



Verocytotoxin-producing *E. coli* Food Poisoning and its Prevention

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SUMMARY

Foodborne illness caused by verocytotoxin-producing *Escherichia coli* (VTEC) - sometimes also referred to as shiga toxin producing *E. coli* (STEC) or enterohaemorrhagic *E. coli* (EHEC) - was first recognised in the early 1980s. Although the illness is uncommon, VTEC is now regarded as an important pathogen because of the very serious complications which may follow infection. The O157:H7 serotype is the predominant cause of VTEC infection in the UK and USA but other serotypes are implicated, particularly in mainland Europe. In comparison with, for example, Salmonellosis, numbers of cases appear to be low. Infection may produce mild or severe bloody diarrhoea, as well as severe and sometimes fatal complications including the haemolytic uraemic syndrome. The infective dose may be very low.

The main reservoir for VTEC is the bovine intestine, although other ruminants may also be important. There are four main transmission routes for infection: food-borne, water-borne, direct or indirect contact with animals and person to person spread. Most cases are not recognised as parts of outbreaks and where these do occur, more than one transmission route may be involved. Food vectors linked to transmission include ground beef, poorly-prepared dried and fermented sausages, milk and milk products, apple juice, sprouting seeds and fresh produce (salads, herbs etc) that have become contaminated with animal faeces. Water has been responsible for some of the largest outbreaks.

Control of VTEC illness in humans requires good slaughterhouse and kitchen hygiene and heat treatment of raw meat and milk. VTEC is destroyed by heat; adequate cooking of meat (an internal temperature of 70°C for 2 minutes) and pasteurisation of milk will protect consumers from infection from these sources. It is essential to provide hygienic food handling and good chilled storage conditions to ensure that other foods do not become contaminated. Cases of infection should be excluded from working as food handlers until microbiological clearance of a stool sample has been obtained.

End-product testing for VTEC, as for other pathogens, is not an effective control strategy. However, in the USA, the Department of Agriculture (USDA) has adopted precisely that regulatory strategy for ground beef. Contamination rates in suspect foods are low, so the chance of isolating the bacteria from samples in a batch of food is small. The widely used standard methods for detection and confirmation of *E. coli* are not appropriate as many VTEC strains grow poorly or not at all at 44°C. There are standardised and sensitive methods to detect and isolate VTEC O157 from food, and animals. For the other serotypes, there are no universally accepted and validated methods, but pragmatic approaches have been produced.

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BACKGROUND

Escherichia coli is a common organism found in the lower intestinal tract of healthy humans and animals. As a result of contamination via animal faeces or sewage, it is also readily found in the environment, e.g. untreated water, agricultural run-off, soil, vegetation, some moist or wet areas in factories and abattoirs, etc. There are many types of *E. coli*, a few of which are potentially pathogenic by a variety of infective and toxin-producing mechanisms. Symptoms vary according to the strain of *E. coli* encountered, and the resistance of the individual to such illnesses. Infants, young children, elderly and sick people are generally more susceptible to *E. coli* (and other) infections than healthy older children and adults.

VTECs produce verocytotoxins (VT), some of which are similar to a toxin produced by *Shigella dysenteriae*. The pathogenicity of VTEC not only involves the production of toxin but also the adhesion to, and colonisation of, the intestinal tract and the production of VT. Clinical symptoms are very variable; some patients are completely asymptomatic whilst in others infection can be fatal or be very serious with long-term health impairment. Disease symptoms range from mild diarrhoea to severe bloody diarrhoea (haemorrhagic colitis) and in some patients (particularly children) serious sequelae develop, including the haemolytic uraemic syndrome (HUS, damage to the kidneys resulting in blood in the urine), haemolytic anaemia (loss of red cells), and thrombocytopenia (loss of platelets) and thrombotic thrombocytopenic purpura (TTP, loss of platelets and excessive clot formation, leading to kidney and nervous system damage). In some outbreaks, a high proportion of cases develop HUS, which is the most common cause of renal failure in children in the UK. Most VTEC infections in the UK and USA arise from strains of serotype O157, but other serotypes can produce VT and this serotype is in the minority in some mainland European countries. Most routinely used procedures for diagnosis of infection will only detect VTEC O157, which may account for the apparent predominance of this serotype in some countries. However this probably also reflects true national differences in the distribution of VTEC types in the food chain.

