacteria and arranged
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Bacterial colonies appeared as smooth, shiny, donut-shaped, and are surrounded by dark pink area, strong lactose fermenting colonies on MacConkey's agar. The typical biochemical reactions of isolated *E. coli* strains are lactose and glucose-fermenting colonies and positive tests for indole, methyl red, and motility; tests were negative for citrate administration, urea hydrolysis, voges-proskauer, and no H₂S generation (Table 3).

### 3.3 Determination of serotypes of isolated strains of *E. coli*

The serotypes of isolated *E. coli* strains were determined by the slide agglutination test (Table 4). The results showed that from 45 isolated *E. coli* strains were classified into 7 serotypes including O103 (20.00%), O158 (20.00%), O125 (15.55%), O153 (13.34%), O169 (13.34%), O44 (8.89%), O157 (6.66%) and Untypable (2.22%).

### Table 1 Conditions of PCR for virulence gene amplification

| Target Gene          | Oligonucleotide sequences (5'-3') | Size Fragment (bp) | Annealing Temperature (°C) | Reference               |
|----------------------|----------------------------------|--------------------|----------------------------|-------------------------|
| Fimbrial (F4)        | GAA TCT GTC CGA GAA TAT CA GGT ACA GGT CTT AAT GG | 505                | 53                         | Boerlin et al., 2005    |
| Fimbrial (F5)        | AAT ACT TGT TCA GGG AGA AA AAC TTT GTG GTA CAC CT | 230                | 50                         |                         |
| Fimbrial (F6)        | GTAAC TCCACGTT GTATC AAGTT ACGTC CCTAGTGC | 409                | 53                         |                         |
| Attaching and effacing (eaeA) | ATG CTT AGT CCT GGT TTA GG GCC TTC ATC ATT TCG TTT GCC | 248                | 51                         | Bisi-Johnson et al., 2011 |
| Temperature sensitive hemagglutinin (tsh) | AGT CCA GCG TGA TAG TGG AGT CCA GCG TGA TAG TGG | 620                | 54                         | Delicato et al., 2003   |
| Shiga-Like Toxin (stxl) | ACAGCTGGATGATCTCAGTGG CTGAATCCCCTCCATTAG | 641                | 58                         | Dipineto et al., 2006   |
| Shiga-Like Toxin (stx2) | CCATGACAACGGACAGCAGTT CCTGTCAACTGAGCAGGACTTGG | 779                | 58                         |                         |

### Table 2 Prevalence of *E. coli* isolated from diarrhea rabbits

| Days old | Number of examined samples | Number of positive samples | Percentage (%) |
|----------|----------------------------|----------------------------|----------------|
| 1-15     | 50                         | 16                         | 32.00          |
| 16-30    | 50                         | 37                         | 74.00          |
| 31-45    | 50                         | 46                         | 92.00          |
| 46-60    | 50                         | 24                         | 48.00          |
| >60      | 50                         | 15                         | 30.00          |
| Total    | 250                        | 138                        | 55.20          |

### Table 3 Biochemical identification of isolated *E. coli*

| Biochemical test | Reaction |
|------------------|----------|
| Glucose          | +        |
| Lactose          | +        |
| Motility         | +        |
| Indole           | +        |
| Methyl red       | +        |
| Voges-proskauer  | -        |
| Citrate utilization | -    |
| Urea utilization | -        |
| Hydrogen sulphide | -      |

### Table 4 Serotypes of isolated *E. coli* strains from diarrhea rabbits

| Serotypes | Number | Percentage (%) |
|-----------|--------|----------------|
| O103      | 9      | 20.00          |
| O158      | 9      | 20.00          |
| O125      | 7      | 15.55          |
| O153      | 6      | 13.34          |
| O169      | 6      | 13.34          |
| O44       | 4      | 8.89           |
| O157      | 3      | 6.66           |
| Untypable | 1      | 2.22           |
| Total     | 45     | 100            |
The antibiotic susceptibility of isolated \textit{E. coli} strains was conducted with 12 antibiotics that are often used at rabbit farms in Vietnam. The results of the study showed that isolated \textit{E. coli} have a higher sensitivity to cefuroxime (95.45%), akamicin (86.37%), streptomycin (81.82%), amoxicillin (81.82%), tetracycline (68.18%), colistin (68.18%), ampicillin (63.63%), gentamycin (59.10%) and levofloxacin (50.0%) while isolated \textit{E. coli} were resistance to doxycycline (100%), sulfamethoxazole-bactrim (95.46%), neomycine (86.37%) (Table 5).

