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Microbial quality of ready-to-eat vegetable salads vended in the central business district of Tamale, Ghana

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Abstract

Background: Food safety problems still persist across the globe and remain a challenge to the general public and government. The study determined the microbiological quality of pre-cut vegetable salads sold in the Central Business District (CBD) of Tamale.

Results: A total of thirty (30) salad samples were purchased from four zones of the District and transported to the Spanish Laboratory of the University for Development Studies, Ghana for analysis. Standard microbiological methods that are in accordance with American Public Health Association (APHA) were used in determining the presence and levels of bacteria in the salad samples. *Escherichia coli* were detected in 96.7% of salad samples with levels ranging from 0 to 7.56 log10 cfu/g. *Bacillus cereus* were present in 93.3% of ready-to-eat vegetable salads with counts ranging from 0 to 7.44 log10 cfu/g. Further, *Salmonella* spp. and *Shigella* spp. were present in 73.3% and 76.7% of salads, respectively.
Salmonella spp. and *Shigella* spp. counts ranged from 0 to 4.54 log10 cfu/g and 0 to 5.54 log10 cfu/g, respectively. Statistically, *Escherichia coli*, *Bacillus cereus* and *Shigella* spp. Contamination varied significantly ($p < 0.05$) across the four zones demarcated. However, *Salmonella* spp. contamination did not vary significantly ($p > 0.05$) across the zones.

Conclusions: The study revealed that salads sold by street food vendors in the CBD of Tamale were unwholesome for human consumption and could be deleterious to the health of consumers. The contamination could be attributable to the source of production of the vegetables and improper food handling. It is recommended that the Food and Drugs Authority should enforce strict compliance to food quality standards at all food vending establishments in the CBD.

Keywords: Ready-to-eat, Salads, Tamale, *Salmonella* spp., *Shigella* spp., *Escherichia Coli*, *Bacillus cereus*

Background

Food safety has become a serious concern and a major focus for many scientists in recent years. Also, the interest of the public on food safety issues is on the ascendancy worldwide (WHO/FAO, 2015). Nonetheless, food safety problems continue to persist across the globe and remain a great challenge (Ntuli et al., 2017). It has been established that the business of food vending has created jobs and contributes significantly to the informal sector of the economies of most countries across the globe and as well resolves serious issues confronting major social problems in less developed countries due to the sector's role of providing inexpensive meals to consumers (Alimi et al., 2016). Notably, Estrada-Garcia et al. (2002) reported that in 1998 approximately 28.5% of the work force in Mexico were said to be employed in the informal sector, in addition 30.8% of the Informal sector's activities were in the food vending business employing about 120,000 people. It is worth noting that, the activities of most food vendors and practitioners especially street food vendors usually go on unregulated mainly due to negligence and lack of enforcement of the laws governing food safety resulting in serving unwholesome foods to the populace (Alimi et al., 2016).

The consumption of vegetables and vegetables products are vital for the total health of every individual, however, microbial contamination of these vegetables has become a serious challenge deserving of greater

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attention. Globally, Salad vegetables are one group of vegetables which are a major component of food vending and mostly implicated in this regard.

Salads are fresh vegetables which require minimal washing and processing and cut into desired shapes and sizes with knives or other shredding utensils and usually serve as along with other foods including rice (Ababio and Lovatt, 2014). Worldwide, salad vegetables are considered a major source of nutrients for people and particularly as sources of cancer fighting agents for the skin (Ramteke et al.,2016). Recent studies have established that consumption of salad vegetables can prevent heart diseases and skin cancers (Coulibaly-Kalpy et al., 2017).

Salad vegetables are mostly consumed due to their nutritious components as well as their gustatory attributes when consumed in combination with other foods, which is sometimes as result of the culinary prowess of the food vendors (Choudhury et al., 2011; Alimi et al., 2016).

Salads are also sources of vitamins, minerals, proteins and relevant nutritional components for the proper functioning of the human body (Amoah, 2014). However, ready to eat food like vegetable salads are major potential sources of entropathogens and food borne illness (Mensah et al., 2002). Feglo and Sakyi (2012) recorded various levels of *Staphylococcus aureus, Bacillus species, Klebsiella pneumoniae, Escherichia coli* in different ready-to-eat foods in the Kumasi metropolis of Ghana. *Salmonella, Shigella, Escherichia coli (E. coli), Clostridium, Staphylococcus, Campylobacter,* and *Vibrio* are some of the common bacteria that cause food-related illness (Amoah, 2014).

Mensah et al. (2002) examined 511 ready to eat food in Accra and reported the presence of mesophilic bacteria, *Bacillus cereus, E. coli, Staphylococcus aureus, Enterobacteriaceae* and *Shigella sonnei* in most ready to eat foods. Similarly, bacteria such as *Salmonella species*, *Staphylococci aureus* and *Escherichia coli,* which can be conveyed by food, cause food poisoning and food-borne illness such as tuberculosis, typhoid fever and cholera (Foskett et al., 2003).

