Characterization of Shiga toxin-producing *Escherichia coli* (STEC) in feces of healthy and diarrheic calves in Urmia region, Iran

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**ABSTRACT**

**Background and Objectives:** Shiga toxin-producing *Escherichia coli* (STEC) have emerged as human pathogens and contamination of foods of animal origin has been a major public health concern. The aim of the present study was to determine the dissemination of STEC in healthy and diarrheic calves in Urmia region which is located in West Azerbaijan province, Iran.

**Materials and Methods:** In the current study, a total of 124 *Escherichia coli* isolates from clinically healthy (n = 73) and diarrheic calves (51) belonging to 6 different farms located in West Azerbaijan province, Iran, were screened by the polymerase chain reaction (PCR) assay for the presence of virulence genes characteristic for STEC, that is, Shiga-toxin producing gene(s) (*stx1*, *stx2*), intimin (*eaeA*) and enterohemolysin (*hlyA*).

**Results:** STEC isolates were recovered from 21.92% (16/73) in healthy calves, and 19.6% (10/51) in diarrheic calves. Overall, PCR results showed that 6 (23.1%) isolates carried *stx1* gene, 7 (26.92%) possessed *stx2* gene while 13 isolates (50%) gave positive amplicon both for *stx1* and *stx2* genes. All *stx* positive isolates were assayed further to detect *eaeA* and *hlyA* sequences. Seven out of the 26 (26.92%) Shiga toxin gene positive isolates were positive for the *eaeA* gene, and 15 (57.69%) were positive for the *hlyA* gene. Both virulence genes (*eaeA* and *hlyA*) in the same isolate were observed in 5 (19.23%) of the *stx* isolates. In total, diverse virulence gene profiles were detected, from which isolates with the genetic profile *stx1 stx2 hlyA* was the most prevalent. In addition, *eaeA* gene was more evident in isolates from diarrheic calves than in healthy calves.

**Conclusion:** There was no significant difference in detecting STEC isolates between healthy and diarrheic calves. It seems that calves to be the reservoir of STEC within the herds and calf management may represent specific control points for reducing STEC spread within dairy units.

**Keywords:** Shiga toxin, *E. coli*, calves, Iran

**INTRODUCTION**

*Escherichia coli* is the most common facultative anaerobe found in the gastrointestinal tract of warm-blooded animals and humans. In contrast to pathogenic *E. coli* strains, which typically carry certain virulence gene patterns associated with specific pathotypes (1), commensal *E. coli* strains rarely contain virulence genes (2). Pathogenic strains that are characterized by their ability to produce verotoxins (also called Shiga toxins) are known as the verocytotoxigenic *E. coli* (VTEC) or Shiga toxin-producing *E. coli* (STEC). In developed countries STEC O157:H7 represents the major cause of human diseases; however, there have been increasing reports of non-O157 STEC strains
associated with gastrointestinal infections (3, 4). The pathogenicity of STEC is mediated mainly through Shiga toxins 1 (which is almost identical to Stx produced by Shigella dysenteriae) and 2 encoded by stx1 and stx2 genes, respectively (5). Many STEC also produce intimin, an outer membrane surface adhesin encoded by the chromosomal eaeA gene with several variants located on the pathogenicity island termed the locus of enterocyte effacement (LEE) (6). Intimin is responsible for intimate attachment of STEC to the intestinal epithelial cells, causing attaching and effacing (A/E) lesions in the intestinal mucosa (7). A factor that may also affect the virulence of STEC strains is the 60-MDa plasmid borne enterohemolysin (Ehly) which is encoded by the hlyA gene (8). It has been suggested that enterohemolysins may enhance the effect of Shiga toxins (9) and hemolytic activity is thought to correlate with the pathogenicity of E. coli. Domestic ruminants, particularly cattle and sheep, have been pointed out to be the major source of E. coli O157:H7 and other STEC (9, 10). Many studies also showed that both healthy and diarrheic calves harbor STEC in their intestine (11, 12) and shed the bacteria for several months and in great quantities (13, 14). Control of STEC is required at the farm level and may be achieved through a reduction of horizontal transmission within cattle groups, thus decreasing STEC prevalence (15). Therefore, the characterization of intestinal E. coli strains with respect to diversity, virulence trait profiles, phylogenetic affiliations, and antibiotic resistance provides important information about the health status of the harboring host and the risks for development of diseases, transmission of pathogens, or resistance to antibiotic treatment (16). In Iran, shiga toxin producing Escherichia coli O157:H7 has been identified in raw cow milk samples (17) and STEC isolates are one of the major etiologic agents of diarrhea (18, 19). Hence, an attempt was made in the present study to determine and compare the prevalence and virulence characteristics of STEC isolates isolated from calves with diarrhea and those without diarrhea to assess their significance as STEC reservoirs in Urmia region, Iran.