### Table 5 Susceptibility of isolated \textit{E. coli} to 12 commonly used antibiotics

| Antibiotics          | Number | Susceptible | Intermediate | Resistance  |
|----------------------|--------|-------------|--------------|-------------|
|                      | No     | Percentage (%) | No   | Percentage (%) | No   | Percentage (%) |
| Ampicillin           | 22     | 14          | 63.63 | 6           | 27.28 | 2            | 9.09 |
| Amoxicillin          | 22     | 18          | 81.82 | 3           | 13.63 | 1            | 4.55 |
| Colistin             | 22     | 15          | 68.18 | 4           | 18.18 | 3            | 13.64 |
| Gentamycin           | 22     | 13          | 59.10 | 0           | 0     | 9            | 40.9 |
| Akamicin             | 22     | 19          | 86.37 | 2           | 9.09  | 1            | 4.54 |
| Streptomycin         | 22     | 18          | 81.82 | 1           | 4.54  | 3            | 13.64 |
| Tetracycline         | 22     | 15          | 68.18 | 2           | 9.09  | 5            | 22.73 |
| Doxycycline          | 22     | 0           | 0     | 0           | 0     | 22           | 100  |
| Sulfamethoxazole-bactrim | 22  | 1           | 4.54  | 0           | 0     | 21           | 95.46 |
| Cefuroxime           | 22     | 21          | 95.45 | 0           | 0     | 1            | 4.55 |
| Levofloxacin         | 22     | 11          | 50.0  | 5           | 22.72 | 6            | 27.28 |
| Neomycine            | 22     | 2           | 9.09  | 1           | 4.54  | 19           | 86.37 |

#### 3.4 Determination of antibiotic susceptibility of isolated \textit{E. coli} strains

The antibiotic susceptibility of isolated \textit{E. coli} strains was conducted with 12 antibiotics that are often used at rabbit farms in Vietnam. The results of the study showed that isolated \textit{E. coli} have a higher sensitivity to cefuroxime (95.45%), akamicin (86.37%), streptomycin (81.82%), amoxicillin (81.82%), tetracycline (68.18%), colistin (68.18%), ampicillin (63.63%), gentamycin (59.10%) and levofloxacin (50.0%) while isolated \textit{E. coli} were resistance to doxycycline (100%), sulfamethoxazole-bactrim (95.46%), neomycine (86.37%) (Table 5).

#### 3.5 Detection of common virulence genes of isolation \textit{E. coli} by PCR

A total of 44 isolated \textit{E. coli} strains, only 7 different serotypes for each strain were tested by PCR to detect the presence of virulence genes including \textit{eaeA}, \textit{tsh}, \textit{stx1}, \textit{stx2}, \textit{F4}, \textit{F5}, and \textit{F6}. The results showed that the tested \textit{E. coli} strains had the presence of one of the virulence genes (\textit{eaeA}, \textit{tsh}, \textit{stx1} and \textit{stx2}) accounting for 100% (7/7). Whereas, the virulence genes \textit{F4}, \textit{F5}, and \textit{F6} were not found in all serotypes in this report (Table 6, Table 7, and Figure 1).
Table 6 The common virulence genes of isolated E. coli strains

| Virulence genes | E. coli isolates | Percentage (%) |
|-----------------|-----------------|----------------|
| eaeA            | 4/7             | 57.14          |
| Tsh             | 4/7             | 57.14          |
| stx1            | 1/7             | 14.28          |
| stx2            | 2/7             | 28.57          |
| F4, 5, 6        | 0/7             | 0.00           |