INCIDENCE

VTEC illness was first recognised in the UK in 1982 and, since then, infections have been reported from more than 30 countries on 6 continents. In 1996, there was an outbreak of gastrointestinal infections with *E. coli* O157 in Scotland during which 20 people died and just over 500 became ill. Nearly 11% of the patients with the outbreak had a diagnosis of HUS and TTP (Dundas, *et al*, 1999, Pennington 2000). This outbreak was associated with a raw and cooked meat operation and was investigated by the Pennington Group (1997). This Group identified failures in training of employees, use of temperature probes to monitor the cooking process, cleaning schedules, separation of raw and cooked product, provision of lists of the places supplied and local authority inspections. This Group proposed far-reaching recommendations, which, *inter alia*, gave rise to the licensing of butchers' shops (now discontinued) and Hazard Analysis Critical Control Point (HACCP) training programmes for butchers (mandatory for those handling raw meat and ready-to-eat foods). The outbreak was also the subject of a Fatal Accident Inquiry. The FSA Scotland and the Scottish Executive set up a Task Force, which reported in June 2001 with 105 recommendations in areas as diverse as waste recycling, access to the countryside, diagnosis, patient care by health professionals, and outbreak control. An Action Plan was established in response to the Task Force Report..

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Although large outbreaks of VTEC infection have occurred in the UK, the majority of cases are sporadic in nature. In England and Wales, the number of laboratory reports of VTEC infections reached a peak of 1087 in 1997 and has ranged from 595 to 1084 infections between 1998 and 2006 (HPA, 2007). Scotland generally reports a higher rate of VTEC infection than other parts of the UK (Locking et al, 2006).

Non-food routes of infection are important in transmission of VTEC infections. For example, in 2000 more than 1,000 cases (six deaths) were associated with contaminated drinking water in Ontario (Woodward et al., 2002). In addition to waterborne sources, cases have been associated with direct or indirect contact with animals and person to person spread. Most cases are not recognised as parts of outbreaks and, where outbreaks do occur, more than one transmission route may be involved. Outbreaks are well-recognised amongst children in nurseries and kindergartens as well as with visits to open farms and “petting zoos” and county fairs in the USA. There was evidence of airborne transmission in the USA. At least 19 people who had visited a county fair in Ohio in 2001 fell ill with *E. coli* that apparently spread through sawdust in the air at an exhibition hall, the first time researchers have connected an outbreak to a contaminated building. Testing at the building found *E. coli* O157 in the rafters, the walls and the sawdust, in some cases 10 months after the fair (Varma et al, 2003).

E. coli O157 is a worldwide threat to public health and outbreaks have been reported in Europe, North America, the Far East and Australasia. It is estimated that about 75,000 cases of *E. coli* O157 occur annually in USA (Perna et al., 2001) with an estimated 2,100 cases (2.8%) requiring hospitalisation. It was estimated that, in 2000, the 995 cases of foodborne diseases in England and Wales resulted in 377 hospital admissions, 2,149 hospital bed days and 22 deaths (Adak et al., 2002). However VTEC infections are less commonly reported in patients in less industrialised countries.

FOOD SAFETY

It is estimated that *E. coli* O157 has an infective dose of only 10 to 100 organisms; therefore, with such a small infective dose, cross contamination of high risk foods with raw food is a potential problem in retail outlets and at home. The intestinal tracts of cattle are considered to be the major animal source of VTEC that are virulent to humans (Caprioli *et al.*, 2005). VTEC O157 and other serotypes associated with human infections have also frequently been isolated from the intestinal content of other ruminant species, including sheep, goat, water buffalo, and wild ruminants, while pigs and poultry have not been identified to be major sources of VTEC. Therefore foods most likely to be contaminated are raw meats, particularly beef, and raw milk as well as fresh produce that is exposed to animal faeces, e.g. via contaminated water, or from feral animals.

Cattle are asymptomatic excretors of VTEC O157, which are transient members of their gut microflora. The presence of VTEC O157 appears to be influenced by the age of the animals and by the season. Shedding is usually longer and more intense in calves than in adult cattle, and increases after weaning. It is also much higher during the summer period (Caprioli *et al.*, 2005). The reported prevalence of VTEC and/or VTEC O157 in cattle is also influenced by the sampling and detection methods adopted in the investigations. Faecal carriage rates in cattle worldwide can vary between <1 to 70% of all animals tested (Hussein and Bollinger, 2005). Some animals excrete very large numbers of VTEC O157 at certain times and these are referred to as super-shedders. It has been suggested that these super-

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shedders are of prime importance in transmission and maintenance within herds and the wider environment (Low *et al.*, 2005).