MATERIALS AND METHODS

Samples collection and E. coli isolates. During a time span of March 2010 to July 2010, fecal samples were collected from the rectum of each 2-6 months old healthy and diarrheic calves on six farms of Urmia region which is located in West Azerbaijan province, Iran. The health status of each calf was evaluated by clinical examination. Healthy calves had to be free from diarrhea, whereas sick calves showed fever, anorexia, abnormal fecal constancy and/or signs of dehydration and weakness. Fecal samples were collected into sterile plastic tubes and submitted to the laboratory on ice packs in chests. One gram of feces was resuspended in 10 ml 0.85% NaCl, and MacConkey-lactose agar plates per sample were swab inoculated and streaked for isolation. After overnight incubation at 37°C,lactose-positive (rose pink) colonies were counted as E. coli and further streaked onto eosin methylene blue (EMB) and incubated overnight at 37°C again. Green metallic sheen colonies indicative of E. coli of both the STEC and the non-STEC groups were selected and subcultured on sheep blood agar plates. All isolates were subjected to standard microbiological techniques, including indole, methyl red, Voges–Proskauer and Simmons citrate and were stored at -20°C in containing glycerol until molecular tests were carried out.

Bacterial DNA preparation for PCR. A loop-full of overnight culture of bacterial colony was suspended in 100 µl of sterile water, boiled for 10 min and the cell debris was removed by centrifugation at 13000 rpm for 2 min. The supernatant was subsequently used as a source of DNA template (20).

Molecular characterization of E. coli using the polymerase chain reaction (PCR). The biochemical results were confirmed by PCR amplification using E. coli species-specific primers Eco 2083 (GCT TGA CAC TGA ACA TTG AG) and Eco 2745 (GCA CTT ATC TCT TCC GCA TT) (21). The reactions were performed in 25 µl volumes comprising of 20 ng of the template DNA, 12.5 µl of 2X PCR master mix (3 mM MgCl2, 0.04U/µl Taq polymerase, reaction buffer, 0.4 mM of each dNTPs), 0.4 µM of each primer. The amplifications were performed in Corbett thermal cycler (Model CP2-003, Australia) at 94°C for 4 min; 35 cycles of 94°C for 45 s; 57°C for 1 min; 72°C for 2 min and a final elongation step at 72°C for 10 min. Both positive and negative control reactions were included in each PCR amplification experiment. For negative controls template DNA was replaced with sterile water. E. coli O157:H7 (ATCC 43895) was used as positive control. Then, 662 bp-positive bacterial samples were tested for virulence
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marker genes (stx1, stx2, eaeA, and hlyA) using two duplex-PCRs (22, 23).

Detection of virulence genes using PCR. Initial screening for STEC was performed by means of a duplex-PCR using specific primers to determine the presence of stx1 and stx2 genes (22). Primer sequences and predicted size of the corresponding amplified product are shown in Table 1. Reaction mixture consisted of 12.5 µl of 2X PCR master mix, 0.4 µM stx1 primers, 0.4 µM stx2 primers, and 2 µl aliquot of the supernatant of the boiled bacterial suspension as DNA template in a 25 µl reaction volume. The PCR condition adopted in this study were similar to those previously used by Osek et al. (23). Amplification was performed beginning with 94°C for 5 min followed by 30 cycles of 94°C for 1 min; 53°C for 1 min; 72°C for 1 min; and a final extension at 72°C for 5 min. PCR products were electrophoresed on 1.2% (w/v) agarose gel containing 5 µg/ml ethidium bromide in 0.5X TBE electrophoresis buffer for approximately 90 min at 80 v. Products were visualized by a UV transilluminator and size determination was achieved using a 100 bp DNA ladder (Fermentas, Germany). Samples showing a positive PCR result for one or both stx1 or stx2 were then tested for the presence of eaeA and hlyA genes with the primer pairs (8, 23, 24) using duplex-PCR as described previously by Osek et al. (23).