Table 7 Virulence genes in serotypes of isolated E. coli strains

| Serotypes | eaeA | Tsh | stx1 | stx2 | F4,5,6 |
|-----------|------|-----|------|------|--------|
| O103      | -    | -   | -    | -    | +      |
| O157      | -    | -   | -    | -    | -      |
| O158      | +    | +   | -    | -    | -      |
| O169      | -    | +   | -    | -    | +      |
| O44       | +    | -   | +    | -    | -      |
| O125      | +    | +   | -    | -    | -      |
| O153      | +    | +   | -    | -    | -      |

4 Discussion and conclusions

E. coli is one of the common bacteria in the gut microbiota of rabbits, when the body is exposed to adverse conditions, they will become pathogens causing infections inside and outside of the digestive tract (Okerman, 1994). Rabbit farms are severely affected economically by the high mortality rate in rabbits caused by Enteropathogenic E. coli (Stakenborg et al., 2006). Diarrhea caused by E. coli leads to a high mortality rate in a rabbit farm with a rate of 75% (Hong et al., 2017). In this study, E. coli were isolated from the diarrheic rabbits with an overall incidence rate of 55.2% (Table 1). This number is similar to the findings of Alton et al. (2013), Entssar et al. (2000), and Sawsan (2012), those who have isolated E. coli from diarrheic rabbits with percentages of 53.7%, 61%, and 64%, respectively. In contrast, lower rates of E. coli from diarrheic rabbits were recorded by Sharada et al. (2010), Hasan et al. (2011), Literak et al. (2013), and Radwan et al. (2014) with 44.61%, 36.20%, 35.74%, and 41.5%, correspondingly. In the current study, the highest incidence of diarrhea caused by E. coli was reported at the age of 31 to 45 days old, accounting for 92% (Table 2). The reason may be that at this stage, rabbits are often weaned, so their ability to be affected by adverse factors such as housing, food, and care conditions are high which lead to rabbits at a high disease rate (Dung, 2011, Bekheet, 1983; Sahin et al., 2011).

The classification of serotypes isolated from 44 E. coli strains are O103, O158, O125, O153, O169, O44, and O157 (Table 4). These serotypes are similar to O125 and O158 which were reported by Aisha & Yousief (1999). Further, the serotypes O44 and O158 are associated with the diarrhea rabbits (Shahin et al., 2011) while serotype O125 is associated with the rabbit’s enteritis (Alshimaa, 2007). Besides, the presence of different serotypes such as O111 and O114 were also reported by Scaletsky et al. (1984), serotypes O119, O55, and O128 by Morsy et al. (2002), and serotypes O109, O15, and O8 by Walaa & Lamyaa (2016). Some reports indicated that the common serotypes among the E. coli strain associated with rabbit diarrhea are O103, O49, O26, O128, O92, and O44 in which serotype O44 is present most frequently (Blanco et al., 1997; Marches et al., 2000; Morsy et al., 2002).

Regarding antibiotic sensitivity of isolated E. coli serotypes, out of 25 E. coli O serotypes identified, only 22 different serotypes were used for antibiotic susceptibility testing (Table 5). Results of antibiotic sensitivity showed variable sensitive to cefuroxime (95.5%), ampicillin (86.37%), streptomycin (81.82%), amoxicillin (81.82%), tetracycline (68.18%), colistin (68.18%), ampicillin (63.63%), gentamicin (59.10%), and levofloxacin (50.0%). High resistance was reported against the doxycycline (100%), sulfamethoxazole (95.46%), and neomycin (86.37%). Similarly, E. coli strains isolated from diarrhea rabbits were resistant to sulfamethoxazole and susceptible to gentamycin (Moharam et al., 1993; Abd-El Rahman et al. 2005; Rhouma et al., 2020). In this study, all isolated E. coli showed high resistance to doxycycline, sulfamethoxazole, and neomycin. This is consistent with the fact that these antibiotics were widely used for the prevention and treatment of diseases in rabbits. Besides, they were very susceptible to cefuroxime, ampicillin, streptomycin, amoxicillin, tetracycline, and different antibiotics. This suggests that these antibiotics are less frequently used in rabbit farms.