The considerably different isolation rates partly reflect differences in material studied and methods used for isolation and detection. Since faecal contamination occurs, VTEC can be transferred onto carcasses at slaughter, or into milk at milking. Since these bacteria are readily killed by heat (including pasteurisation), the consumption of raw milk, cream and cheeses made from raw milk is strongly discouraged because they are a potential source of VTEC infections, as well as for other pathogens. Uncooked produce (including vegetables and fruit) can also become contaminated by faeces, and hence cause outbreaks, e.g. lettuce, spinach, bean sprouts, sandwiches, and unpasteurised apple juice. Waterborne outbreaks have occurred either because clean water was not available (or had become contaminated with run-off from cattle pastures) or because of chlorination failure. Exposure to recreational water has also caused outbreaks.

Over 200 serotypes producing VT have been identified from all sources and over 100 have been associated with disease in humans. However, in most countries, strains of VTEC of serotypes O157 in addition to O26, O103, O111 and O145 constitute the majority of infections. The serotype, however, is only a surrogate marker for the potential to cause human disease but the availability of molecular techniques enables simple direct detection and subtyping of VT genes as well other virulence-associated genes. This has led to the concept of the 'seropathotype' that classifies VTEC into five groups based on the incidence of serotypes in human disease, associations with outbreaks versus sporadic infection, and their capacity to cause HUS or HC (Karmali, 2003; Wickham *et al.*, 2006). This classification attempts to provide an understanding in differences in virulence of VTEC. Seropathotype A strains (VTEC O157) have a high relative incidence, commonly cause outbreaks and are associated with HUS. VTEC O26, O103 O111 and O145 together with O121 fall into Seropathotype B, as they have a moderate incidence and are uncommon in outbreaks but are associated with HUS. Seropathotype C includes O91, O104 and O113 strains associated with HUS, but these strains were of low incidence and rarely caused outbreaks. Seropathotypes D and E are not HUS-associated and are uncommon in man or found only in non-human sources. Surveys targeting isolation of VTEC (but not specifically O157) and from non-human sources generally produce isolates from groups C and D.

The organism is heat-sensitive and should be destroyed by the same temperature that is recommended to eliminate *Salmonella* and *Listeria*. The advice in the UK is that minced beef and minced beef products, including beefburgers, should be cooked to a minimum internal temperature of 70°C for 2 minutes or equivalent. Industry should provide cooking instructions for burgers to ensure that they are adequately cooked, that the meat juices run clear and there are no pink areas inside cooked products. In USA, the Food & Drug Administration (FDA) now recommend that ground beef products should be cooked so that all parts of the food are heated to at least 68.3°C for a minimum of 15 seconds. Pasteurisation of milk also effectively eliminates VTEC: thus, at 72°C for 16.2 seconds more than 10⁴ cells/ml will be killed. Several of the recorded outbreaks of VTEC illness are likely to have been caused by undercooking of beefburgers and similar products.

The minimum pH for growth is around pH 4.5 but some strains of VTEC can survive in lower pH products. The organism can survive fermentation, drying and storage for up to 2 months in fermented sausage with a pH of 4.5 and, indeed, this food type has been associated with outbreaks. The organism was shown to survive between 1 and 7 weeks in other acidic foods

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(mayonnaise and apple juice) with pH values between 3 and 4; and these food types have been associated with VTEC outbreaks. VTEC are resistant to drying and can survive for long periods under hostile conditions. However, VTEC does not have unusual heat resistance and D values at 57°C to 64°C are between 270 and 9.6 seconds. Some VTEC strains will grow at 8°C, but refrigeration at or below 5°C should prevent growth. However, any organisms present may survive normal refrigeration temperatures for several weeks.

Large multi-state outbreaks of VTEC infection in the USA have drawn attention to fresh produce as a food vehicle. In 2006, 205 cases (3 deaths, 103 hospitalisations and 31 cases of HUS) were identified as associated with consumption of spinach (Anon, 2006a). Furthermore, in the same year, 71 cases (53 hospitalisations and 8 cases of HUS) were associated with consumption of lettuce (Anon 2006b). In both instances, the raw foods were suspected to have become contaminated in the environment, probably via water contaminated with agricultural run-off from cattle farming or via the faeces of feral animals.