Statistical analysis. Statistical analysis was performed using GraphPad Prism version 5 software. Differences between the frequency of STEC from healthy and diarrheic calves were analyzed by Fisher’s exact test. P values < 0.05 were considered to be statistically significant.

RESULTS

A total of 124 E. coli isolates from healthy (n = 73) and diarrheic (n = 51) calves were identified by conventional as well as molecular method using species-specific primers Eco2083 and Eco2745. PCR amplification revealed a band at approximately 662 bp from all isolates, indicating the presence of bacterial DNA (data not shown). Of 124 E. coli, a total of 26 STEC isolates (20.97%) were identified, from which 6 (23.1%) isolates carried stx1 gene, 7 (26.92%) possessed stx2 gene while 13 isolates (50%) gave positive amplicon for both stx1 and stx2 genes (Table 2). The genes eaeA and hlyA were present in 7 (26.92%) and 16 (61.54%) of the isolates, respectively.

As shown in Table 2, isolates harboring only stx1 corresponded to 31.25% (5/16) and 10% (1/10) of the

Table 1. Primer sequences and predicted lengths of PCR amplification products.

| Virulence gene | Oligonucleotide primer (5'→3') | Amplicon size (bp) | Ref. |
|---------------|--------------------------------|-------------------|-----|
| stx1          | CAG TTA ATG TCG TGG CGA AGG CAC CAG ACA ATG TAA CCG CTG | 348               | 22  |
| stx2          | ATC CTA TTC CCG GGA GTT TAC G GCG TCA TCG TAT ACA CAG GAG C | 584               | 22  |
| eaeA          | GGG ATC GAT TAC CGT CAT TTT ATC AGC CTT AAT CTC       | 837               | 24  |
| hlyA          | GCA TCA TCA AGC GTA CGT TCC AAT GAG CCA AGC TGG TTA AGC T | 534               | 8   |

Table 2. Distribution of virulence factors of E. coli isolates recovered from healthy and diarrheic calves.

| Genetic profile | No. of isolate | Total |
|-----------------|----------------|-------|
|                 | healthy calves | Diarrheic calves | |
| stx1            | 2              | 1     | 3   |
| stx2            | 2              | 1     | 3   |
| stx1 and stx2   | 2              | -     | 2   |
| stx1 and hlyA   | 1              | -     | 1   |
| stx2 and hlyA   | 1              | 1     | 2   |
| stx1, stx2, eaeA| -              | 2     | 2   |
| stx1, stx2, hlyA| 5              | 3     | 8   |
| stx1, eaeA, hlyA| 2              | -     | 2   |
| stx2, eaeA, hlyA| 1              | 1     | 2   |
| stx1, stx2, eaeA, hlyA | - | 1 | 1 |
| 16              | 10             | 26    |
This study reports on the isolation of 26 STEC recovered STEC isolates from healthy and diarrheic calves, respectively. stx2 was found in 25% (4/16) and 30% (3/10) of the isolates from healthy and diarrheic calves, respectively. stx1 plus stx2 sequences were harbored by 43.75% (7/16) and 60% (6/10) of the isolates obtained from healthy and diarrheic calves, respectively. The eaeA gene was also detected in 18.75% (3/16) and 40% (4/10) of STEC isolates from healthy and diarrheic calves, respectively, while the corresponding percentages for the hlyA gene were 62.5% (10/16) and 60% (6/10), respectively. Homogeneity in the distribution of the later gene among different virulence gene profiles was observed. The distribution of virulence genes is presented in Table 2.

