

# Molecular characterization and antibiotic susceptibility pattern of caprine Shiga toxin producing-*Escherichia coli* (STEC) isolates from India

Mahanti, A.<sup>1</sup>; Samanta, I.<sup>2\*</sup>; Bandyopadhyay, S.<sup>3</sup>  
and Joardar, S. N.<sup>2</sup>

<sup>1</sup>Ph.D. Scholar, Department of Veterinary Microbiology, Faculty of Veterinary and Animal Sciences, West Bengal University of Animal and Fishery Sciences, 37, K. B. Sarani, Kolkata-700037, West Bengal, India; <sup>2</sup>Department of Veterinary Microbiology, Faculty of Veterinary and Animal Sciences, West Bengal University of Animal and Fishery Sciences, 37, K. B. Sarani, Kolkata-700037, West Bengal, India; <sup>3</sup>Division of Veterinary Medicine, Indian Veterinary Research Institute, Eastern Regional Station, Kolkata, West Bengal, India

\*Correspondence: I. Samanta, Department of Veterinary Microbiology, Faculty of Veterinary and Animal Sciences, West Bengal University of Animal and Fishery Sciences, 37, K. B. Sarani, Kolkata-700037, West Bengal, India. E-mail: isamanta76@gmail.com

(Received 6 Apr 2014; revised version 28 Jul 2014; accepted 16 Nov 2014)

## Summary

The present study was conducted to detect the occurrence, serotype, genotype, phylogenetic relationship and antimicrobial resistance pattern of STEC from healthy goats of West Bengal, India. From the 125 faecal samples collected from healthy goats, 245 isolates were identified as *Escherichia coli*. The *E. coli* harbouring any gene for Shiga toxins (*stx*<sub>1</sub>/*stx*<sub>2</sub>) was detected in 36 (14.7%) of the 245 *E. coli* isolates. These STEC strains belonged to 22 different serogroups (O2, O5, O20, O21, O22, O25, O41, O44, O45, O60, O71, O76, O84, O85, O87, O91, O103, O112, O113, O120, O156, and O158) and three were untypeable. The *stx*<sub>1</sub> and *stx*<sub>2</sub> was detected in 26 (72.2%) and 21 (58.3%) of Shiga toxin producing-*E. coli* (STEC) isolates, respectively. Further, *E. coli* harbouring *eaeA* only (Enteropathogenic *E. coli*) and *ehxA* was detected in 22 (61.1%) and 28 (77.7%) isolates, respectively. Whereas the *saa* was present in 8 (22.2%) *E. coli* isolates. The subtyping of the 26 *E. coli* strains possessing *stx*<sub>1</sub> showed that 73.3% (19/26) of these isolates were positive for *stx*<sub>1C</sub> subtype. Of the 21 isolates with the *stx*<sub>2</sub> gene, 42.8% (9/21) were positive for *stx*<sub>2C</sub>, and 38.1% (8/21) were positive for *stx*<sub>2d</sub> gene. The phylogenetic analysis of STEC strains after RAPD reveals eight major clusters. However, no serogroup specific cluster was observed. Resistance was observed most frequently to erythromycin (80.5%), amikacin (52.7%), cephalothin (50%), kanamycin (41.6%), neomycin (36.1%) and gentamycin (36.1%) and less frequently to norfloxacin (2.7%), enrofloxacin (2.7%), and ciprofloxacin (2.7%). Multidrug resistance was observed in eleven STEC isolates.

**Key words:** Goat, EPEC, STEC, West Bengal

## Introduction

Shiga toxin producing-*Escherichia coli* (STEC) are food borne pathogens associated with a spectrum of human illness ranging from bloody diarrhoea to life-threatening infection such as hemolytic uraemic syndrome (HUS), thrombotic thrombocytopenic purpura (TTP) and hemorrhagic colitis (HC). The bacteria produce the life-threatening infection with the help of Shiga toxins, encoded by *stx*<sub>1</sub> and *stx*<sub>2</sub> genes and the products of the locus of enterocyte effacement (LEE) pathogenicity island such as *eaeA* gene. The *eaeA* gene encodes for the "intimin" protein which is involved in the intimate adhesion of bacteria to the enterocytes and production of attaching and effacing (AE) lesion (Paton and Paton, 1998a). Some LEE negative strains can also possess *saa* gene encoding a novel outer membrane protein which acts as auto agglutinating adhesin (Paton *et al.*, 2001). The majority of STEC strains also have hemolytic phenotype in washed sheep blood agar due to production of enterohemolysin, encoded by *ehxA* gene (Beutin *et al.*, 1989).

