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Microbial quality of oysters sold in Western Trinidad and potential health risk to consumers

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SUMMARY

The prevalence and characteristics of *Escherichia coli* and *Salmonella* spp. as well as counts of *E. coli* in raw oysters, condiments/spices, and raw oyster cocktails sampled from 72 vendors across Western Trinidad were determined. The microbial quality of the water used in the preparation of raw oysters was also investigated. Of 200 samples each of raw oysters, condiments/spices and oyster cocktails tested, 154 (77·0%), 89 (44·5%) and 154 (77·0%) respectively yielded *E. coli*. The differences were statistically significant ($P = \leqslant 0{\cdot}001$; $\chi^2 = 62{\cdot}91$). The mean *E. coli* count per g in the ready-to-eat oyster cocktail ranged from $1{\cdot}5 \times 10^3 \pm 2{\cdot}7 \times 10^3$ in Couva to $8{\cdot}7 \times 10^6 \pm 4{\cdot}9 \times 10^7$ in San Fernando. One hundred and forty-six (73·0%) oyster cocktails contaminated with *E. coli* had counts that exceeded the recommended standard of 16 per g. Of a total of 590 *E. coli* isolates from various sources tested, 24 (4·1%), 20 (3·4%) and 69 (11·7%) were mucoid, haemolytic and non-sorbitol fermenters respectively. Twelve (2·0%) isolates of *E. coli* were O157 strains, while 92 (46·0%) of 200 *E. coli* isolates tested belonged to enteropathogenic serogroups. Ninety (45·0%) and 73 (36·5%) of 200 water samples contained total coliforms and faecal coliforms respectively, with counts that exceeded 2·2 coliforms per 100 ml. *Salmonella* spp. were isolated from 7 (3·5%), 1 (0·5%) and 2 (1·0%) of 200 samples each, of raw oysters, condiments/spices and oyster cocktails respectively. Oysters pose a health risk to consumers in Trinidad, particularly from colibacillosis and salmonellosis, and the need for increased public awareness of this hazard cannot be over-emphasized.

INTRODUCTION

There has been a long-standing history of illness associated with consumption of bivalve molluscan shellfish [1]. Several epidemics of gastroenteritis in consumers of oysters have been reported worldwide due to bacterial [2, 3] and viral [4, 5] pathogens. Oysters, being filter feeders, have been demonstrated to concentrate and retain human pathogens in their tissues [1, 6, 7] especially when harvested from habitats which are contaminated with faeces [6, 8]. Insanitary practices at sale outlets, coupled with temperature abuse of the product, present potential for contamination and multiplication of pathogens in oysters [9, 10]. This poses a direct hazard to consumers.

In Trinidad and Tobago, the mangrove swamp situated in the western coast of Trinidad provides ideal conditions for the growth of oysters, *Crassostrea rhizophorae* [11]. There have been reports of faecal pollution of swamps and other oyster habitats in

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Trinidad [11, 12]. The only existing report to date on oysters in Trinidad determined the microbial quality of swamp waters and of oysters immediately post-harvest [11]. Despite widespread suspicion in the population that oysters are responsible for illnesses in consumers, there is a dearth of information on the microbial quality of oysters sold by vendors in the country.

The specific objectives of the study were to determine the prevalence and characteristics of *Salmonella* spp. and *E. coli*, as well as the load of *E. coli* in raw oysters, condiments/spices and ready-to-consume oyster cocktails offered for sale in Trinidad. The potential for water used in the preparation of oysters to serve as a source of contamination was also investigated.

MATERIALS AND METHODS

Study design and type of samples

In this cross-sectional study, we determined the bacteriological quality of samples obtained from raw oyster vendors located in Western Trinidad (Fig. 1). Each vendor was identified from a list of addresses obtained from the Oyster Vendors' Association of Trinidad and Tobago (OVATT), as well as vendors not affiliated with OVATT identified by the investigators. Western Trinidad was subdivided into four areas (East–West Corridor, Chaguanas, Couva and San Fernando) with 50 samples taken from each area. Overall, 72 participating vendors were visited, each of whom provided samples of raw oysters, condiments/spices, and raw oyster cocktails (oyster and condiment/spice mixtures). In addition, the water used at each vendor's roadside stall was sampled. Random identification codes were assigned to vendors, and no more than four sampling trips, usually over 4 days apart, were made to any vendor.