In general, STEC isolates carrying stx1 plus stx2 sequences were found more frequently (50%) in calves. As shown in Table 2, the virulence gene profile of the STEC isolates from calves was found in 10 diverse combinations, from which isolates with the genetic profile stx1 stx2 hlyA was the most prevalent. The eaeA gene was detected in 7 (26.92%) isolates, of these 3 isolates were positive for stx1 plus stx2, 2 for stx2 and 2 for stx1.

Statistical analysis showed that there was not a significant difference in the frequencies of STEC isolates between healthy and diarrheic calves.

**DISCUSSION**

This study reports on the isolation of 26 STEC (20.97%) from clinically healthy and diarrheic calves in the West Azerbaijan province, Iran. Our result supported the findings of other workers, who showed that calves are possible reservoir of STEC in their gastrointestinal tract (20, 25). According to the results, 21.92% of the E. coli isolates recovered from clinically healthy calves carried at least one of the stx genes. The frequency detected in the present study is, however, lower than the 37% and 44% reported for calves in Spain and Brazil, respectively (11, 26), but higher than the 5.4% found in calves in Poland (27). These variations are likely due to geographical differences. It has been shown that environment may have an influence on the shedding of STEC in calves (28). Individual differences in fecal excretion by cattle have also been observed, and one of the factors proposed to explain this phenomenon is climate condition (15). Higher prevalence of stx1 gene than stx2 gene in healthy calves, in this study, corroborates the findings of other studies (27, 29). Presence of stx genes-carrying E. coli isolates in the gastrointestinal tract of healthy calves suggests that these are transient commensal bacteria in calves and the virulence genes of these E. coli isolates are either not or only very poorly expressed in the intestine. This may be clarified through further research into the expression of particular genes in vivo.

With regards to isolates from diarrheic calves, 19.6% were positive for stx genes. The frequency detected in the present study is lower than those reported for calves in various regions (30, 31), but higher than 9.73%, 7.6% and 3.3% reported by Wani et al. (32), Osek et al. (25) and Guler et al. (20), respectively. Higher frequency of stx2 gene (30%) than stx1 gene (10%) in diarrheic calves observed in the present study is contrary to the observations of Mercado et al. (33) who reported predominance of stx1 over stx2 in diarrheic calves in Argentina. Natural outbreaks and experimental conditions have demonstrated the association of STEC with diarrhea and dysentery in calves (34, 35). However, in this study the significance of STEC in diarrheic calves is unclear because other enteric pathogens were not examined.

The relative occurrence of STEC virulence factors changed as calves aged, with stx1-positive isolates replaced by stx2-positive isolates (28). In the current study, however, stx1 plus stx2 sequences were present in a higher number (50%) of isolates from both healthy and diarrheic calves. This may
be due to differences in age of calves, season of collection, ruminal development, immune response, diet and other aspects of calves' management. In a study carried out by Fernandez et al. (36), calves in spring showed an increase of the percentage of stx1 + stx2 positive bacteria, indicating the fact that the relationship between age and type of stx is influenced by the season in which the study has been carried out.

Numerous investigators have underlined the strong association between the carriage of eaeA gene and the capacity of STEC to cause severe human disease, especially HUS (37, 38). In the current study, the eaeA gene was detected in 18.75% (3/16) and 40% (4/10) of STEC isolates from healthy and diarrheic calves, respectively. Similar prevalence of eaeA gene was also found in other studies (39, 40). Several authors have found that STEC isolated from diarrheic calves frequently share virulence-associated traits, i.e. genes with human enterohaemorrhagic E. coli (EHEC) strains (41).

A high frequency (57.69%) of the hlyA gene with uniform distribution was detected in stx1 and/or stx2 positive isolates. This could have resulted from the fact that it can be easily transferred among bacterial isolates since it is plasmid encoded (42). No differences of carriage of STEC in diarrheic and healthy calves were observed in this study. This is in agreement with study reported by Irino et al. (43) in dairy cattle (STEC prevalence among diarrheic and healthy cattle: 21.4% versus 26.4%, respectively) and in contrast to the results previously described for beef cattle by Leomil et al. (44) (the frequency of carriage of STEC was higher in diarrheic calves than in non-diarrheic animals, 20% versus 8% respectively, P<0.001) in Sao Paulo. The occurrence of virulence factors therefore does not serve as proof of the pathogenicity of a given clone. The verification of virulent E. coli clones as agents of disease and the distinction between virulent and commensal E. coli clones will require a number of different approaches, including determination of the relative proportion of a given clone to the total E. coli.