The domestic and wild ruminants act as the major

reservoir of STEC which can secrete the bacteria through the faeces (Wani *et al.*, 2004). Due to absence of clinical manifestation the reservoir animals are included in the food production. The food products from the reservoir animals are at risk of contamination with STEC either with their faeces or intestinal contents during slaughter (Asakura *et al.*, 2014). Thus, STEC can enter the human food chain through contaminated food products and is responsible for several food borne outbreaks as reported earlier (CDC, 2008; Ethelberg *et al.*, 2009). So, the present study was conducted to detect the occurrence, serotype, genotype, phylogenetic relationship and antimicrobial resistance pattern of STEC from healthy goats of West Bengal, India. Multiplex PCR was used for primary screening of *E. coli* isolates for Shiga toxin genes, *eaeA* and *ehxA*. PCR based subtyping of the Shiga toxin genes, serogrouping and RAPD based phylogenetic relationship were determined among the isolates.

## Materials and Methods

### Sampling

A total of 125 faecal samples were collected from

healthy goats in different locations of West Bengal, India. The samples were transported to the laboratory in transport medium in sterile vials on ice for further processing. None of the samples were held for more than 24 h at 4°C.

### Isolation of *Escherichia coli*

The collected samples were inoculated into the nutrient broth and were incubated at 37°C for 24 h (HiMedia, India). The growth in the nutrient broth was transferred to MacConkey's agar (HiMedia, India) and again incubated at 37°C overnight. The next day 2-3 rose pink colonies were randomly picked and transferred to EMB agar (HiMedia, India) followed by an overnight incubation at 37°C. The colonies were observed for metallic sheen and single colony was streaked into nutrient agar slant for further biochemical confirmation. All the pure cultures obtained from nutrient agar slant were subjected to Gram's staining and standard biochemical tests as described earlier (Quinn *et al.*, 1994). The strains were preserved in glycerol broth at -70°C for subsequent characterization.

### Multiplex-PCR for detection of *stx*<sub>1</sub>, *stx*<sub>2</sub>, *eaeA*, *ehxA*, *saa* gene sequences

For PCR based detection of STEC genes, all the *E. coli* isolates were subjected to DNA extraction as per previously described method of Samanta *et al.* (2014). All the *E. coli* isolates were subjected to multiplex-PCR (m-PCR) for the detection of Shiga toxin gene(s) (*stx*<sub>1</sub>, *stx*<sub>2</sub>), intimin (*eaeA*), enterohaemolysin (*ehxA*) and STEC autoagglutinating adhesin (*saa*) as per the previously described primers and protocol (Paton and Paton, 1998b, 2002; Paton *et al.*, 2001). The m-PCR was performed in a gradient thermocycler (Eppendorf ProS, Germany). All the reagents and oligo nucleotide primers were procured from Genetix Biotechnology Asia Private Limited, India. The amplified DNA products were visualized by Gel Documentation System (UVP, UK) after gel electrophoresis in 2% agarose containing ethidium bromide (0.5 µg ml<sup>-1</sup>) (SRL, India) as per the standard protocol (Sambrook and Russel, 2001).

### Subtyping of *stx*<sub>1</sub> and *stx*<sub>2</sub> gene

All the *stx*<sub>1</sub> positive *E. coli* isolates were subjected to PCR amplification for the presence of *stx*<sub>1c</sub> gene by using the previously described method of Zhang *et al.* (2002). Further, all the *stx*<sub>2</sub> positive *E. coli* isolates were subjected to m-PCR amplification for the presence of *stx*<sub>2c</sub>, *stx*<sub>2d</sub>, as described (Wang *et al.*, 2002).

### Serogrouping

The *E. coli* isolates harbouring characteristic virulence genotype were O-serogrouped from National *Salmonella* and *Escherichia* Centre, Central Research Institute, Kausali, Himachal Pradesh, India.

### Molecular characterization of STEC isolates and phylogenetic analysis

All the STEC isolates were subjected to RAPD-PCR

as described (Mahanti *et al.*, 2013). The amplified DNA products were visualized by Gel Documentation System (UVP, UK) after gel electrophoresis in 1% agarose containing ethidium bromide (0.5 µg ml<sup>-1</sup>) (SRL, India) as per the standard protocol (Sambrook and Russel, 2001). An unrooted phylogenetic tree was created by using neighbour joining method in the Doc-itLs image analysis software (UVP, UK).