Sample collection

The following samples and amounts were obtained from every vendor at each visit: a 'single' order of raw oyster meat (approx. 12 oyster innards without condiments); condiment (25 ml) of 'medium' hotness as assessed by the vendor; a ready-to-consume 'single' order of oyster meat (12 oyster innards) and 'medium' sauce (i.e. raw oyster cocktail); and water (250 ml) used in product preparation.

The sampling period was from 25 May 1998 to 27 June 1998, the beginning of the wet season (May–December) in Trinidad. The average temperature during this period was 28 °C.

Oyster and condiment/spice samples were collected in wide-mouth, plastic sterile containers, while sterile glass bottles were used to collect water samples. All samples were ice-cooled and transported to the laboratory within 2 h of collection.

Isolation, enumeration and identification of pathogens

For qualitative detection of *E. coli* in raw oysters, condiments/spices and oyster cocktails, sterile swabs were applied to each sample and used to inoculate eosin methylene blue (EMB) agar. These were then incubated at 37 °C overnight, and typical colonies with greenish metallic sheen were observed and identified as suggested [13].

For the enumeration of *E. coli*, 25 g of sample was blended in 225 ml of lactose broth (1:10 dilution) and was serially diluted by adding 0·1 ml of the sample suspension to 9·9 ml of sterile saline [13]. One-tenth millilitre of dilutions were then plated on EMB agar. Inoculated EMB agar plates were incubated at 37 °C for 18 h. Colonies (30–300) at the highest dilutions were counted using a Quebec Darkfield Colony Counter (Cambridge Instruments Inc., New York, USA) and expressed as colony forming units (c.f.u.) per gram of sample.

To detect *Salmonella* spp., the 25 g of each sample blended in lactose broth as pre-enrichment was incubated at 37 °C overnight as recommended [13]. One millilitre each of the pre-enriched samples was inoculated into 9 ml each of tetrathionate (TT) and selenite cysteine (SC) broths for enrichment, and incubated overnight at 37 and 42 °C, respectively. Growths in TT and SC broths were inoculated onto xylose lysine desoxycholate (XLD) agar and MacConkey agar and incubated at 37 °C for 24 h. Biochemical identification of salmonella isolates also followed the procedure described by the FAO [13]. Polyvalent antiserum (A–I & Vi) was used initially to serotype salmonella isolates by slide agglutination. Confirmation and complete serological typing was done by the Caribbean Epidemiology Centre (CAREC), Port-of-Spain, Trinidad.

Characterization of *E. coli* strains

E. coli isolates were plated on blood agar (BA) and sorbitol MacConkey agar (SMAC) and incubated aerobically at 37 °C overnight to detect mucoid and haemolytic colonies on BA plates, and non-sorbitol fermenters on SMAC plates as recommended [13].