Bruce et al. (2005) reported that diarrhoea diseases are the major causes of hospital attendance in Ghana. Studies conducted in Kumasi have also identified vegetables prepared by food vendors especially the street food vendors to be highly contaminated with faecal material and harmful micro-organisms (Amoah et al., 2006) and several related risk practices of food handling have been identified by Henseler (2005) and Olsen (2005).

The most predominant bacteria in Ghanaian foods are *Enterobacter* spp., *Citrobacter* spp., *Klebsiella* spp. and *Escherichia* spp. which were found to be present in 65, 50, 46 and 38% respectively, of the food samples considered in the studies analysed (Saba and Gonzalez-Zorn, 2012).

Research conducted in the international front on bacteria contamination show series of outbreaks. In India, Sabbithi et al. (2014) reported the microbial quality of salads served along with street foods in Hyderabad from which he recovered *Salmonella* spp., *Staphylococcus* aureus and *Yersinia* at unacceptable levels and for which the source of contamination was attributed to the unhygienic practices of food vendors after HACCP was conducted on the vendors. Moreover, De Oliveira et al., 2011 also examined the microbial contamination of 162 samples of minimally processed ready-to-eat vegetables in Brazil were *Salmonella* spp., *Escherichia coli*, Psychrophilic aerobic bacteria, total and thermotolerant coliforms and *Listeria* spp. were recorded at levels above WHO recommended limits. The various microbial contaminations have caused serious health implications when ingested by consumers. Annually, about a million cases of foodborne salmonella illness is reported in U.S, and about 19,000 hospitalizations and 380 death cases are reported every year (CDC, 2014). It is reported that listeria can cause listeriosis a serious and deadly foodborne illness that can be dangerous when ingested especially by pregnant women, fetuses and embryos including individuals with a weakened immune system (Centre for Disease Control and Prevention, 2008). The Centre for Disease Control and Prevention (2008) has described microbial contamination of ready-to-eat foods as a public health concern and usually in the developed countries, especially the U.S, products of vegetable origin are most usually recalled due to the presence of bacteria that are of public health concern.

Though, a number of studies have been carried out on microbial quality of vegetables and other foods, there is a paucity of information on the microbial quality and safety of precut salads served at food joints in the Central Business District (CBD) of Tamale, Ghana. Hence, the present study on the microbial quality of precut salads in the CBD is timely and provides information on the safety of consuming ready-made salads at food joints.

Methods

Study area

The study was conducted in the Central Business District which is the heart of the Tamale Metropolis of Ghana where most business activities take place. The Tamale Metropolitan area is located geographically between latitudes 09°24′27″ and 9.40750° north and longitudes 00°51′12″ and 0.85333° west. It covers a total area of about 750 km2 (Ghana Statistical Service, 2010). It is specifically regarded as the fastest-growing city in the whole of West Africa (Abanka et al., 2009) and by its strategic location, Tamale has a market potential for local goods from the agricultural and commerce sectors from other districts in the region (Ghana Statistical Service, 2010) (Fig. 1).