### Antibiotic sensitivity test of STEC isolates

All the STEC isolates were tested for their sensitivity and resistance to different antibiotics by the disc diffusion method (CLSI, 2008). The antibiotics used were chloramphenicol (25 µg), co-trimoxazole (25 µg), ciprofloxacin (5 µg), gentamicin (10 µg), neomycin (30 µg), norfloxacin (10 µg), streptomycin (30 µg), oxytetracycline (30 µg), cephalothin (30 µg), amikacin (30 µg), ceftazidime (30 µg), kanamycin (30 µg), ceftriaxone (30 µg), levofloxacin (5 µg), amoxicillin + clavulanic acid (30 µg), cefaclor (30 µg), cefuroxime (30 µg), azithromycin (30 µg), piperacillin + tazobactam (100 + 10 µg), cefepime + tazobactam (30 + 10 µg), ampicillin + cloxacillin (10 µg), enrofloxacin (10 µg), amoxicillin (25 µg), erythromycin (10 µg), doxycycline hydrochloride (30 µg) and pefloxacin (5 µg).

## Results

### Prevalence of Shiga toxin producing-*E. coli*

From the 125 faecal samples collected from healthy goats of different places in West Bengal, India, 245 isolates were identified as *E. coli* after morphological and biochemical confirmation. The *E. coli* harbouring any gene for Shiga toxins (*stx*<sub>1</sub>/*stx*<sub>2</sub>) was detected in 36 (14.7%) of the 245 *E. coli* isolates. These STEC strains belonged to 22 different serogroups (O2, O5, O20, O21, O22, O25, O41, O44, O45, O60, O71, O76, O84, O85, O87, O91, O103, O112, O113, O120, O156, and O158) and three were untypeable (Table 1).

The *stx*<sub>1</sub> and *stx*<sub>2</sub> were detected in 26 (72.2%) and 21 (58.3%) of STEC isolates, respectively. Further, *E. coli* harbouring *eaeA* only (Enteropathogenic *E. coli*) and *ehxA* was detected in 22 (61.1%) and 28 (77.7%) isolates, respectively. Whereas the *saa* was present in 8 (22.2%) *E. coli* isolates from goat in this study, out of which 5 (62.5%) were associated with the *ehxA* gene (Table 1, Fig. 1).

### Subtyping of *stx*<sub>1</sub> and *stx*<sub>2</sub>

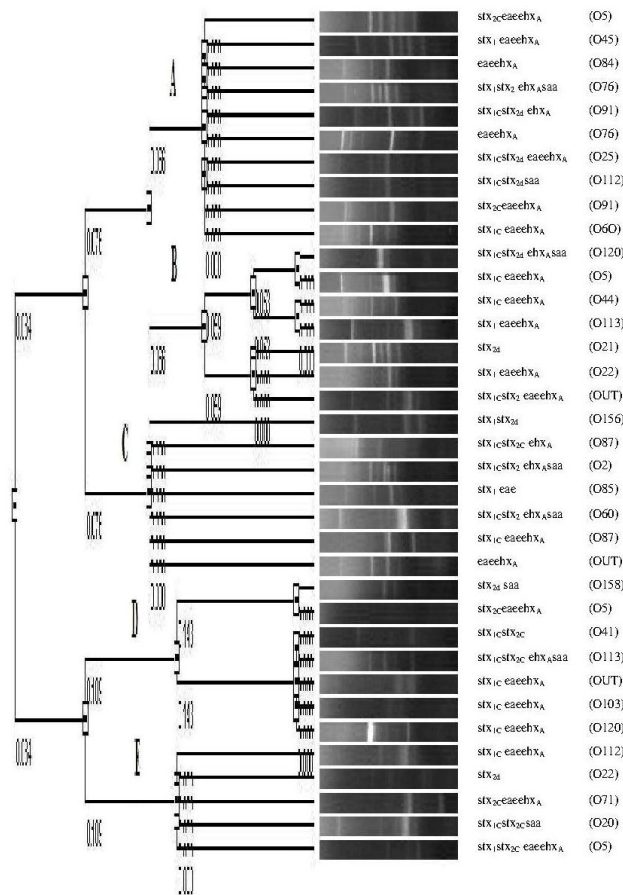
The subtyping of the 26 *E. coli* strains possessing *stx*<sub>1</sub> showed that 73.% (19/26) of these isolates were positive for *stx*<sub>1c</sub> subtype. Most of the *stx*<sub>1c</sub> possessing strains occurred in combination with *ehxA*, *saa* or both. Of the 21 isolates with the *stx*<sub>2</sub> gene, 42.8% (9/21) were positive for *stx*<sub>2c</sub>, and 38.1% (8/21) were positive for *stx*<sub>2d</sub> gene (Table 1, Fig. 1).