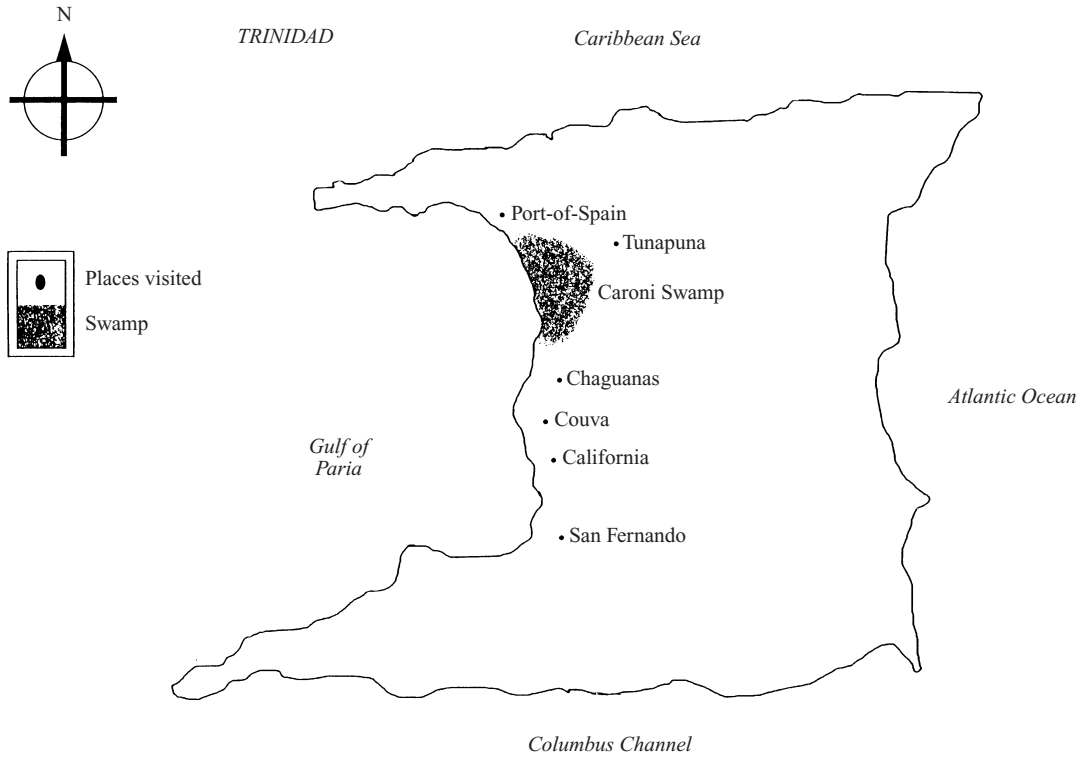

Fig. 1. Sources of oyster and condiment samples in Western Trinidad.

To detect possible enteropathogenic strains among *E. coli* isolates, 200 isolates were selected, in proportion to the number of isolates recovered from each area, and tested by slide agglutination using polyvalent antisera A, B and C (Central Veterinary Laboratory, Weybridge, UK).

All non-sorbitol fermenting *E. coli* isolates were inoculated onto BA and subjected to slide agglutination testing using *E. coli* O157 antiserum (Difco, Michigan, USA) to detect O157-positive strains.

Detection of total and faecal coliforms in water

Water used by each vendor during the sampling visit was tested for total coliforms and faecal coliforms by the membrane filter technique [14]. Initially, 100 ml portions of water were filtered through membrane filters (0·45 μm) and the filters rested on endo agar (Difco, Michigan, USA) for total coliforms and MFc agar (Difco, Michigan, USA) for faecal coliforms [14]. These plates were incubated for 24 h at 37 and 44·5 °C respectively. Where the counts were too high for accurate enumeration, the process was repeated using lower volumes, usually 50 ml or 10 ml. Counts were expressed as total coliforms or faecal coliforms per 100 ml.

Representative colonies with characteristic appearance on endo agar (metallic gold colonies) and MFc agar (blue colonies) were inoculated onto EMB agar plates to isolate *E. coli* strains amongst the coliforms. Standard methods [13, 15] were then used to identify *E. coli* isolates.

Statistical analysis

Chi-square (χ^2) tests were used to determine whether statistically significant differences existed between the prevalence of *E. coli*, salmonella and the virulence markers (mucoid, haemolytic, non-sorbitol fermenters, O157 strains and enteropathogenic *E. coli*, EPEC) among *E. coli* isolates from the four sampling areas studied. Similar analyses were also done on the frequency of occurrence of samples of raw oysters, condiments/spices, raw oyster cocktails and water considered unfit for human consumption based on accepted standards [16, 17]. In all cases, type 1 error ($\alpha = 0{\cdot}05$) was used, and P values stated. The computer programme used to analyse the data was Epi Info (CDC, Atlanta, version 6.02).

RESULTS

Prevalence of pathogens in oysters and water

The prevalences of *E. coli* and salmonella in raw oysters, condiments/spices and raw oyster cocktails,

Table 1. *Prevalence of* E. coli, *coliforms and salmonella in oysters, condiments/spices and water sampled from oyster vendors. Values are the number* (%) *of positive samples*

Sampling area	No. of samples tested	Raw oysters		Condiments/spices		Oyster cocktails		Water	
		E. coli	Salmonella	*E. coli*	Salmonella	*E. coli*	Salmonella	Total coliforms	Faecal coliforms
East–West Corridor	50	44 (88·0)	5 (10·0)	26 (52·0)	0 (0·0)	39 (78·0)	0 (0·0)	25 (50·0)	20 (40·0)
Chaguanas	50	37 (74·0)	0 (0·0)	25 (50·0)	0 (0·0)	41 (82·0)	1 (2·0)	31 (62·0)	27 (54·0)
Couva	50	35 (70·0)	1 (2·0)	19 (38·0)	1 (2·0)	36 (72·0)	1 (2·0)	28 (56·0)	21 (42·0)
San Fernando	50	38 (76·0)	1 (2·0)	19 (38·0)	0 (0·0)	38 (76·0)	0 (0·0)	31 (62·0)	25 (50·0)
Total	200	154 (77·0)	7 (3·5)	89 (44·5)	1 (0·5)	154 (77·0)	2 (1·0)	115 (57·5)	93 (46·5)