In conclusion, this study revealed no significant difference between healthy and diarrheic calves for carrying STEC in gastrointestinal tract, which highlight the importance of calves as a reservoir of STEC isolates in Urmia region. More serious assessment of these zoonotic pathogens in feces of calves and other animals must be carried out to determine the STEC reservoirs in this area.

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REFERENCES

1. Frydendahl K. Prevalence of serogroups and virulence genes in Escherichia coli associated with postweaning diarrhoea and edema disease in pigs and a comparison of diagnostic approaches. Vet Microbiol 2002; 85: 169-182.
2. Boerlin P, Travis R, Gyles CL, Reid-Smith R, Janeczek N, Lim H, et al. Antimicrobial resistance and virulence genes of Escherichia coli isolates from swine in Ontario. Appl Environ Microbiol 2005; 71: 6753-6761.
3. Lockary VM, Hudson RF, Ball CL. Shiga toxin-producing Escherichia coli, Idaho. Emerg Infect Dis 2007; 13: 1262-1264.
4. Werber D, Behinke SC, Fruth A, Merle R, Menzler S, Glaser S, et al. Shiga toxin-producing Escherichia coli infection in Germany: different risk factors for different age groups. Am J Epidemiol 2007; 165: 425-434.
5. Paton AW, Paton JC. Detection and characterization of Shiga toxinogenic Escherichia coli by using multiplex PCR assays for stx1, stx2, eaeA, enterohemorrhagic E. coli hlyA, rfbO111, and rfbO157. J Clin Microbiol 1998; 36: 598-602.
6. Blanco M, Blanco JE, Mora A, Dahbi G, Alonso MP, Gonzalez EA, et al. Serotypes, virulence genes, and intimin types of Shiga toxin (verotoxin)-producing Escherichia coli isolates from cattle in Spain and identification of a new intimin variant gene (eae-ξ). J Clin Microbiol 2004; 42: 645-651.
7. Mora A, Blanco JE, Blanco M, Alonso MP, Dahbi G, Echeita A, et al. Antimicrobial resistance of Shiga toxin (verotoxin)-producing Escherichia coli O157:H7 and non-O157 strains isolated from humans, cattle, sheep and food in Spain. Res Microbiol 2005; 156: 793-806.
8. Schmidt H, Beutin L, Karch H. Molecular analysis of the plasmid-encoded hemolysin of Escherichia coli O157:H7 strain EDL 933. Infect Immun 1995; 63: 1055-1061.
9. Caprioli A, Morabito S, Brugere H, Oswald E. Enterohaemorrhagic Escherichia coli: emerging issues on virulence and modes of transmission. Vet Res 2005; 36: 289-311.
10. Renter DG, Sargeant JM. Enterohaemorrhagic Escherichia coli O157: epidemiology and ecology in bovine production environments. Anim Health Res Rev 2002; 3: 83-94.
11. Blanco M, Blanco JE, Blanco J, Mora A, Prado C, Alonso MP, et al. Distribution and characterization of faecal verotoxin-producing Escherichia coli (VTEC) isolated from healthy cattle. Vet Microbiol 1997; 54: 309-319.
12. Roopnarine RR, Ammons D, Rampersad J, Adesiyun AA.
Occurrence and characterization of verocytotoxigenic Escherichia coli (VTEC) strains from dairy farms in Trinidad. Zoonoses Public Health 2007; 54: 78-85.

13. Cray WC, Jr., Moon HW. Experimental infection of calves and adult cattle with Escherichia coli O157:H7. Appl Environ Microbiol 1995; 61: 1586-1590.

14. Widiasih DA, Ido N, Omoe K, Sugi S, Shinagawa K. Duration and magnitude of fecal shedding of Shiga toxin-producing Escherichia coli from naturally infected cattle. Epidemiol Infect 2004; 132: 67-75.