### Molecular characterization of STEC isolates and phylogenetic analysis

All 36 STEC strains were characterized by RAPD-

**Table 1:** Serogroup and genotype of the STEC and EPEC isolates from goats in West Bengal, India

Serial No.	Serogroup	Genotype
G1	O5	<i>stx<sub>2C</sub>, eae, ehxA</i>
G2	O45	<i>stx<sub>1</sub>, eae, ehxA</i>
G3	O84	<i>eae, ehxA</i>
G4	O76	<i>stx<sub>1</sub>, stx<sub>2</sub>, ehxA, saa</i>
G5	O91	<i>stx<sub>1C</sub>, stx<sub>2d</sub>, ehxA</i>
G6	O76	<i>eae, ehxA</i>
G7	O25	<i>stx<sub>1C</sub>, stx<sub>2d</sub>, eae, ehxA</i>
G8	O112	<i>stx<sub>1C</sub>, stx<sub>2d</sub>, saa</i>
G9	O91	<i>stx<sub>2C</sub>, eae, ehxA</i>
G10	O60	<i>stx<sub>1C</sub>, eae, ehxA</i>
G11	O120	<i>stx<sub>1C</sub>, stx<sub>2d</sub>, ehxA, saa</i>
G12	O5	<i>stx<sub>1C</sub>, eae, ehxA</i>
G13	O44	<i>stx<sub>1C</sub>, eae, ehxA</i>
G14	O113	<i>stx<sub>1</sub>, eae, ehxA</i>
G15	O21	<i>stx<sub>2d</sub></i>
G16	O22	<i>stx<sub>1</sub>, eae, ehxA</i>
G17	OUT	<i>stx<sub>1C</sub>, stx<sub>2</sub>, eae, ehxA</i>
G18	O156	<i>stx<sub>1</sub>, stx<sub>2d</sub></i>
G19	O87	<i>stx<sub>1C</sub>, stx<sub>2C</sub>, ehxA</i>
G20	O2	<i>stx<sub>1C</sub>, stx<sub>2</sub>, ehxA, saa</i>
G21	O85	<i>stx<sub>1</sub>, eae</i>
G22	O60	<i>stx<sub>1C</sub>, stx<sub>2</sub>, ehxA, saa</i>
G23	O87	<i>stx<sub>1C</sub>, eae, ehxA</i>
G24	OUT	<i>eae, ehxA</i>
G25	O158	<i>stx<sub>2d</sub>, saa</i>
G26	O5	<i>stx<sub>2C</sub>, eae, ehxA</i>
G27	O41	<i>stx<sub>1C</sub>, stx<sub>2C</sub></i>
G28	O113	<i>stx<sub>1C</sub>, stx<sub>2C</sub>, ehxA, saa</i>
G29	OUT	<i>stx<sub>1C</sub>, eae, ehxA</i>
G30	O103	<i>stx<sub>1C</sub>, eae, ehxA</i>
G31	O120	<i>stx<sub>1C</sub>, eae, ehxA</i>
G32	O112	<i>stx<sub>1C</sub>, eae, ehxA</i>
G33	O22	<i>stx<sub>2d</sub></i>
G34	O71	<i>stx<sub>2C</sub>, eae, ehxA</i>
G35	O20	<i>stx<sub>1C</sub>, stx<sub>2C</sub>, saa</i>
G36	O5	<i>stx<sub>1</sub>, stx<sub>2C</sub>, eae, ehxA</i>



**Fig. 1:** Phylogenetic analysis using RAPD-PCR profiles of the STEC and EPEC strains isolated from goats in West Bengal (India) using neighbour-joining method and dice similarity