Table 2. *Mean counts of* E. coli *in oysters and condiments/spices and coliform in water used by oyster vendors*

Sampling area	No. of samples tested	Raw oysters (mean (±S.D.) count of *E. coli* per g)	Condiments/spices (mean (±S.D.) count of *E. coli* per g)	Oyster cocktails (mean (±S.D.) count of *E. coli* per g)	Water	
					Total coliform count per 100 ml	Faecal coliform count per 100 ml
East–West Corridor	50	$4{\cdot}2 \times 10^5 \pm 1{\cdot}7 \times 10^6$	$5{\cdot}3 \times 10^2 \pm 1{\cdot}0 \times 10^3$	$6{\cdot}4 \times 10^4 \pm 2{\cdot}9 \times 10^5$	$1{\cdot}5 \times 10^3 \pm 5{\cdot}6 \times 10^3$	$4{\cdot}8 \times 10^3 \pm 3{\cdot}2 \times 10^4$
Chaguanas	50	$3{\cdot}8 \times 10^7 \pm 2{\cdot}7 \times 10^8$	$6{\cdot}8 \times 10^2 \pm 1{\cdot}5 \times 10^3$	$3{\cdot}5 \times 10^4 \pm 1{\cdot}3 \times 10^5$	$3{\cdot}4 \times 10^4 \pm 1{\cdot}5 \times 10^5$	$2{\cdot}7 \times 10^4 \pm 1{\cdot}1 \times 10^5$
Couva	50	$1{\cdot}2 \times 10^5 \pm 6{\cdot}9 \times 10^5$	$1{\cdot}0 \times 10^3 \pm 3{\cdot}2 \times 10^3$	$1{\cdot}5 \times 10^3 \pm 2{\cdot}7 \times 10^3$	$1{\cdot}6 \times 10^4 \pm 7{\cdot}1 \times 10^4$	$4{\cdot}6 \times 10^4 \pm 3{\cdot}0 \times 10^5$
San Fernando	50	$4{\cdot}5 \times 10^6 \pm 2{\cdot}8 \times 10^7$	$1{\cdot}1 \times 10^2 \pm 3{\cdot}5 \times 10^2$	$8{\cdot}7 \times 10^6 \pm 4{\cdot}9 \times 10^7$	$5{\cdot}5 \times 10^3 \pm 2{\cdot}3 \times 10^4$	$3{\cdot}1 \times 10^3 \pm 1{\cdot}8 \times 10^4$

Table 3. *Prevalence of unfit samples of oysters, condiments/spices and water from various sources using acceptable standards. Values are number* (%) *of samples*

Sampling area	No. of samples tested	Raw oysters with *E. coli* count/g over 16 per g*	Condiments/spices with *E. coli* count/g over 16 per g*	Oyster cocktails with *E. coli* count/g over 16 per g*	Water with:	
					Total coliform count over 2·2 per 100 ml†	Faecal coliform count over 2·2 per 100 ml†
East–West Corridor	50	42 (84·0)	21 (42·0)	39 (78·0)	18 (36·0)	14 (28·0)
Chaguanas	50	31 (62·0)	22 (44·0)	35 (70·0)	26 (52·0)	21 (42·0)
Couva	50	32 (64·0)	16 (32·0)	33 (66·0)	21 (42·0)	16 (32·0)
San Fernando	50	34 (68·0)	13 (26·0)	39 (78·0)	25 (50·0)	22 (44·0)
Total	200	139 (69·5)	72 (36·0)	146 (73·0)	90 (45·0)	73 (36·5)

* Using standards recommended [16]. † Using recommended standards [17].