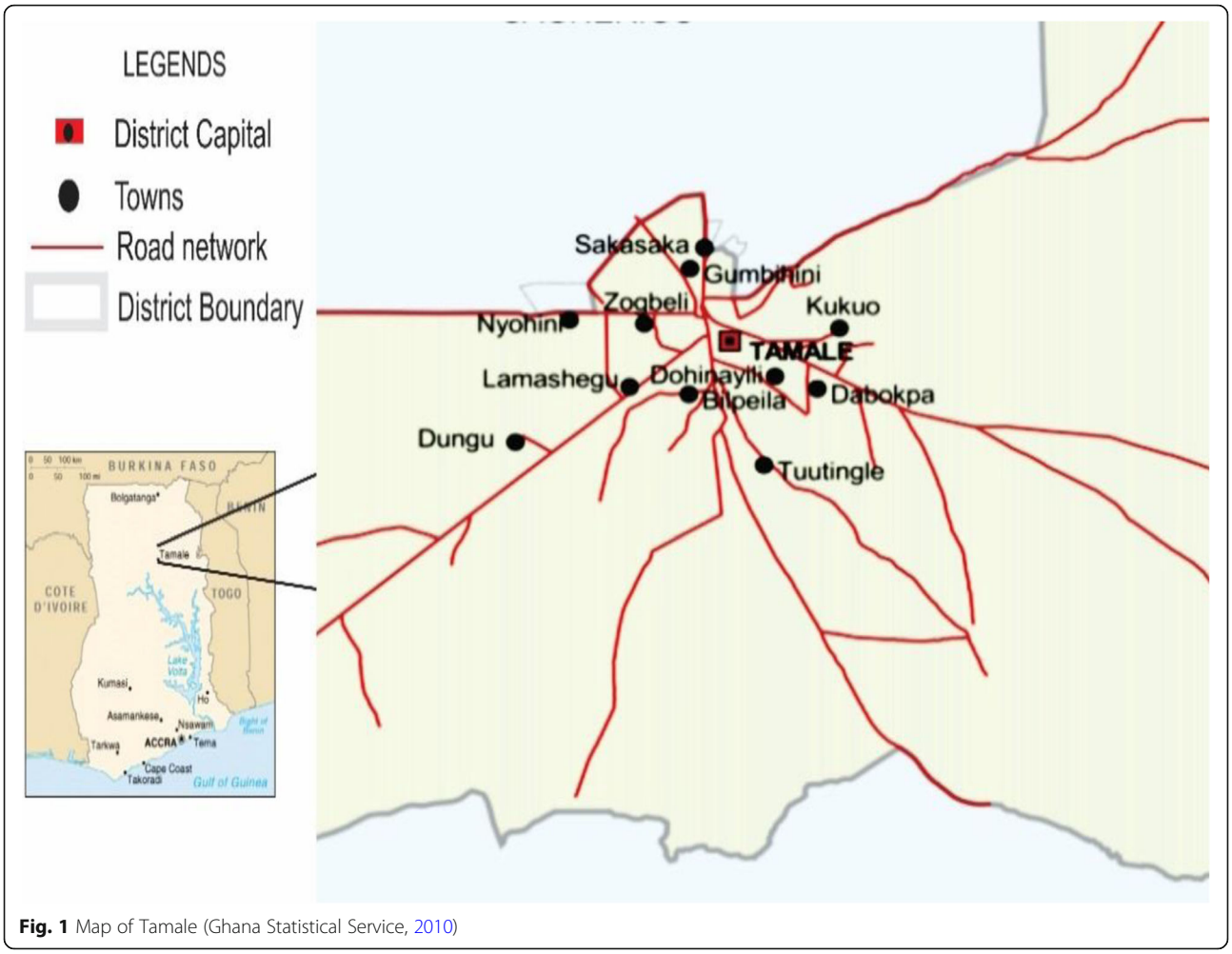

Fig. 1 Map of Tamale (Ghana Statistical Service, 2010)

Sample collection

Stratified random sampling was implored based on the proximity of the food joints as well as sampling convenience, the study area was stratified into four zones/strata (zone1-zone 4). Zone one (1) included areas such as the Timber market, Transport Yard and Nyohini, while Zone two (2) included; Zobgeli, Aboabo and Sabonjida. Localities that made up zone three (3) were; Changli, Taxi Rank, Bus Stop and Tishigu. Zone four (4) constituted; Moshie Zongo, Gumbihini and Parks and Gardens and its surroundings all in the Central Business District (CBD) in the Tamale Metroplis. The salads considered in this study composed of cabbage, lettuce, onions and tomatoes mixtures. A total of thirty (30) samples of ready-to-eat (pre-cut salads for ready consumption) mixture of salad vegetables (cabbage, lettuce, onions and tomatoes) vended at food joints in the CBD were collected from December, 2016 to February, 2017 using the stratified random sampling procedure. Specifically, based on the number of vendors of pre-cut salads in each zone demarcated, seven (7) samples were taken from zone 1, nine (9) samples were taken from zone 2, eight (8) samples were taken from zone 3 and six (6) samples were taken from zone 4. Approximately, 200 g of salad vegetable mixtures from each vendor which are usually served directly to consumers were aseptically collected into sterile polythene zip lock bags, kept in ice chest, maintained at 0–4 °C and were then transported to the Spanish Laboratory Complex of the University for Development Studies, Nyankpala campus, Ghana processed within 2–4 h for microbial analysis.

Microbial analyses and culture conditions

All media were prepared in accordance with the manufacturer's protocol. Media used included. MacConkey agar (Oxoid Ltd., Basingstoke, Hampshire, England), *Salmonella-Shigella* agar. (Techno Pharmchem, India) Simmon Citrate Agar and MYP agar base. These were used for the. Isolation, growth and maintenance of microorganisms.

Preparation of salad samples

Twenty-five grams (25 g) of each salad sample was weighed and transferred into sterile polythene zip lock bags under a laminar flow hood (Envair, UK). Salad in each sterile bag was then mixed thoroughly with 225 ml of buffered peptone water. This mixture was homogenized

very well by simple "hand massaging" and constant shaking to obtain a uniform mixture (stock). Ten (10)-fold serial dilutions were also carried out at five (5) levels.