15. Cobbold R, Desmarchelier P. Horizontal transmission of Shiga toxin-producing Escherichia coli within groups of dairy calves. Appl Environ Microbiol 2002; 68: 4148-4152.

16. Schierack P, Romer A, Jores J, Kaspar H, Guenther S, Filter M, et al. Isolation and characterization of intestinal Escherichia coli clones from wild boars in Germany. Appl Environ Microbiol 2009; 75: 695-702.

17. Brenjichi M, Jamshidi A, Farzaneh N, Bassami MR. Identification of shiga toxin producing Escherichia coli O157:H7 in raw cow milk samples from dairy farms in Mashhad using multiplex PCR assay. Iran J Vet Res 2011; 12: 145-149.

18. Jafari F, Shokrzadeh L, Hamidian M, Salmanzadeh-Ahrabi S, Zali MR. Acute diarrhea due to enteropathogenic bacteria in patients at hospitals in Tehran. Jpn J Infect Dis 2008; 61: 269-273.

19. Aslani MM, Ahrabi SS, Alikhani YM, Jafari F, Zali RM, Mani M. Molecular detection and antimicrobial resistance of diarrheagenic Escherichia coli strains isolated from diarrheal cases. Saudi Med J 2008; 29: 388-392.

20. Guler L, Gunduz K, Ok U. Virulence factors and antimicrobial susceptibility of Escherichia coli isolated from calves in Turkey. Zoonoses Public Health 2008; 55: 249-257.

21. Riffon R, Sayasith K, Khalil H, Dubreuil P, Drolet M, Lagace J. Development of a rapid and sensitive test for identification of major pathogens in bovine mastitis by PCR. J Clin Microbiol 2001; 43: 2584-2589.

22. Cebula TA, Payne WL, Peng P. Simultaneous identification of strains of Escherichia coli serotype O157:H7 and their Shiga-like toxin type by mismatch amplification mutation assay-multiplex PCR. J Clin Microbiol 1998; 33: 248-250.

23. Osek J. Development of a multiplex PCR approach for the identification of Shiga toxin-producing Escherichia coli strains and their major virulence factor genes. J Appl Microbiol 2003; 95: 1217-1225.

24. Batchelor M, Knutton S, Caprioli A, Huter V, Zanial M, Dougan G, et al. Development of a universal intimin antisurum and PCR primers. J Clin Microbiol 1999; 37: 3822-3827.

25. Osek J, Gallien P, Protz D. Characterization of shiga toxin-producing Escherichia coli strains isolated from calves in Poland. Comp Immunol Microbiol Infect Dis 2000; 23: 267-276.

26. Moreira CN, Pereira MA, Brod CS, Rodrigues DP, Carvalhal JB, Aleixo JA. Shiga toxin-producing Escherichia coli (STEC) isolated from healthy dairy cattle in southern Brazil. Vet Microbiol 2003; 93: 179-183.

27. Osek J, Winiarczyk S. Prevalence of eae and stx genes among Escherichia coli strains isolated from healthy calves. J Vet Med B Infect Dis Vet Public Health 2001; 48: 67-72.

28. Shaw DJ, Jenkins C, Pearce MC, Cheasty T, Gunn GJ, Dougan G, et al. Shedding patterns of verocytotoxin-producing Escherichia coli strains in a cohort of calves and their dams on a Scottish beef farm. Appl Environ Microbiol 2004; 70: 7456-765.

29. Wani SA, Hussain I, Nabi A, Fayaz I, Nishikawa Y. Variants of eae and stx genes of atypical enteropathogenic Escherichia coli and non-O157 Shiga toxin-producing Escherichia coli from calves. Lett Appl Microbiol 2007; 45: 610-615.

30. Arya G, Roy A, Choudhary Y, Yadav MM, Joshi CG. Serogroups, atypical biochemical characters, colicinogeny and antibiotic resistance pattern of Shiga toxin-producing Escherichia coli isolated from diarrhoeic calves in Gujarat, India. Zoonoses Public Health 2008; 55: 89-98.