Table 4. *Characteristics of* E. coli *and salmonella strains isolated from raw oysters, condiments/spices, and ready-to-consume cocktails and water*

Sampling area	*E. coli*							Salmonella	
	No. of isolates tested	No. (%) of *E. coli* strains positive for:				No. of isolates tested for EPEC‡	No. (%) positive for EPEC	No. of isolates tested	Serotype [ ]
		Mucoid	Haemolytic	NSF*	O157†				
East–West Corridor	177	7 (4·0)	9 (5·1)	24 (13·6)	3 (1·7)	60	32 (53·3)	8	*S. thompson*[1] *S. newport* [1] *S. schwarzengrund* [1] *S. aberdeen* [2] *S. agona* [2] *S. kentucky* [1]
Chaguanas	137	10 (7·3)	7 (5·1)	15 (10·9)	1 (0·7)	46	21 (45·7)	2	*S. aberdeen* [1] *S.* group F [1]
Couva	124	2 (1·6)	1 (0·8)	5 (4·0)	0 (0·0)	42	20 (47·6)	4	*S. derby* [4]
San Fernando	152	5 (3·3)	3 (2·0)	25 (16·4)	8 (5·3)	52	19 (36·5)	1	*S.* group C1 [1]
Total	590	24 (4·1)	20 (3·4)	69 (11·7)	12 (2·0)	200	92 (46·0)	15	—

[ ] Number of isolates of serotypes recovered. * Non-sorbitol fermenters. † *E. coli* O157 strains. ‡ *E. coli* strains in enteropathogenic serogroups: 73 (36·5%), 70 (35·0%), and 6 (3·0%) of the 200 strains were agglutinated by *E. coli* antisera A, B and C respectively.

as well as that of coliforms in water are shown in Table 1. The difference in prevalence of *E. coli* in raw oyster samples across the four sampling areas was not statistically significant ($P = 0{\cdot}17$; $\chi^2 = 5{\cdot}08$). There was also no statistically significant difference across areas in the prevalence of *E. coli* in condiment/spice and oyster cocktail samples ($P = 0{\cdot}33$; $\chi^2 = 3{\cdot}46$ and $P = 0{\cdot}7$; $\chi^2 = 1{\cdot}47$ respectively).

However the prevalence of *E. coli* in the condiment/spice samples (44·5%) was significantly lower ($P = < 0{\cdot}001$; $\chi^2 = 62{\cdot}91$) than that found in raw oysters and raw oyster cocktails (77·0%).

The prevalence of water samples positive for total coliforms and faecal coliforms was not significantly different across the four areas ($P = 0{\cdot}57$; $\chi^2 = 2{\cdot}03$ and $P = 0{\cdot}45$; $\chi^2 = 2{\cdot}63$ respectively).

Counts of *E. coli* in oysters and coliforms in water

The mean counts of *E. coli* in raw oysters, condiments/spices and raw oyster cocktails, and coliforms in water are shown in Table 2.

Prevalence of oyster, condiment/spice and water samples unfit for human consumption

Table 3 shows the frequency of occurrence of samples of raw oysters, condiments/spices, raw oyster cocktails and water considered unfit for human consumption based on accepted standards. Based on *E. coli* counts which exceeded 16·0 per g, the difference in frequency of unfit raw oyster samples across sampling areas was not statistically significant ($P = 0{\cdot}07$; $\chi^2 = 7{\cdot}05$). Also, the frequency of unfit samples of condiments/spices and raw oyster cocktails across areas was not significantly different ($P = 0{\cdot}20$; $\chi^2 = 4{\cdot}69$ and $P = 0{\cdot}43$; $\chi^2 = 2{\cdot}74$ respectively).

However, among the three types of products, the difference in frequency of unfit samples was statistically significant ($P = < 0{\cdot}001$; $\chi^2 = 69{\cdot}26$).

There were no statistically significant ($P = 0{\cdot}35$; $\chi^2 = 3{\cdot}31$ and $P = 0{\cdot}28$; $\chi^2 = 3{\cdot}86$) differences in the numbers of water samples that exceeded recommended total or faecal coliform counts among the four areas studied.

Characteristics of *E. coli* and salmonella strains

Table 4 shows the frequency of occurrence of various virulence markers in *E. coli* strains, as well as the serotypes of the salmonella isolates. There was a statistically significant ($P = 0{\cdot}011$; $\chi^2 = 11{\cdot}04$) difference across areas in the frequency of *E. coli* isolates which were non-sorbitol fermenters.