Specifically, 0.1 ml each of 100, 10–1, 10–2, 10–3, 10–4 and 10–5 dilutions were taken aseptically under the laminar flow hood and inoculated on a solidified MacConkey (Oxoid Ltd., Basingstoke and Hampshire, England), *Salmonella-Shigella* (Techno Pharmchem, India) and Mannitol Egg Yolk Polymyxin (MYP) agars. The inoculated plates were then inverted and incubated at 37 °C (44.5 °C for MacConkey) for 24 h.

After 24 h of incubation, bacterial colonies were identified based on the colour depicted by the colonies on each agar plate. Growth of pink colonies were depicted as *Escherichia coli* and growth of colourless colonies with black centres were depicted as *Salmonella* spp. and growth of colourless colonies without black centres were depicted as *Shigella* spp. based on description by Acumedia Manufacturers (2011). The growth of *Bacillus cereus* on M.Y.P agar plates were depicted as pink colonies. All bacteria colonies were enumerated in accordance with American Public Health Association APHA (American Public Health Association) (2008).

Confirmatory tests (catalase/citrate tests)

Catalase test was carried out for all the bacteria isolates. A drop of Hydrogen per Oxide was put on a glass slide. Colonies were picked with a sterile loop and added to the drop. Observation was made for bubbles production. Colonies that have catalase are able to break down Hydrogen per oxide into water and Oxygen, which can be seen in the form of air bubbles leaving the solution.

Citrate test was done were unique colonies were picked with a sterilized loop and streaked across the plates containing citrate media without breaking the agar and then incubated for 24 h. Data was collected based on color change.

Data analysis

The analysis was carried out by descriptive statistics (finding means and standard deviations) and (ANOVA) of mean microbial counts among the four zones were also determined by checking for significant differences. Pearson's correlation analysis was also carried out to determine the correlation of bacterial loads among the four zones. (Genstat twelfth (12) edition and Microsoft excel software were used).

Results and discussion

Prevalence of bacteria isolates in salad

Vegetables such as salad vegetables after cultivations from the farm go through a series of handling processes and preparations before they are served to consumers. The present study shows variations in bacteria presence and levels in ready-to-eat vegetable salad mixtures obtained from the Business District of Tamale which may be attributed to the different hygienic practices by food vendors as well as the sources of cultivation from which these vegetables were obtained.

Out of 30 salad samples collected from the CBD, *E. coli* were detected in 29 (96.7%) of them.

(Table 1). Also, 28 (93.3%) samples of salad recorded positive for *Bacillus cereus* whilst the, and 23 (76.7%) showed positive results for *Shigella* spp. (Table 1). *Salmonella* spp. were least prevalent with 22 (73.3%) samples that indicated positive prevalence of the bacteria (Table 2).

The mean count of bacteria in the salad samples

The isolates obtained and the mean bacterial count of the various bacteria in the read to eat salads expressed as log10 Cfu/g were as follows: *Escherichia coli* (7.12 ± 6.96*), Bacillus cereus* (7.22 ± 7.12), *Shigella* spp. (5.00 ± 6.30) and *Salmonella* spp. (3.90 ± 4.05).

Table 3 presents the results of bacteria isolates with their mean values expressed in log10 cfu/g. The minimum count recorded for each bacterium was 0 whereas the maximum values ranged from 4.54 to 7.56 log10 cfu/g. among the bacteria. *E. coli* count from the salad samples ranged from 0 to 7.56 log10 cfu/g. with a mean of 7.12 ± 6.96 log10 cfu/g.. *Bacillus cereus* count from the salad samples ranged from 0 to 7.54 log10 cfu/g with a mean of 7.22 ± 7.11 log10 cfu/g. The study also showed that *Shigella* spp. count in the salad samples ranged from 0 to 5.44 log10 cfu/g with a mean of 5.04 ± 6.30.

Salmonella spp. count from the salad samples also ranged from 0 to 4.54 log10 cfu/g. with a mean of 3.90 ± 4.05 log10 cfu/g.

The elevated presence and levels may also be linked to contamination from the production source of the raw vegetables. This was affirmed by personal observation upon several visits to farms from which these salad vegetables were obtained, it was revealed that untreated waste water from storm drains was mainly used in irrigating the vegetables at the source of cultivation**.** This conclusion was due to the findings of Muinde and Kuria (2005), who indicated that contamination of most vegetables by bacteria is usually as a result of grey water (waste water generated from bathroom, kitchen and laundry used in the cultivation of these vegetables. The presence of *E. coli* in food samples was an indication of faecal contamination and improper hygienic practices by food vendors (Bakobie et al., 2017). Some strains of *E. coli* when in food could cause gastroenteritis and diarrhea in humans when ingested (Akter, 2016). Adams and Moss (2008) established that *E. coli* do not usually lead to foodborne illness in humans but can however cause diarrhea in children in less developed countries. In a related study, Boateng (2014) reported 64% contamination of products of vegetable origin (pepper/ tomatoes sauce)