31. Nguyen TD, Vo TT, Vu-Khac H. Virulence factors in Escherichia coli isolated from calves with diarrhea in Vietnam. J Vet Sci 2011; 12: 159-164.

32. Wani SA, Bhat MA, Samanta I, Nishikawa Y, Buchh AS. Isolation and characterization of Shiga toxin-producing Escherichia coli (STEC) and enteropathogenic Escherichia coli (EPEC) from calves and lambs with diarrhea in India. Lett Appl Microbiol 2003; 37: 121-126.

33. Mercado EC, Gioffre A, Rodriguez SM, Cataldi A, Irino K, Elizondo AM, et al. Non-O157 Shiga toxin-producing Escherichia coli isolated from diarrheic calves in Argentina. J Vet Med B Infect Dis Vet Public Health 2004; 51: 82-88.

34. Sandhu KS, Gyles CL. Pathogenic Shiga toxin-producing Escherichia coli in the intestine of calves. Can J Vet Res 2002; 66: 65-72.

35. Hall GA, Reynolds DJ, Chanter N, Morgan JH, Parsons KR, Debrengy TG, et al. Dysentery caused by Escherichia coli (S102-9) in calves: natural and experimental disease. Vet Pathol 1985; 22: 156-163.

36. Fernandez D, Rodriguez EM, Arroyo GH, Padola NL, Parma AE. Seasonal variation of Shiga toxin-encoding genes (stx) and detection of E.a coli O157 in dairy cattle from Argentina. J Appl Microbiol 2009; 106: 1260-1267.

37. Blanco JE, Blanco M, Alonso MP, Mora A, Dabhi G, Coira MA, et al. Serotypes, virulence genes, and intimin types of Shiga toxin (verotoxin)-producing Escherichia coli isolates from human patients: prevalence in Lugo, Spain, from 1992 through 1999. J Clin Microbiol 1999; 37: 311-319.

38. Beutin L, Krause G, Zimmermann S, Kaulfuss S, Gleier K. Characterization of Shiga toxin-producing Escherichia coli strains isolated from human patients in Germany over a 3-year period. J Clin Microbiol 2004; 42: 1099-1108.

39. Aidar-Ugrinovich L, Blanco J, Blanco M, Blanco JE, Leonil M, Dabhi G, et al. Serotypes, virulence genes, and
intimin types of Shiga toxin-producing *Escherichia coli* (STEC) and enteropathogenic *E. coli* (EPEC) isolated from calves in Sao Paulo, Brazil. *Int J Food Microbiol* 2007; 115: 297-306.

40. Blanco M, Padola NL, Kruger A, Sanz ME, Blanco JE, Gonzalez EA, et al. Virulence genes and intimin types of Shiga-toxin-producing *Escherichia coli* isolated from cattle and beef products in Argentina. *Int Microbiol* 2004; 7: 269-276.

41. Maidhof H, Guerra B, Abbas S, Elsheikha HM, Whittam TS, Beutin L. A multiresistant clone of Shiga toxin-producing *Escherichia coli* O118:[H16] is spread in cattle and humans over different European countries. *Appl Environ Microbiol* 2002; 68: 5834-5842.

42. Schmidt H, Geitz C, Tarr PL, Frosch M, Karch H. Non-O157:H7 pathogenic Shiga toxin-producing *Escherichia coli*: phenotypic and genetic profiling of virulence traits and evidence for clonality. *J Infect Dis* 1999; 179: 115-123.

43. Irino K, Kato MA, Vaz TM, Ramos, IL, Souza MA, Cruz AS, et al. Serotypes and virulence markers of Shiga toxin-producing *Escherichia coli* (STEC) isolated from dairy cattle in Sao Paulo State, Brazil. *Vet Microbiol* 2005; 105: 29-36.

44. Leomil L, Aidar-Ugrinovich L, Guth BE, Irino K, Vettorato MP, Onuma DL, et al. Frequency of Shiga toxin-producing *Escherichia coli* (STEC) isolates among diarrheic and non-diarrheic calves in Brazil. *Vet Microbiol* 2003; 97: 103-109.