Ten samples of oysters and condiments/spices positive for salmonellae yielded 15 isolates of the pathogen. A total of nine different serotypes of salmonella were identified, of which the predominant serotype was *S. derby*, which accounted for 26·7% (4 of 15) of the salmonella isolates.

DISCUSSION

Trinidad and Tobago is a developing cosmopolitan society located in the tropics where a wide variety of exotic foods is readily available from road side vendors. The microbial quality and associated health risk of some of these foods have been investigated [18–20]. The ready-to-consume raw oyster cocktail, a mixture of raw oysters, hot sauce and spices is one such delicacy [12], the microbial quality of which was hitherto unknown.

An important finding was that 77% of the shucked raw oyster meat from the four areas of Western Trinidad studied was contaminated with *E. coli*. Variable prevalences of *E. coli* in oyster meat have been reported by others in the United States of America [21, 22]. The 77% prevalence of *E. coli* in the present study is considerably lower than the 98% rate reported for fresh oysters sampled immediately, post-harvest, from the estuarine habitat of the Caroni Swamp [11]. The difference may be explained in part by the fact that 62·5% of the raw oyster meat samples studied here were harvested from outside the Caroni Swamp oyster reserve.

In Trinidad and Tobago, it is known that the practice of animal husbandry and raw sewage dumping into the Caroni River contribute substantially to the faecal contamination of the Gulf coast [11, 12]. Coliforms are good indicators of such faecal contamination [23].

It was of interest to observe that the prevalence of *E. coli* in raw oysters (77%) was the same as was found in oyster cocktails (77%), despite handling and preparation by the vendor. Also, the frequency of raw oysters considered unfit for human consumption (69·5%) was similar to that detected for oyster cocktails (73%). Failure to detect any significant difference between the number of oyster cocktails and raw oysters fit for human consumption based on

recommended standard [16] may be explained in part by the initially high load of *E. coli* in the raw oysters.

The prevalence and counts of *E. coli* per g in condiments/spices from all areas studied were significantly lower than those found in raw oysters or oyster cocktails. Furthermore, it was found that in most areas, the mean *E. coli* counts per g of oyster cocktails were considerably lower than those for raw oysters. The possible inhibitory activity of the condiments/spices on *E. coli* in raw oysters cannot be ignored since some spices exhibit antimicrobial activity [16, 24]. In another study hot sauce was, however, not found to reduce significantly the numbers of microorganisms inside freshly shucked oysters [25].

Of epidemiological significance was the finding that 45% of the water samples tested gave total coliform counts that exceeded the 2·2 coliforms per 100 ml recommended as being safe for human consumption [17]. This was a surprising finding since most of the vendors reported using pipeborne water supplied by the Water and Sewerage Authority (WASA) of Trinidad and Tobago. The containers used in water storage may therefore have contributed to the contamination of water by coliform since the WASA water supply is chlorine-treated. The possibility of contamination of water in the WASA distribution system cannot be ignored as in developing countries like Trinidad, the quality of pipeborne water is considered poor [26].

Of public health concern was the fact that the mean *E. coli* counts per g for both the raw oysters and the ready-to-consume oyster cocktails far exceeded the recommended standards [16, 27]. The counts of *E. coli* per g of these products in fact far exceed the known infective dose for most strains of *E. coli* in humans [28]. The practice of vending raw oysters at ambient temperatures that sometimes exceed 30 °C, coupled with insanitary handling, may also have contributed to the high counts of *E. coli* detected.

The potential health risk posed to the consumer by raw oyster cocktails was further heightened by the finding that a number of the strains of *E. coli* isolated from oysters and condiments/spices exhibited virulence markers. Production of mucoid or haemolytic colonies by *E. coli* is associated with increased pathogenicity [29, 30]. Despite the low prevalences of mucoid (4·1%) and haemolytic (3·4%) isolates detected in this study, other virulence markers, not investigated here, may have pathogenic significance [31]. Studies on *E. coli* strains isolated from milk and dairy cows in the same environment have shown that the frequency of mucoid and haemolytic strains of *E. coli* was 1·1 and 13·8% respectively [32].