Out of 44 serotypes, only 7 isolates of E. coli were identified with different serotypes to detect the presence of common virulence genes by PCR (Table 6, 7). The results showed that the presence of the eaeA gene in serotypes O157, O158, O125, and O153 with 57.14% (4/7). Further, 57.14% (4/7) were positive to tsh gene present in serotypes O158, O169, O125, and O153; while 28.57% (2/7) were positive to stx2 gene present in serotype O103, O169; and 14.28% (1/7) were positive to stx1 gene present in serotype O44. Camarda et al. (2003) reported that the eaeA gene accounted for 28.57% of the isolated E. coli strains tested by PCR, while Alexis & James (2003) reported that, 25% of the eaeA gene was present in a total of 28 samples tested, Rhouma et al. (2020) suggested that out of isolated 40 E. coli strains, 17 strains carry the eaeA gene. Similarly, Pohl et al. (1993) and Blanco et al. (2006) showed that the eaeA gene accounts for a high proportion in serotypes isolated from diarrhea rabbits. Hassan & Al-Azeem (2009) reported that 31% of the isolated strains of E. coli carried the eaeA gene and possessed an stx1 gene. Mohamed et al. (2019) suggested that the serotypes of E. coli O148 and O44 isolated from
diarrheal rabbits carried the eaeA, stx1 gene. Regarding, the tsh gene, Ashraf et al. (2014) detected in serogroups of E. coli O55, O125, and O146 possessing tsh, eaeA genes while virulence gene stx2 was detected in serotypes O55 and O125. In this report, the presence of the serotypes carries virulence genes F4, F5 and F6 were not found in all serotypes in this study.

Conclusion

In this study, E. coli strains from diarrhea rabbits were isolated from households and farms in Thua Thien Hue, Vietnam. Isolated strains of E. coli were identified as belonging to seven serotypes including O103, O158, O125, O153, O169, O44, O157, and Untypable. The classified serotypes carry different virulence genes that cause diarrhea in rabbits. In addition, isolated strains of E.coli showed high resistance to some antibiotics commonly used in rabbit farms in Vietnam.

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

Abd-El Rahman AA, Hamed NA, Mostafa FA (2005) Isolation and pathogenicity of intestinal pathogens associated with the enteritis complex in rabbits with special reference to Escherichia coli and Salmonella. Veterinary Medical Journal 51(106): 180-197.

Aisha RA, Yousief HMZ (1999) Escherichia coli isolated from chickens and rabbits with special reference to their pathogenicity. Journal of the Egyptian Veterinary Medical Association 59(1): 45–59.

Alexis G, James GF (2003) The Rabbit as a New Reservoir Host of Enterohemorrhagic Escherichia coli. Emerging Infectious Diseases 79(1):411-414.

Alshimaa AM (2007) Bacteriological studies on enteric m.os in rabbits. Master degree in bacteriology. Faculty of Veterinary Medicine Beni-Suef University, Egypt.

Alton GS, Ellen MB, Carolyn MM, Charles PB, Rachel SD, Loretta R, Nicola MAP, James GF(2013) Enteropathogenic Escherichia coli Prevalence in Laboratory Rabbits. Veterinary Microbiology 163(3-4): 395–398.

Ashraf AA, Ahmed AA, Maarouf S, Hofy, Emad EAE (2014) Detection of some virulence genes of avian pathogenic E.coli by polymerase chain reaction. Benha Veterinary Medical Journal 26(2):159-176.

Bauer AW, Kirby WMM, Sherris JC, Turek M (1966) Antibiotic susceptibility testing by standardized single disk method. American Journal of Clinical Pathology 45: 493.

Bekheet AA (1983) Some studies on bacteria causing mortalities on rabbits with special reference to E. coli. M.V.Sc. Thesis, Faculty of Veterinary Medicine, Zagazig University, Egypt.

Bisi-Johnson MA, Chikwelw LO, Sandeep DV, Kamaldeen AB, Toshio H (2011) Molecular basis of virulence in clinical isolates of Escherichia coli and Salmonella species from a tertiary hospital in the Africa. Eastern Cape, Gut Pathogens.

Blanco JE, Blanco M, Blanco J, Mora A, Balaguer L, Cuervo L, Balsalobre C, Munof A (1997) Prevalence and characteristic of enteropathogenic Escherichia coli eaeA gene in diarrhoeic rabbits. Microbiology and Immunology 41(2):77-82.