Table 1 Microbiological assessment of salad samples collected from local food joints

				Microbial Count				Occurrence	
Site	Sample	Condition	TBC cfu/ml	TSsC cfu/ml	E. coli cfu/ml	TSC cfu/ml	Bacillus spp	Salmonella spp.	E.coli
Zone 1	1F	Semi-closed	TNTC	TFTC	9.2×10^6	0	+	+	+
Zone 1	2 R	Opened	TFTC	0	1.51×10^7	0	+	–	+
Zone 1	3 H	opened	TNTC	1.45×10^4	5.7×10^6	0	+	+	+
Zone 2	4 F	Semi-closed	TNTC	1.18×10^4	2.15×10^7	0	+	+	+
Zone 1	5 R	Semi-closed	0	4.1×10^3	2.15×10^7	0	–	+	+
Zone 1	6 R	Semi-closed	0	0	1.46×10^7	0	–	–	+
Zone 1	7 S	Semi-closed	TNTC	0	1.55×10^7	0	+	–	+
Zone 1	8 S	Semi-closed	TNTC	TNTC	2.79×10^7	TFTC	+	+	+
Z0ne 2	9 H	opened	TNTC	TNTC	1.44×10^7	7.1×10^3	+	+	+
Zone 2	10 H	Semi-closed	1.18×10^7	0	1.98×10^7	7.9×10^3	+	–	+
Zone 2	11 H	Semi-closed	1.3×10^7	TFTC	3.8×10^6	4.0×10^3	+	+	+
Zone 2	12 H	opened	TNTC	2.0×10^4	TNTC	8.1×10^3	+	+	+
Zone 2	13 H	Semi-closed	TFTC	5.4×10^3	1.26×10^7	1.1×10^4	+	+	+
Zone 2	14 H	opened	TNTC	0	1.52×10^7	7.2×10^3	+	–	+
Zone 2	15 S	Semi-closed	9.7×10^6	0	1.38×10^7	1.04×10^4	+	–	+
Zone 2	16 H	Semi-closed	TNTC	5.5×10^3	TNTC	7.3×10^3	+	+	+
Zone 3	17 F	Semi-closed	9.0×10^6	3.4×10^3	1.56×10^7	TFTC	+	+	+
Zone 3	18 H	opened	1.83×10^7	0	4.7×10^6	8.1×10^3	+	–	+
Zone 3	19 H	opened	3.1×10^6	TFTC	6.5×10^6	9.2×10^3	+	+	+
Zone 3	20 S	Semi-closed	7.4×10^6	1.17×10^4	9.9×10^6	TNTC	+	+	+
Zone 3	21 F	opened	TFTC	TFTC	TFTC	1.61×10^4	+	+	+
Zone 3	22 F	Semi-closed	1.08×10^7	TFTC	8.3×106	1.40×10^4	+	+	+
Zone 3	23 S	Semi-closed	2.12×10^7	TFTC	7.0×10^6	TNTC	+	+	+
Zone 3	24 H	opened	1.07×10^7	1.36×10^4	4.0×10^6	TNTC	+	+	+
Zone 4	25 H	opened	4.4×10^6	TFTC	TFTC	TNTC	+	+	+
Zone 4	26 H	Semi-closed	1.2×10^7	8.4×10^3	TFTC	3.5×10^3	+	+	+
Zone 4	27 H	opened	1.43×10^7	0	TFTC	4.9×10^3	+	–	+
Zone 4	28 S	opened	2.4×107	TNTC	TFTC	TFTC	+	+	+
Zone 4	29 R	opened	2.21×10^7	TNTC	0	2.96×10^4	+	+	–
Zone 4	30 R	open	TNTC	TNTC	4.3×10^6	1.15×10^4	+	+	+

Total *Bacillus* spp. Count (TBC), Total *Salmonella* spp. Count (TSsC), Total *Shigella* spp. Count (TSC) *E. coli* count (*E. coli*). TNTC (too numerous to count) > 300. TFTC (too few to count) < 30 counts. R (Rubber), S (Spoon), H (Hands), F (Tongs)

Table 2 Summary of Prevalence of Bacteria isolates in 30 salad samples collected

Bacteria	No of Samples (+)	Percentage (%)
Escherichia coli	29	96.70%
Bacillus cereus	28	93.30%
Shigella spp	23	76.70%
Salmonella spp	22	73.30%

Positive occurrence (+)

with *E. coli* in Kumasi. Similarly, Bonah (2014) also reported the presence of *E. coli* in 66.6% of sampled ready-to-eat tomatoes sauce in the Tamale Metropolis.