Forty-six percent of the *E. coli* isolates from all products belonged to enteropathogenic serogroups. This prevalence is considerably higher than the frequency of 28% found among *E. coli* strains isolated from milk and dairy cows in Trinidad [32] but comparable to the 37% prevalence of EPEC strains found among black pudding ('boudin noir') isolates of *E. coli* [20]. The fact that these isolates of *E. coli* belong to enteropathogenic serogroups, is an indication that they are potentially enteropathogenic in infected humans. EPEC strains have been linked to human gastroenteritis in Trinidad [Public Health Laboratory, Port-of-Spain, personal communication]. EPEC is an important recognized cause of diarrhoea in humans of various ages [31].

Also important was the finding that 12% of the *E. coli* isolates were non-sorbitol fermenters, a characteristic displayed by verocytotoxin-producing strains of *E. coli*, and that 2% of the *E. coli* isolates were O157 strains, which are known to produce verocytotoxins [33–35]. This is the first report of isolation of *E. coli* O157 strains from seafood in Trinidad, and the health risk is substantial since these products are consumed raw. Verocytotoxigenic *E. coli* (VTEC) have been isolated from milk and meat in Trinidad [36, 37]. Although only 2% of the *E. coli* isolates were O157 strains in the present study, non-O157 strains have also been known to be verocytotoxigenic [33, 35]. VTEC strains have caused epidemics of gastroenteritis and haemolytic uremic syndrome in humans [35, 38, 39].

The prevalence of salmonella (1%) found in raw oyster cocktails appears low, considerably lower than a prevalence of 11% found in black pudding, another delicacy in Trinidad [18]. Salmonella are pathogenic for humans and have been responsible for diarrhoea in Trinidadian children [40]. Many foods, including seafoods, have been associated with gastroenteritis due to salmonellosis elsewhere [41, 42].

The fact that 50% of the salmonella isolates originated from vendors in the East–West Corridor did not come as a surprise because their oysters were mostly harvested from faecally contaminated parts of the Gulf Coast mangrove [12]. Although a variety of salmonella serotypes were isolated across sampling areas with *S. derby* being predominant, all these serotypes, with the exception of *S. schwarzengrund*, *Salmonella* group F and *Salmonella* group C1, have previously been isolated from animals, foods and

human gastroenteritis cases in Trinidad [43–46]. The poor investigation and reporting of foodborne outbreaks in Trinidad and Tobago, as in most developing countries, have made it difficult to establish direct links between consumption of oysters and human illness. It is however generally believed that they are responsible for gastroenteritis in consumers, leading to a temporary ban of their sale by government in 1993 following a national cholera alert.

In one instance, a sample of condiments/spices from Couva was contaminated with potentially pathogenic *Salmonella* spp. It is known that certain spices, due to insanitary practices during harvest or preparation, may also serve as vehicles of microorganisms in foods [16, 24, 47].

In conclusion, the poor microbial quality of ready-to-consume raw oyster cocktails sold in Trinidad pose a health hazard to both local consumers and international visitors to the island. Trinidad and Tobago is a Caribbean country visited by tourists all the year round, with the highest number of visitors recorded during the annual Carnival festivals in February. It is highly probable that these unsuspecting visitors may consume for the first time, oyster cocktails during their stay in the country. The risk of salmonellosis and colibacillosis, in addition to diseases caused by other pathogens such as *Vibrio* spp. which were not sought in this study cannot be ignored. Furthermore, the high microbial load of raw oysters may have economic significance as exporters may be unable to meet the stipulated microbial quality of international markets thereby affecting the country's ability to earn foreign exchange.

Based on our findings, the following preventive and control measures are suggested:

(i) Education of oyster vendors on the need for good sanitary practices and a strict enforcement of these measures.
(ii) Enforcement of the existing laws regarding indiscriminate dumping of effluents and garbage, both domestic and industrial, into the nation's waterways.
(iii) Establishment of an oyster aquaculture project to enhance the quality of oysters available in the market.
(iv) Holding of shellstock for a maximum of 24 h and at temperatures between 0 °C and 4 °C, using ice or refrigeration.
(v) Enhancement of water quality and its availability to vendors and emphasizing the need to treat water by boiling or chlorination and at the same time, ensuring that storage vessels are clean.
(vi) Given the high level of contamination observed, heating of shucked oyster meat for 10 min in water at 50 °C at sale outlets, should this practice be acceptable to consumers.
(vii) Use of fresh, properly cleaned ingredients for condiments/spices.

Finally, regular monitoring of the recommendations would help to ensure that safe and wholesome oyster cocktails are available to consumers in Trinidad.

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