Blanco M, Blanco JE, Bahbi G, Alonso MP (2006) Identification of two new intimin types in atypical enteropathogenic Escherichia coli. International Microbiology 9(2):104-110.

Boerlin P, Travis R, Gyles, CL, Reid-Smith R, Janecko N, Lim H, Nicholson V, McEwen SA, Friendship R, Archambault M (2005) Antimicrobial Resistance and Virulence Genes of Escherichia coli Isolates from Swine in Ontario. Applied and Environmental Microbiology Journal 71(11): 6753-6761.

Camarda A, Pennelli D, Battista P, Martella V (2003) Virulence genes and antimicrobial resistance patterns of enteropathogenic Escherichia coli from rabbits in southern Italy. 8th World Rabbit Congress 7-10 September. Puebla City Mexico.

CLSI (2015) Clinical and Laboratory Standards Institute. Performance Standards for Antimicrobial Susceptibility Testing: Twenty-Fifth Informational Supplement. CLSI document M100-S25. Wayne, PA: Clinical and Laboratory Standards Institute.

Cruickshank R, Duguel JP, Marmion BP, Swain RHA (1975) Medical microbiology. 12th ed. Vol. II Churchill Living stone, Edenburg, London and New York. Des 5: 895–913.

Delicato ER, de Brito BG, Gazarzi LCI, Vidotto MC (2003) Virulence- associated genes in Escherichia coli isolates from poultry with coli bacillosis. Veterinary Microbiology 94(2): 97–103.

Dipineto L, Santaniello A, Fontanella M, Lagos K, Fioretti A, Menna LF (2006) Presence of Shiga toxin producing Escherichia coli O157:H7 in living layer hens. Letters in Applied Microbiology 43: 293–295.
Dung NV (2011) Study on some epidemiological and pathogenic characteristics of E.coli bacteria in rabbit diarrhea syndrome in Bac Giang, Vietnam. M.V.Sc. Thesis, Faculty of Animal Science and Veterinary Medicine, Bac Giang Agriculture and Forestry University, Vietnam.

Edwards PR, Ewing WH (1972) Identification of Enterobacteriaceae, 3rd Ed. Minnea polis, Burgess Publishing, Co.

Enttsar AA, Souad A, Magda S (2000) The biological and biochemical studies on the Eimeria stiedae and E. coli infections in rabbits. Beni-Suef Veterinary Medical Journal 10(1): 179 - 190.

Hasan B, Faruque R, Drobi M, Waldenstrom J, Sadique A, Ahmed KU, Islam Z, Parvez MB H, Olsen B, Alam M (2011) High prevalence of antibiotic resistance in pathogenic E.coli from large- and small-scale poultry farms in Bangladesh. Avian Diseases Journal 55(4):689-692.

Hassan SA, Al-Azeem MW (2009) Determination of virulence gene markers and antibiotic resistance in E. coli isolated from rabbit in Egypt. Global Veterinaria 3(3): 260-267.

Hong JC, Wan YY, Chun YW (2017) The Review on Structure of Intestinal Flora at Different Growth Stages of Rabbits. International Conference on Medicine Sciences and Bioengineering 245-253.

Licois D (2004) Domestic Rabbit Enteropathies. Proceeding of the 8th Congress of World Veterinary Rabbit Association (WRSA), puebla, Pp. Mexico: 385-403.

Literak I, Reitschmied T, Bujnakova D, Dolejska M, Cizek Loveless BJ and MH, Saier JR (2013) A novel family of channel-forming, autotransporting, bacterial virulence factors. Molecular Membrane Biology 14 (3):113–123.

Marches O, Nougayrede JP, Boullier SG, Raymond I, Pohl P, Boury M, De Rycke J, Milon A, Oswald E (2000) Role of tirand intimin in the virulence of rabbit enteropathogenic Escherichia coli serotypes 0103: H2. Infection and Immunity 68(4): 2171-2182.

Milon A (1996) Weaned rabbit colibacillosis: a model for study of enteropathogenic Escherichia coli. 6th World rabbit congress, Toulouse 3: 1322.