**Table 2:** Antibiotic resistance pattern of the STEC and EPEC from goats in West Bengal, India

Name of the antimicrobial agent (Conc. µg)	Sensitive (%)	Intermediate (%)	Resistant (%)
Chloramphenicol (25 µg)	77.78	11.11	11.11
Co-trimoxazole (25 µg)	77.78	16.67	5.55
Ciprofloxacin (5 µg)	88.89	8.33	2.78
Gentamicin (10 µg)	5.56	58.33	36.11
Neomycin (30 µg)	0	63.89	36.11
Norfloxacin (10 µg)	88.89	8.33	2.78
Streptomycin (30 µg)	5.55	77.78	16.67
Oxytetracycline (30 µg)	19.44	55.56	25
Cephalothin (30 µg)	5.56	44.44	50
Amikacin (30 µg)	2.78	44.44	52.78
Ceftazidime (30 µg)	97.22	2.78	0
Kanamycin (30 µg)	5.55	52.78	41.67
Ceftriaxone (30 µg)	88.89	11.11	0
Levofloxacin (5 µg)	100	0	0
Amoxicillin + clavulanic acid (30 µg)	80.56	13.89	5.55
Cefaclor (30 µg)	36.11	38.89	25
Cefuroxime (30 µg)	72.23	19.44	8.33
Azithromycin (30 µg)	11.11	69.45	19.44
Piperacillin + tazobactam (100 + 10 µg)	52.78	47.22	0
Cefepime + tazobactam (30 + 10 µg)	100	0	0
Ampicillin + cloxacillin (10 µg)	69.45	22.22	8.33
Enrofloxacin (10 µg)	80.55	16.67	2.78
Amoxicillin (25 µg)	75	19.45	5.55
Erythromycin (10 µg)	0	19.45	80.55
Doxycycline hydrochloride (30 µg)	36.11	55.56	8.33
Pefloxacin (5 µg)	75	19.45	5.55

PCR to determine the genetic diversity among the strains. All the strains were typeable with primer 1247 and produced amplified fragment size ranging from 250

bp to 1900 bp (calculated by Doc-itLs image analysis software, UVP, UK). The phylogenetic analysis of STEC strains after RAPD reveals eight major clusters (clusters

A to E, Fig. 1). No serogroup specific cluster was observed.

### Antibiotic sensitivity test

Resistance was observed most frequently to erythromycin (80.5%), amikacin (52.7%), cephalothin (50%), kanamycin (41.6%), neomycin (36.1%) and gentamycin (36.1%) and less frequently to norfloxacin (2.7%), enrofloxacin (2.7%), and ciprofloxacin (2.7%). No resistance was observed in case of ceftazidime, levofloxacin, piperacillin along with tazobactam, cefepime along with tazobactam and ceftriaxone. Multidrug resistance was observed in eleven STEC isolates (Table 2).

### Discussion

The study was aimed to detect the occurrence of STEC from healthy goats in West Bengal, India. Of the total 245 *E. coli* isolated during the present study 36 (14.7%) isolates harboured at least one marker gene for STEC. Similar occurrence of STEC was observed in previous studies conducted in local and migratory goats in Kashmir Valley, India (Wani *et al.*, 2006) and from faecal samples, meat and milk of goats in other parts of the world (Orden *et al.*, 2003; Islam *et al.*, 2008; Momtaz *et al.*, 2013). However, lower or higher occurrence of STEC was detected from faeces of healthy and diarrhoeic goats, chevon and goat milk cheese in other countries throughout the world (Orden *et al.*, 2003; Horcajo *et al.*, 2010; Ojo *et al.*, 2010; Schilling *et al.*, 2012). It seems that the occurrence of STEC varies with different geographical location and season.

All the STEC strains belonged to 22 different serogroups (O2, O5, O20, O21, O22, O25, O41, O44, O45, O60, O71, O76, O84, O85, O87, O91, O103, O112, O113, O120, O156, and O158) and three were untypeable. Similarly, the serogroups O2, O5, O22, O45, O60, O76, O87, O91, O103, O112, O113 and O156 were also previously isolated from faeces and milk product of goats (Wani *et al.*, 2006; Vu-Khac and Cornick, 2008; Horcajo *et al.*, 2010; Schilling *et al.*, 2012; Jacob *et al.*, 2013).