Outbreaks may also be caused by cross-contamination of ready-to-eat foods from raw foods or dirty utensils and by post-pasteurisation contamination of milk. Person-to-person spread also occurs and has caused outbreaks in hospitals, day care centres, infant schools and nursing homes. It has not been possible to pinpoint the source of infection in many sporadic cases and small outbreaks. Normal good manufacturing/catering practices should ensure that the chance of cross-contamination occurring is minimised. The measures needed to protect consumers from VTEC are the same as those needed to protect against *Salmonella*, *Campylobacter*, *Listeria* and most other non-spore-forming foodborne pathogens.

Food handlers suffering from *E. coli* O157 infection should be excluded from work until two negative faecal specimens taken at intervals of not less than 48 hours have been obtained (Dept of Health, 1995).

QUALITY ASSURANCE

VTEC have been found in the faeces of healthy cattle, and it is currently not feasible either to detect all contaminated animals or to eliminate the bacterium at source. Quality assurance programmes in slaughterhouses should stress the need to minimise faecal contamination of carcasses and to chill meat rapidly. Measures must be taken in slaughterhouses to minimise faecal contamination of carcasses. (EC Regulation 854/2004 specifies that dirty animals that pose an unacceptable risk of contamination to meat during slaughter cannot be slaughtered for human consumption unless they are cleaned beforehand.)

One of the slaughterhouse measures is an assessment by a veterinarian (vet) of the fleece/hide cleanliness of animals arriving at the slaughterhouse. Animals are graded from 1 to 5 with the highest score indicating high faecal contamination. The vet has to decide if the animals are to be rejected, cleaned for re-submission to *ante mortem* inspection or particular attention paid to hygiene procedures during processing. The use of potable water or steam as well as decontamination with organic acids in the USA of whole carcasses after slaughter can reduce pathogens (including VTEC) that originate from faecal contamination.

Elsewhere in the food industry, procedures to ensure that incoming food materials and ingredients are of good quality should be in place and should be followed. Screening of raw meats for VTEC is not an effective control mechanism because contamination rates are low

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and routine screening specifically for this organism is considered unlikely to be successful. The value of screening raw meat is being debated widely. Undoubtedly, screening will detect some contaminated material and this can then be designated to a secure heat treatment process but, as screening can never detect all contaminated lots, it is a poor control procedure. Nevertheless, in the USA, the USDA has adopted exactly that regulatory strategy for ground beef, with consequent huge recalls (e.g. Hudson Foods in 1997, ConAgra Foods in 2002) (USDA FSIS Final Rule, 1999).

In 1999, the USDA approved the use of irradiation to treat ground beef in order to inactivate pathogenic bacteria, particularly VTEC. While the use of this technique would improve the safety of ground beef, adequate cooking of meat remains the most practical and sure way of eliminating the danger of VTEC infection from this source.

In food manufacture and processing, quality assurance of raw and in-process materials, finished products and the manufacturing environment should be based on the requirements identified by a HACCP evaluation and the end-product specification. This can include minimising faecal contamination from animals and via contaminated water in the field, effective washing and disinfection during processing and avoiding cross contamination from contaminated products. Following a series of outbreaks of *E. coli* O157 associated with unpasteurised apple juice, culminating in the large Odwalla outbreak, the US Food and Drug Administration (FDA) in 1998 introduced a rule for warning labelling of unpasteurised juice, and in 2001 introduced a rule (finalised in 2004) requiring that juice processors must use FDA-specified HACCP principles for juice processing in accordance with 21. CFR Part 120; Health Canada introduced similar requirements in August 2000. The presumed problem with apple juice arises from use of faecally contaminated fallen apples in orchards where livestock have been grazing. A Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables is available from the FDA (FDA, 1998).

Good hygiene practices at processing plants, including monitoring for microbiological indicators (*Enterobacteriaceae* and in generic *E. coli*), are likely to be the most effective method for reducing the public health risks from VTEC infection. However, compliance with the hygiene criteria does not guarantee the absence of VTEC at concentrations sufficient to cause human disease. Therefore, monitoring should take into account compliance with the criteria of the Regulation (EC) No 2073/2005, the presence of VTEC in high risk foodstuffs and other risk-based supporting data. Application of efficient, validated HACCP-procedures for production of raw ready-to-eat meat, meat preparations and other foods is important to reduce the public health risks for VTEC infection. Any increases in 'normal' levels of indicator organisms should trigger an active investigation for their increased levels. Effective process control of all cooking/pasteurisation stages is essential to ensure that the correct heating temperatures and times are achieved.