According to guidelines from the Health Protection Agency (2009) *E coli* load in 25 g of ready-to-eat vegetables > 10^2 cfu/g is categorized as unwholesome for human consumption however the vegetables will be categorized as satisfactory if the load in 25 g is < 20 cfu/g, therefore, all 96.7% (29) of samples that indicated the presence of *E. coli* were all considered unsatisfactory for consumption with only 1 sample representing 3.3% which was satisfactory. This contradicts that of Coulibali-Kalpy et al. (2017), who

Table 3 Guidance on the interpretation of results for specific food-borne pathogens in ready-to-eat food in general (colony-forming unit (cfu)/g)

Criterion	Satisfactory	Borderline	Unsatisfactory (potentially injurious to health and/or unfit for human consumption)
Escherichia coli O157 (and other Shiga toxin-producing *E. coli* (STEC))	n.d. in 25 g	N/A	Detected in 25 g
Salmonella spp.	n.d. in 25 g	N/A	Detected in 25 g
Shigella spp.	n.d. in 25 g	N/A	Detected in 25 g
Bacillus cereus	$< 10^3$	10^3 to $< 10^5$	$> 10^5$
Hygiene indicator organism	Satisfactory	Borderline	Unsatisfactory (potentially injurious to health and/or unfit for human consumption)
Escherichia coli	< 20	20 to $< 10^2$	$> 10^2$

Source: Health Protection Agency, 2009. Guidelines for Assessing the Microbiological Safety of Ready-to-Eat Foods Placed on the Market. http://www.gov.uk/phe. (Accessed 4 March 2017)

reported 94% of some raw vegetables including pre-cut salads samples contaminated with *E. coli* as Satisfactory for consumption in their study carried out in Cote d'Ivoire.

The study also revealed that there was a significant difference in the mean counts of *E. coli* among the four zones which suggests that *E. coli* contamination was influenced by the location or zone in which sampling was done (Fig. 2). This finding is in contrast to that of Bakobie et al. (2017), who noted that there was no significant difference in pathogenic bacteria in spices sampled from four sites in the CBD of Tamale.

Studies showed that *Bacillus cereus* was recorded in almost every friendly environment.

(Samapundo et al., 2011). Salads contamination with *Bacillus cereus* might have resulted also from the source of production of the vegetables based on the nature of water used in irrigating them, contamination of salads vegetables from coming into contact with soils and also using contaminated utensils during the preparation of salads. Akusu et al. (2016) reported that the raw materials for salad making often come into contact with soil and thus improper washing with water may result in high human health risk. The present study established the presence of *Bacillus cereus* in salad samples in the study area. This could be attributed to the improper treatment of raw materials for salad preparation which could lead to the contamination of these vegetables by *Bacillus cereus* (Ghosh et al., 2007). This finding corroborates Coulibaly-Kalpy et al. (2017) who attributed contamination of food to contaminated utensils coming in contact with vegetables.

Out of the total number of salad samples collected 83.3% were unsatisfactory for consumption. Whilst 16.7% were classified as satisfactory according to the guidelines stipulated by the Health Protection Agency

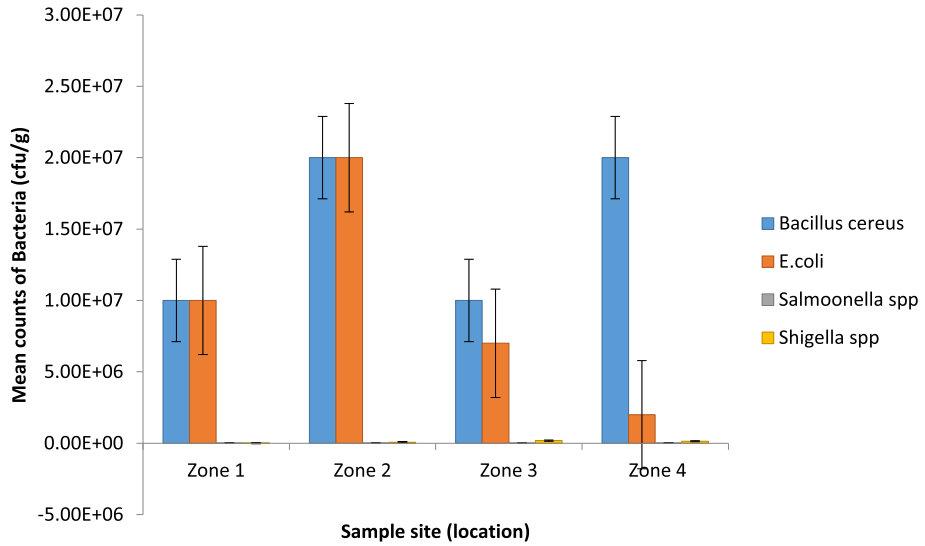

Fig. 2 Mean count of bacteria across four zones in the business district of Tamale

(2009) which provides that in 25 g of sampled ready-to-eat vegetables, *Bacillus cereus* load of $>10^5$cfu/g is described as unsatisfactory for human consumption whereas a load of $<10^3$cfu/g is described as satisfactory.