Out of the 36 STEC isolates of the present study, 26 (72.2%) and 21 (58.3%) isolates possessed the *stx*<sub>1</sub> and *stx*<sub>2</sub> gene, respectively. Similar occurrence of *stx*<sub>1</sub> and higher occurrence of *stx*<sub>2</sub> was observed in goats in previous studies (Oliveira *et al.*, 2008; Vu-Khac and Cornick, 2008). Further characterization of the 26 *stx*<sub>1</sub> positive isolates identified 19 (73%) strains positive for *stx*<sub>1C</sub>. Similarly, higher number of *stx*<sub>1C</sub> was observed in *stx*<sub>1</sub> positive isolates from goats in Spain (Horcajo *et al.*, 2010) and Central Vietnam (Vu-Khac and Cornick, 2008). In this study, we found that *stx*<sub>1C</sub> genes most commonly occurred with *ehxA*, *saa* or both which is in agreement with the previous finding by Vu-Khac and Cornick (2008). Subtyping of the isolates possessing *stx*<sub>2</sub> gene, produced 9 (42.8%) and 8 (38.1%) isolates positive for *stx*<sub>2C</sub> and *stx*<sub>2d</sub> gene, respectively. Similarly, Zheng *et al.* (2005) found high proportion of isolates bearing *stx*<sub>2C</sub>

genes in healthy goats in China which is consistent with the present finding. In contrast, higher recovery of *stx*<sub>2d</sub> gene has been observed in caprine isolates in Central Vietnam (Vu-Khac and Cornick, 2008). It seems that the prevalence of *stx*<sub>2C</sub> isolates is higher in this geographical region as China is nearer than Vietnam to the present study area.

The *eaeA* gene coding intimin protein was present in 22 (61.1%) isolates. Lower occurrence of *eaeA* was found in a study conducted by Vu-Khac and Cornick (2008), whereas Islam *et al.* (2008) could not isolate *eaeA* in non-O157 STEC from goats. Higher prevalence of *eaeA* in the present study may be a concern as LEE positive strains were considered highly virulent in human (Toma *et al.*, 2004). A large number of isolates (77.7%) was found to possess enterohaemolysin (*ehxA*) in combination with other virulence genes in the present study which is in contrast with the previous study (Vu-Khac and Cornick, 2008). Association of *saa* gene in STEC isolates (22.2%) from healthy goats in the present study might be remarkable because in another study, *saa* was not detected in caprine STEC isolates (Cortes *et al.*, 2005). Among the *saa* positive isolates 5 (62.5%) were concomitantly present with the *ehxA*, which is consistent with the previous studies (Paton *et al.*, 2001; Paton and Paton, 2002).

The RAPD results showed genetic heterogeneity of the STEC isolates. No serogroupwise clustering of the STEC isolates in the present study was detected. This is in agreement with the previous observation by Mahanti *et al.* (2013) who found many RAPD banding patterns among the STEC isolates from buffalo belonging to a similar serogroup.

Resistance of STEC isolates against chloramphenicol, co-trimoxazole, ciprofloxacin, gentamicin, neomycin, norfloxacin, streptomycin, tetracycline, ampicillin, enrofloxacin, erythromycin as reported in the present study was also supported by earlier studies in goats (Ojo *et al.*, 2010; Medina *et al.*, 2011). However, higher occurrence of multidrug resistant STEC (69.5%) was reported in Nigerian goats than in the present study (Ojo *et al.*, 2010). Isolation of enterovirulent *E. coli* such as STEC and EPEC is a serious public health concern in this area where the farmers stay in close proximity to goats with little concern for hygiene and people consume undercooked goat milk and meat products.

### References

- Asakura, H; Masuda, K; Yamamoto, S and Igimi, S (2014). Molecular approach for tracing dissemination routes of Shiga toxin-producing *Escherichia coli* O157 in bovine offal at slaughter. Biomed. Res. Int., <http://dx.doi.org/10.1155/2014/739139>.
- Beutin, L; Montenegro, MA; Orskov, I; Orskov, F; Prada, J; Zimmerman, S and Stephan, R (1989). Close association of verotoxin (Shiga-like toxin) production with enterohemolysin production in strains of *Escherichia coli*. J. Clin. Microbiol., 7: 2559-2564.
- Centers for Disease Control and Prevention (CDC) (2008). *Escherichia coli* O157:H7 infections in children associated