DETECTION

Methods used in medical laboratories to detect the organism from stools are usually more successful, probably because the number of VTEC cells present in the stools of someone made ill by the organism is often relatively high in comparison to the background flora. The gold standard for the diagnosis of VTEC infection is by detection of specific toxic effects from the VT in a patient's stool sample by using Vero cells (mammalian cells growing in tissue culture). However, toxin is now more usually detected by the use of immunological methods

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and VTEC can indirectly be diagnosed by examining *E. coli* strains or samples for the genes encoding VT (*vtx*). Microbiological methods for isolation of VTEC are available (see below) and, since a relatively small number of VTEC serotypes are responsible for the majority of human VTEC infections, serotype-specific detection methods have been developed where strains are isolated on the basis of their O antigen and are subsequently analysed for VT production or presence of *vtx* genes. However, the diagnosis of VTEC in medical laboratories is laborious and, currently, there are no simple, inexpensive methods available for routine isolation of all VTEC strains.

It is not easy to detect VTEC in foods where low levels of *E. coli* may be swamped by high numbers of other bacteria, particularly in unprocessed foods such as raw meats. VTEC are phenotypically very similar to all other *E. coli*; however, VTEC O157 are usually both unable to ferment sorbitol within 24 hours of incubation and lack β -glucuronidase activity (March and Ratnam, 1986; Ratnam *et al.*, 1988; Thompson *et al.*, 1990). These characteristics are utilised in the routine selective isolation of VTEC O157. The most widely used solid medium for the detection of non-sorbitol fermenting VTEC O157 is sorbitol MacConkey (SMAC) agar. Media that simultaneously indicate sorbitol fermentation and β -glucuronidase activity have also been developed, including different chromogenic media. A range of selective indicative media is commercially available. The selectivity of the different solid media can be improved by the use of selective supplements, the most frequently used being cefixime, a third generation cephalosporine, and potassium tellurite (e.g. CT-SMAC) (Zadik *et al.*, 1993). However, some VTEC O157 strains are sensitive to cefixime and potassium tellurite and therefore may not be detected on CT-SMAC agar (MacRae *et al.*, 1997).

Following incubation of the isolation media, individual colonies suspected to be VTEC O157 should be tested for the O157 antigen by using VTEC O157 antiserum or latex agglutination reagents. Isolates agglutinating with O157 antiserum should be confirmed as *E. coli* by biochemical reactions, since other species and VTEC non-O157 can cross-react with O157 antiserum. Since not all VTEC O157 strains produce VT, it is necessary to confirm VT production or the presence of *vtx* genes.

Since food and environmental samples usually contain low numbers of VTEC O157 together with an abundant microbial flora, selective enrichment steps are therefore required. The most widely used media for the enrichment of VTEC O157 for food uses is tryptone soya broth (TSB), which can be supplemented with selective agents including novobiocin, vancomycin, cefsulodin, cefixime, and bile salts (Doyle and Schoeni, 1987, Chapman *et al.*, 1994). There is currently no consensus on optimal incubation temperature (37°C versus 42°C) and time (6-8 hours incubation versus overnight incubation) for all types of samples.

The incubation period required will depend on the competing microflora. Standard methods for food include the analysis of both the 6-h and 18-h incubation enrichment cultures. A 6-8 hour incubation of the enrichment broth increases the sensitivity when analysing matrices with a high number of background flora. However, when stressed or sub-lethally injured VTEC O157 are present, there are difficulties in reaching a detectable level after 6-8 hours of enrichment. Therefore, this short period of incubation can only be recommended when testing matrices where *E. coli* has a short-lag time before onset of growth, as for example with minced meat products. This is also relevant to challenge testing (many companies use this to establish safety of their products), where inappropriate recovery conditions can lead the researcher to conclude more rapid die-off than actually occurs. Conditions should be used that allow

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recovery of injured cells (e.g. some initial recovery on non-selective agar and then transfer via membrane to selective agar).

Following incubation, enriched cultures are subcultured directly onto selective indicative solid media. However, the sensitivity of culture-based enrichment is vastly improved by the use of immunomagnetic separation (IMS) techniques. IMS is a process whereby specific antibodies are linked to paramagnetic beads. These reagents are, for example, mixed with enrichment broths. Following antigen/antibody reactions, separation and concentration of the specific organism on to magnetised areas is achieved which allows the discard of other components (including much of the background microflora) from the broth. IMS allow significant improvements in microbiological enrichment procedures and, originally developed for VTEC O157, reagents are now available for other VTEC serotypes (O26, O103, O111, and O145) associated with human disease.