Comparatively, this study recorded the highest occurrence of *Bacillus cereus* in food compared to Mensah et al. (2002) who sampled 511 different food samples and reported that 5.5% of samples tested positive for *Bacillus cereus*. In a related study, Umoh and Odoba (1999) reported 26% contamination of street food samples in Nigeria.

However, statistical analysis revealed that *Bacillus cereus* counts varied significantly across the four zones ($p = 0.02$) (Fig. 2).

This present study has shown the presence of *Salmonella* spp. in salad samples. It is stipulated by.

Health Protection Agency (2009) and the Food and Drugs Board (2013) that *Salmonella* spp. Should not be detected in 25 g of ready to eat foods in order to be satisfactory for human consumption otherwise it should described as unsatisfactory. Following these guidelines, all samples of salad that indicated the presence of *Salmonella* spp. (73.3%) were described as unsatisfactory for human consumption. *Salmonella* spp. presence in food depicts a greater human health risk for consumers of such contaminated foods. The bacterium is mostly associated with cross contamination of food products especially from eggs and egg products National Institute of Allergy and infectious Disease NIAID (2002). The incidence of *Salmonella* spp. in food is generally associated with cross-contamination and also depended on irregular time temperature chain (Mashak et al., 2015). *Salmonella* is mostly implicated in most food borne diseases (Bakobie et al., 2017).

The detection of *Salmonella* spp. may be attributed to poor hygiene practices by the vendors.

(Bakobie et al., 2017) since most vending premises were not kept tidy enough and could have also resulted from cross-contamination of the food substances. The high *Salmonella* spp. load in the present study perhaps could also have resulted from contamination through the value chain thus beginning from the production sites. The present study recorded higher incidence of *Salmonella* spp. in food samples compared to that of Boateng (2014) who detected the presence of *Salmonella* spp. in 32% samples of pepper/ sauce.

In contrast to this, Amoah (2014) did not detect *Salmonella* spp. in all salad samples collected and studied in Kumasi. Mensah et al. (2002) also analysed kenkey samples in Accra and recorded zero prevalence for *Salmonella* spp. This was attributed to the high acidity associated with kenkey which inhibits microbial growth (Mensah et al., 2002). Again, a study by Mutsuddy (2016) contrast the findings of this present study in which all street food samples were free from *Salmonella* spp.

Statistical analysis revealed that there was no significant difference in mean counts of *salmonella* spp. across the four zones demarcated in the present study since p value > 0.05 (Fig. 2). Hence, the contamination across the zones was similar as a result of similar contributing factors in the zones. This finding is in agreement with that of Bakobie et al. (2017) who in their study reported that there was no significant difference in pathogenic bacteria count in sampled spices from four different locations in the central part of Tamale.

The present study has established the presence of *Shigella* spp. in salad samples obtained from the Central Business District of Tamale. The present study has established the presence of *Shigella* spp. in salad samples obtained from the business district of Tamale. A study by Mutsuddy (2016) also isolated *Shigella* spp. in 3% of street vended foods in Dhaka city in Bangladesh.

The Health Protection Agency (2009) stipulated that ready-to-eat foods are satisfactory for consumption if *Shigella* spp. is not detected in 25 g of the food sample and unsatisfactory for consumption if *Shigella* spp. is detected in 25 g of ready-to-eat food including pre-cut salads. Per this guideline, all the samples (76.7%) that showed the presence of the bacterium were unwholesome for human consumption. The presence of *Shigella* spp. in salads might be due to unsanitary practices and lack of hygiene practices on the side of the food vendors in the Business District. Amissah and Owusu (2012) reported that the level and magnitude of sanitary practices/hygienic practices by food vendors can have great influence on the bacterial load in street vended foods.

The absence of *Shigella* spp. in some samples suggests proper hygienic practices on the part of the handlers (Rane, 2011). Sources of the salad vegetables could also have influenced the higher.

Shigella spp. load in some samples.

Also, the study also established the mean counts of *Shigella* spp. varied significantly across the four zones demarcated in the business district of Tamale ($p < 0.05$) (Fig. 2). This implies different factors that might have contributed to the contamination in each zone. The recent study has effectively indicated higher incidence and bacterial load of *E. coli*, *Bacillus cereus*, *Salmonella* and *shigella* spp. in ready to eat vegetable salads sampled. This conclusion affirms the findings of Akusu et al. (2016) who recorded higher bacterial load for vegetable salads among various street foods collected in Port Harcourt Metropolis in Nigeria.