- with raw milk and raw colostrum from cows-California, 2006. *MMWR Morb. Mortal Wkly. Rep.*, 57: 625-628.
- CLSI** (2008). *Performance standards for antimicrobial disk and dilution susceptibility tests for bacteria isolated from animals*. 3rd Edn., Approved Standard, CLSI Document M31-A3. Clinical and Laboratory Standards Institute, Wayne, PA.
- Cortés, C; De la Fuente, R; Blanco, J; Blanco, M; Blanco, JE; Dhabi, G; Mora, A; Justel, P; Contreras, A; Sánchez, A; Corrales, JC and Orden JA** (2005). Serotypes, virulence genes and intimin types of verotoxin-producing *Escherichia coli* and enteropathogenic *E. coli* isolated from healthy dairy goats in Spain. *Vet. Microbiol.*, 110: 67-76.
- Ethelberg, S; Smith, B; Torpdahl, M; Lisby, M; Boel, J; Jensen, T; Nielsen, EM and Mølbak, K** (2009). Outbreak of non-O157 Shiga toxin-producing *Escherichia coli* infection from consumption of beef sausage. *Clin. Infect. Dis.*, 48: 78-81.
- Horcajo, P; Domínguez-Bernal, G; De La Fuente, R; Ruiz-Santa-Quiteria, JA and Orden, JA** (2010). Association of vt1c with verotoxin-producing *Escherichia coli* from goats and sheep. *J. Vet. Diagn. Invest.*, 22: 332-334.
- Islam, MA; Mondol, AS; de Boer, E; Beumer, RR; Zwietering, MH; Talukder, KA and Heuvelink, AE** (2008). Prevalence and genetic characterization of Shiga toxin-producing *Escherichia coli* isolates from slaughtered animals in Bangladesh. *Appl. Environ. Microbiol.*, 74: 5414-5421.
- Jacob, ME; Foster, DM; Rogers, AT; Balcomb, CC; Shi, X and Nagaraja, TG** (2013). Evidence of non-O157 Shiga toxin-producing *Escherichia coli* in the faeces of meat goats at a U.S. slaughter plant. *J. Food Prot.*, 76: 1626-1629.
- Mahanti, A; Samanta, I; Bandopadhyay, S; Joardar, SN; Dutta, TK; Batabyal, S; Sar, TK and Isore, DP** (2013). Isolation, molecular characterization and antibiotic resistance of Shiga toxin-producing *Escherichia coli* (STEC) from buffalo in India. *Lett. Appl. Microbiol.*, 56: 291-298.
- Medina, A; Horcajo, P; Jurado, S; De La Fuente, R; Ruiz-Santa-Quiteria, JA; Domínguez-Bernal, G and Orden, JA** (2011). Phenotypic and genotypic characterization of antimicrobial resistance in enterohemorrhagic *Escherichia coli* and atypical enteropathogenic *E. coli* strains from ruminants. *J. Vet. Diagn. Invest.*, 23: 91-95.
- Momtaz, H; Dehkordi, FS; Rahimi, E; Ezadi, H and Arab, R** (2013). Incidence of Shiga toxin-producing *Escherichia coli* serogroups in ruminant's meat. *Meat Sci.*, 95: 381-388
- Ojo, OE; Ajuwape, AT; Otesile, EB; Owoade, AA; Oyekunle, MA and Adetosoye, AI** (2010). Potentially zoonotic Shiga toxin-producing *Escherichia coli* serogroups in the faeces and meat of food-producing animals in Ibadan, Nigeria. *Int. J. Food Microbiol.*, 142: 214-221.
- Oliveira, MG; Brito, JRF; Gomes, TAT; Guth, BEC; Vieira, MAM; Naves, ZVF; Vaz, TMI and Irino, K** (2008). Diversity of virulence profiles of Shiga toxin-producing *Escherichia coli* serotypes in food-producing animals in Brazil. *Int. J. Food Microbiol.*, 127: 139-146.
- Orden, JA; Ruiz-Santa-Quiteria, JA; Blanco, M; Blanco, JE; Mora, A; Cid, D; González, EA; Blanco, J and de la Fuente, R** (2003). Prevalence and characterization of Vero cytotoxin-producing *Escherichia coli* isolated from diarrhoeic and healthy sheep and goats. *Epidemiol. Infect.*, 130: 313-321.
- Paton, JC and Paton, AW** (1998a). Pathogenesis and diagnosis of Shiga toxin-producing *Escherichia coli* infections. *Clin. Microbiol. Rev.*, 11: 450-479.