Mohamed MS, Sawsan KE, Madiha SI (2019) Detection of Diarrheagenic Escherichia coli in Rabbits. Alexandria Journal of Veterinary Sciences 61(2): 137-143

Moharam HK, Dutta NR, Misra PR (1993) Enteritis in poultry in Orissa: In vitro drug susceptibility to different antimicrobial agents. Indian Veterinary Journal 70: 281-282.

Morsy MK, Mohamed SY, Fathy HM (2002) Diarrhea in newly weaned rabbits, (Bacteriological and pathological studies). SCVM J (2): 221-225.

Okerman L (1994) Diseases of the digestive system. In: Price CJ (Ed), Diseases of Domestic Rabbits. Blackwell Scientific Publications, Oxford: Pp. 71-91.

Pisoni AM, Piccirillo A, Gallazzi D, Agnoletti F, Grilli G (2004) Biotype and susceptibility to antimicrobial agents of rabbit Escherichia coli. Proceedings Of 8th World rabbit congress. Puebla City, Mexico: Pp. 608-613.

Pohl PH, Peeters JE, Jacquemin ER, Lantersmans PF, Mainil JG (1993) Identification of cag sequences in enteropathogenic E. coli strains from rabbits. Infection and Immunity 61(5): 2203 - 2206.

Radwan IA, Salam HSH, Abd-Alwanis SA, Al-Sayed MAY (2014) Frequency of some virulence associated genes among multidrug- resistanceE.coliisolated from septicemic broiler chicken. International Journal of Advanced Research 2(12): 867-874.

Rhouma BR, Jouini A, Klibi A, Hamrouni S, Boubaker A, Kniha S, Maaroufi A (2020) Molecular characterisation of antimicrobial resistance and virulence genes in Escherichia coli strains isolated from diarrhoeic and healthy rabbits in Tunisia. World Rabbit Science 28(2): 81-91.

Sawsan (2012) Studies on some pathogenic bacteria causing mortality in young rabbits and study the effect of honey on these bacteria in vitro. Alexandria Journal of Veterinary Sciences 36(1): 149-162.

Scaletsky ICA, Silva MLM, Trabulsli LR (1984) Distinctive patterns of adherence of enteropathogenic E. coli to Hela cells. Infection and Immunity 45(2): 534-536.

Shahin AM, Lebdah MA, Ali GRM (2011) Escherichia coli as an Etiological Agent of Mucoid Enteropathy in Rabbits. Researcher 3(7):8-16.

Sharada R, Ruban SW, Thiageeswaran M (2010) Isolation, characterization and antibiotic resistance pattern of E.coliisolated from poultry. American-Eurasian Journal of Scientific Research 5(1): 18-22.

Stakenborg T, Vandekerchove D, Mariën J, Laevens H, Imberechts H, Peeters J (2006) Protection of rabbits against Enteropathogenic E. coli (EPEC) using an intimin null mutant. BioMed Central, Veterinary Research 2(22): 1186-1746.
Serotypes, Toxins and Antibiotic Resistance of E. Coli Strains Isolated From Diarrheic Rabbits in Phu Vang, Thua Thien Hue

Walaa FS, Lamyaa MR (2016) Prevalence of diarrheagenic Escherichia coli in suckling rabbits. Japanese Journal of Veterinary Research 64(2): 149-153.

Wang X, Zhai Z, Zhao X, Zhang H, Jiang H, Wang X, Wang H, Chang W (2021) Occurrence and characteristics of Escherichia coli mcr-1-like in rabbits in Shandong, China. Veterinary Medicine and Science 7:219–225.

Xia X, Meng J, McDermott P F, Ayers S, Blickenstaff, K, Tran T, Abbott J, Zheng J, Zhao S (2010) Presence and characterization of shiga toxin-producing Escherichia coli and other potentially diarrheagenic E. coli strains in retail meats. diarrheagenic E. coli strains in retail meats. Applied and Environmental Microbiology 76 (6): 1709-1717.

Yang C, Bohao Z, Yuwei W, Shuaishuai H, Lin M, Cigen Z, Yulai P, Xinsheng W (2017) Impacts of diarrhea on the immunesystem, intestinal environment, and expression of PGRPs in New Zealand rabbits. Peer J 5: e4100. doi: 10.7717/peerj.4100.