The Nordic Committee on Food Analysis (NMKL) and the International Organization for Standardization (ISO) have issued horizontal methods applicable for culture-based detection of VTEC O157 in all types of foods and feeding stuffs (NMKL No. 164, 1999, and ISO 16654: 2001). Both methods prescribe the use of TSB supplemented with bile salts and novobiocin (mTSBn) for the pre-enrichment step, with an incubation period of 6-8 hours as well as 18-24 hours at 41.5°C. Further, both methods prescribe to perform an immunomagnetic affinity purification step and to subculture the immunomagnetic particles with adhering bacteria onto CT-SMAC and the user's choice of a second selective isolation agar.

Currently, there is no international standard method for the detection and isolation of VTEC non-O157. However, under the authority of Working Group 6 of the Technical Committee 275 of the European Normalisation Committee (CEN TC275/WG6) a sub-group is currently preparing a European Standard proposal based on a PCR-based horizontal method.

RESEARCH

VTEC can cause very serious illness in humans and the main source of the organism is the faeces of cattle. It is not likely that VTEC can be completely eliminated from raw meats or the cattle population. However, research is active to reduce faecal spreading in cattle by changing the gut flora by altering their diet as well as feeding them with probiotics, competitive gut flora as well as antibiotics, phage and even vaccination (Callaway et al., 2004). Since some animals excrete very large numbers of VTEC O157 at certain times, it has been suggested that these super-shedders are of prime importance in transmission and maintenance within herds and the wider environment (Low et al., 2005), and strategies to exclude these animals from the food chain, as well as 'disinfection' of their rectal contents may be effective in reducing the input of VTEC into the environment.

More than 95% of infections detected in Scotland, England and Wales were due to VTEC O157 but, in Ireland, this is 86% with the remainder caused by non-O157 strains. However, in continental Europe more than half of the infections were attributed to serotypes other than O157 but there are considerable national differences. O157 is the most commonly detected serotype in Belgium, France, Finland, Hungary, the Netherlands, Sweden and Spain. However, in Denmark, Germany, Italy, Norway and Luxembourg, other serotypes are most commonly recognised. Some of these differences reflect national diagnostic and surveillance strategies; however, they may also reflect natural differences in the disease. Data from

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Scotland (Locking et al., 2001) indicates that even when diagnostic procedures for the detection of VTEC non-O157 are routinely applied to samples of faeces from patients with diarrhoea, VTEC non-O157 are rare. In recent years, human infections with sorbitol-fermenting (SF) VTEC O157 have been increasingly recognised in some parts of Europe. Although the methods used for VTEC O157 are not validated for the detection of SF VTEC O157, these organisms can be detected by testing sorbitol-fermenting colonies grown on solid media that do not present typical VTEC O157 colonies for the O157 antigen. Because of these national differences, efforts are being made to understand better the epidemiology of the non-O157 VTEC, which includes improving diagnostic tests for diagnosis, identifying risk factors, identifying reservoirs of infection, and developing microbiological detection systems for food and the environment.

Manufacturers, caterers and consumers need to understand how they can each reduce the chance of causing foodborne VTEC illness. There is a continued need for education that promulgates the most effective ways of preventing VTEC infections, including thorough cooking of raw meats, pasteurisation of milk and the avoidance of cross-contamination from raw meats or cattle faeces to other foods. Because of the associations with fresh produce (especially salad and other leafy vegetables eaten raw), efforts are needed to better understand the control of these types of foods, including tracking the persistence of VTEC in the environment, improved water management and biosecurity.

CONCLUSION

VTEC can cause very serious illness in humans. Numbers of reported cases are usually low (about 1,000 per year in England and Wales) but, because of the serious nature of the illness, are a considerable health burden and concern. The main source of the organism is the faeces of cattle and it is not likely that VTEC can be completely eliminated from raw meats or the cattle population. Manufacturers, caterers and consumers need to understand how they can each reduce the chance of causing foodborne VTEC illness. Thorough cooking of raw meats, pasteurisation of milk and the avoidance of cross-contamination from raw meats or cattle faeces to other foods are the most effective ways of preventing VTEC infections. Generally, the detection of VTEC is laborious, and currently there are no simple, inexpensive methods available for routine isolation of all VTEC strains. Good hygiene practices at processing plants including monitoring for microbiological indicators (*Enterobacteriaceae* and in generic *E. coli*) are likely to be the most effective method for reducing the public health risks for VTEC infection.

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