Correlation matrix

Correlation analysis revealed that *E. coli* in zone 1 (zone1e) correlated positively and significantly with *Shigella* spp. in Zone 3 (zone3 sh) at 5% significant level (0.876). On the other hand, *Shigella.*

Table 4 Correlation Analysis on Bacteria Isolates across the Four Zones Studied

	zone1e	zone2e	zone2b	zone2s	zone2sh	zone3e	zone3b
zone1e	1						
zone2e	−0.394	1					
zone2b	0.266	0.556	1				
zone2s	−0.200	0.271	0.400	1			
zone2sh	0.124	0.029	−0.446	−0.129	1		
zone3e	− 0.148	− 0.297	0.038	− 0.219	-.779[b]	1	
zone3sh	.876[a]	−0.426	−0.141	− 0.553	0.324	− 0.323	1

[a]Correlation is significant at the 0.01 level (2-tailed)
[b]Correlation is significant at the 0.05 level (2-tailed)
Note (Legend): zone1e (zone 1 *E .coli*), zone2e (zone 2 *E. coli*), zone2b (zone 2 *Bacillus cereus*), zone 2 s (zone 2 *Salmonella* spp.), zone 2 sh (zone 2 *shigella* spp.), zone3e (zone 3 *E. coli*), zone3b (zone 3 *Bacillus cereus*), zone 3 sh (zone 3 *shigella* spp.) (Table IV). Correlation matrix on the four zones in terms of the bacteria isolates revealed that a positive and significant correlation existed between *E. coli* in Zone 1 and *Shigella* spp. in Zone 3. These findings imply that *E. coli* and *Shigella* spp. in the two Zones came from similar sources of contamination and have a strong relationship. However, *Shigella* spp. in Zone 2 negatively but significantly correlated with *E. coli* in Zone 3. These results imply that *Shigella* spp. and *E. coli* in the two zones may have resulted from different sources of contamination since the correlation was showing a negative relationship. The results of the correlation matrix from the present is in contrast to the result established by Bakobie et al. (2017) who found no interrelationship between the various bacteria identified in their study in Tamale

spp. in Zone 2 (zone2 sh) correlated negatively but significantly with *E. coli* in Zone 3 (zone3 e) at 1% significant level (− 0.779). The above information is illustrated in the table below (Table 4).

Conclusion

The study sought to determine the microbial quality of pre-cut ready-to-eat vegetable salads sold by food vendors in the Central Business District of the Tamale Metropolis. The incidence of food borne illness is increasing each day in Ghana. In the present study, *Escherichia coli* was present in 96.7% of the salad samples collected, *Bacillus cereus* was present in 93.3% of salad samples whereas *Salmonella* spp. and *Shigella* spp. were present in 73.3 and 76.5% of salad samples respectively.

The present study revealed that ready-to-eat salads sold by street food vendors in the Business.

District of Tamale constitutes a likely health risk to consumers in terms of microbial quality. The contamination could be attributable to improper food handling, unhygienic food preparation and processing, source contamination of the vegetables from production sites and generally along the value chain and environmental conditions. This study shows there is the urgent need for the improvement in food safety and quality standards of ready-to-eat foods in the Business District of Tamale.

Based on the findings of this study, the following are recommended:

1. Further research should be carried out on salad to determine the antimicrobial susceptibility of the bacteria identified.
2. Further research should be carried out on salad to isolate specific pathogenic strains of the bacteria identified in this present study.

Abbreviations

APHA: American Public Health Association; CBD: Central Business District; CDC: Centre for Disease Control; Cfu/g: Colony Forming Units per Grams; FAO: Food and Agriculture Organisation; GFDB: Ghana Food and Drugs Board; GNA: Ghana News Agency; GSS: Ghana Statistical Service; HACCP: Hazard Analysis Critical Control point; ICMSF: International Commission for Microbiological Specifications; MOFA: Ministry of Food and Agriculture; MYP: Mannitol Egg Yolk Polymyxin; NIAID: National Institute of Allergy and Infectious Disease

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Availability of data and materials

We solemnly hereby declare that this present work submitted to International Journal of Food.
Contamination is the results of our own research and that this article has never been presented anywhere for publication. Works by others which served as a source of information have been duly referenced.

Authors' contributions

the principal author (Abakari Godwin) was the one who conducted the laboratory analyses. He also researched on the topic and came out with the relevant literature for the write-up. The second author (Cobbina Samuel Jerry) supervised the study from start to finish and he was also responsible for all the necessary corrections in the write-up. The third author. (Yeleliere Enoch) assisted in carrying-out the experiment, assemblage of the write-up and making the needed corrections as well as submitting it to a suitable journal for publication. All authors read and approved the final manuscript.

Competing interest

The authors declare that they have no competing interests.

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