- Paton, AW and Paton, JC** (1998b). Detection and characterization of Shiga toxigenic *Escherichia coli* by using multiplex-PCR assays for *stx*<sub>1</sub>, *stx*<sub>2</sub>, *eae*<sub>4</sub>, enterohaemorrhagic *E. coli* hlyA, rfbO111 and rfbO157. *J. Clin. Microbiol.*, 36: 598-602.
- Paton, AW and Paton, JC** (2002). Direct detection and characterization of Shiga toxigenic *Escherichia coli* by multiplex PCR for *stx*<sub>1</sub>, *stx*<sub>2</sub>, *eae*, *ehxA*, and *saa*. *J. Clin. Microbiol.*, 40: 271-274.
- Paton, AW; Srimanote, P; Woodrow, MC and Paton, JC** (2001). Characterization of *saa*, a novel autoagglutinating adhesin produced by locus of enterocyte effacement-negative Shiga-toxigenic *Escherichia coli* strains that are virulent for humans. *Infect. Immun.*, 69: 6999-7010.
- Quinn, PJ; Carter, ME; Markey, BK and Carter, GR** (1994). *Clinical veterinary microbiology*. 3rd Edn., London, UK, Wolfe Publications. PP: 113-129.
- Samanta, I; Joardar, SN; Das, PK; Das, P; Sar, TK; Dutta, TK; Bandyopadhyay, S; Batabyal, S and Isore, DP** (2014). Virulence repertoire, characterization and antibiotic resistance pattern analysis of *Escherichia coli* isolated from backyard layers and their environment in India. *Avian Dis.*, 58: 39-45.
- Sambrook, J and Russel, DW** (2001). *Molecular cloning: a laboratory manual*. 3rd Edn., New York, NY, Cold Spring Harbour. PP: 221-245.
- Schilling, AK; Hotzel, H; Methner, U; Sprague, LD; Schmoock, G; El-Adawy, H; Ehricht, R; Wöhr, AC; Erhard, M and Geued, L** (2012). Zoonotic agents in small ruminants kept on city farms in southern Germany. *Appl. Environ. Microbiol.*, 78: 3785-3793.
- Toma, C; Espinosa, EM; Song, T; Miliwebsky, E; Chinen, I; Iyoda, S; Iwanaga, M and Rivas, M** (2004). Distribution of putative adhesions in different serotypes of Shiga toxin-producing *Escherichia coli*. *J. Clin. Microbiol.*, 42: 4937-4946.
- Vu-Khac, H and Cornick, NA** (2008). Prevalence and genetic profiles of Shiga toxin-producing *Escherichia coli* strains isolated from buffaloes, cattle, and goats in central Vietnam. *Vet. Microbiol.*, 126: 356-363.
- Wang, G; Clark, CG and Rodgers, FG** (2002). Detection in *Escherichia coli* of the genes encoding the major virulence factors, the genes defining the O157:H7 serotype, and components of the type 2 Shiga toxin family by multiplex PCR. *J. Clin. Microbiol.*, 40: 3613-3619.
- Wani, SA; Bhat, MA; Qureshi, S; Ishaq, SM; Buchh, AS; Samanta, I and Ashrafi, MA** (2004). Epidemiology of diarrhoea caused by rotavirus and *Escherichia coli* in calves in Kashmir valley. *Ind. Vet. J.*, 81: 683-686.
- Wani, SA; Samanta, I; Munshi, ZH; Bhat, MA and Nishikawa, Y** (2006). Shiga toxin-producing *Escherichia coli* and enteropathogenic in healthy goats in India: occurrence and virulence properties. *J. Appl. Microbiol.*, 100: 108-113.
- Zhang, W; Bielaszewska, M; Kuczius, T and Karch, H** (2002). Identification, characterization, and distribution of a Shiga toxin 1 gene variant (*stx*<sub>1c</sub>) in *Escherichia coli* strains isolated from humans. *J. Clin. Microbiol.*, 40: 1441-1446.
- Zheng, H; Jing, H; Wang, H; Xia, S; Hu, W; Cui, S; Bi, Z; Yang, J; Pang, B; Zhao, G; Zhang, J; Li, H and Xu, J** (2005). *Stx*<sub>2ha</sub> is the dominant genotype of Shiga toxin-producing *Escherichia coli* O157:H7 isolated from patients and domestic animals in three regions of China. *Microbiol. Immunol.*, 49: 1019-1026.