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Microbial quality of leafy green vegetables grown or sold in Accra metropolis, Ghana

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ABSTRACT

Samples of two exotic (lettuce and cabbage), and four indigenous (African spinach, African eggplant leaves, roselle leaves, and jute leaves) leafy green vegetables were collected from 50 vegetable farms in 12 farming areas (n = 175) and 37 sellers in 4 major market centers (n = 153) in Accra metropolis, Ghana. Microbial quality of collected samples was assessed by isolation of *Salmonella* and enumeration of aerobic bacteria, yeasts and molds, fecal coliforms, and enterococci. Mean aerobic bacteria, yeast and mold, fecal coliform, and enterococcus counts on collected vegetables were 8.80, 4.95, 4.90, and 3.67 log CFU/g, respectively. Approximately 75.4% of the vegetables from 96.0% of the vegetable farms and 84.3% of the vegetables from 97.3% of the vegetable sellers tested positive for enterococci, and 81.1% of the vegetables from 96.0% of the farms and 83.7% of the vegetables from 94.6% of the vegetable sellers tested positive for fecal coliforms. *Salmonella* were isolated from 5.1% of the vegetables from 16.0% of the vegetable farms and 15.7% of the vegetables from 24.3% of the vegetable sellers. Vegetable source and type had significant influence on the microbial counts. Results revealed that the sampled leafy green vegetables had poor microbial quality. Consumption of fresh leafy green vegetables without sanitizing or heat treatment should be discouraged.

1. Introduction

Leafy green vegetables are important components of Ghanaian diets serving as sources of vitamins, minerals, and other nutrients. The vegetables are used as part of a main course or side dish. Both indigenous (cocoyam leaves, African spinach, African eggplant leaves, roselle leaves, and jute leaves, cowpea leaves), and exotic (lettuce, cabbage, spinach, broccoli, Chinese cabbage) leafy green vegetables are currently cultivated and consumed in Ghana (Drechsel, Adam-Bradford, & Raschid-Sally, 2014). Although indigenous leafy vegetables are often cheaper and more nutritious, exotic leafy vegetables are patronized more, especially by urban dwellers due to changes in lifestyle and diets and lack of public knowledge about nutritional benefits of indigenous vegetables (Darkwa & Darkwa, 2013).

Vegetable farming usually takes place in the rural areas of Ghana, and harvested vegetables are transported to markets in urban areas. Over the past decades, vegetable farming activities have increased in the urban and peri-urban areas mainly due to increasing market demands, lack of jobs, and changes in lifestyle and diets. Urbanization and increasing population size has, however, led to scarcity of land and water with most famers having access to smaller land size for farming as observed in other West African countries (Drechsel et al., 2014). The farmers situate their farms close to various water sources such as pipe, wells, streams, and drains for irrigation (Drechsel et al., 2014). Both inorganic and organic fertilizers (poultry and cow manure) are used for vegetable cultivation, with poultry manure being commonly used because it is relatively cheap and easily available (Amoah, Drechsel, Abaidoo, & Henseler, 2007). Leafy green vegetables are harvested by hand with or without knives into buckets, baskets, or sacks, and then transported to market centers and other retail points under non-refrigeration conditions by market women or middle men. Vegetables are sometimes washed with water to remove dirt before

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display for sale.

Increased consumption of fresh produce has been associated with an increasing number of foodborne outbreaks in the U.S., Canada, and European countries (Callejón et al., 2015; Kozak, MacDonald, Landry, & Farber, 2013; Lynch, Tauxe, & Hedberg, 2009). Majority of such outbreaks are caused by bacteria (*S. enterica* and *E. coli*) or viruses (Hepatitis A and Norwalk virus) which can be transmitted through the fecal-oral route (Callejón et al., 2015; De Roever, 1999; Kozak et al., 2013). About 420,000 cases of foodborne illness are reported in Ghana annually with 65,000 deaths (Ababio & Lovatt, 2015). These incidences are believed to be underestimates because most cases of illnesses are not reported to health facilities in Ghana (Ababio & Lovatt, 2015). The number of foodborne illness is likely to increase in Ghana if the consumption of fresh produce increases, a trend that have been observed in other countries (Callejón et al., 2015; Kozak et al., 2013; Lynch et al., 2009).

Indigenous Ghanaian leafy vegetables are mostly used for making stews or soups, which requires minimum to high heat treatments before consumption. Most exotic vegetables are, however, used as side dishes requiring no or minimal heat treatments such as in salads or coleslaws. These leafy vegetables may receive some degree of washing before use. However, research has shown that washing alone is insufficient to reduce microbiological counts on leafy green vegetables to acceptable levels (Almeida De Oliveira, Ritter, Tondo, & Cardoso, 2012; Fishburn, Tang, & Frank, 2012). Consumption of leafy vegetables with no or minimal heat treatments makes them probable vehicles for foodborne infections. The objective of this study was to determine the microbial quality of selected leafy green vegetables that are grown and sold in urban areas in Accra Metropolis, Ghana by isolation of *Salmonella* and enumeration of aerobic bacteria, yeasts and molds, fecal coliforms, and enterococci.

2. Material and methods

2.1. Sample collection

Samples of two exotic, green leaf lettuce (*Lactuca sativa*) and cannonball cabbage (*Brassica oleracea var capitata*), and four indigenous, African spinach (*Amaranthus* sp.), African eggplant leaves (*Solanum macrocarpon),* roselle leaves (*Hibiscus sabdariffa*), and jute leaves (*Corchorus olitorius*) leafy green vegetables (Fig. 1; $n = 175$) were collected in duplicate from 50 farms in 12 different farming areas in Accra Metropolis district of Ghana from March 2016 to March 2017 (Fig. 2; Table 1). Leafy green vegetable samples ($n = 153$) were also collected from 37 sellers in 4 major market centers in the same region. The vegetable samples were collected from farmers who cultivate them or market venders who sell them and were willing to participate in the study. Collected leafy green vegetables were placed into sterile, plastic Ziploc bags (Nasco, Fort Atkinson, WI), kept in a car cooler (Rubbermaid; Newell Brands Inc, Atlanta, GA USA) with ice packs (VWR, Lutterworth, UK), and transported to a microbiological laboratory in the Department of Nutrition and Food Science at University of Ghana. The samples were analyzed immediately upon arrival at the laboratory.

2.2. Microbial enumeration

Each leafy vegetable sample (25 g) was placed in a sterile whirlpak bag, and 225 ml of 0.1 M phosphate buffered saline (pH 7.4) was added to the bag. The vegetable samples were rinsed by shaking on a platform shaker (Lab-Line Instrumental Co., Melrose Park, IL, USA) at 100 rpm for 30 min at room temperature. A 0.1 ml of appropriate dilutions of vegetable-rinsing buffer was inoculated on four different microbiological media including tryptic soy agar (TSA), Enterococcus agar (EA), MacConkey agar (MAC), and potato dextrose agar (PDA) acidified with 10% tartaric acid to pH 3.5 (Becton, Dickinson and Company, Sparks, MD, USA). Inoculated plates of TSA were incubated at 37 °C for 24 h and those of EA were incubated at 37 °C for 24–48 h. The MAC plates were incubated at 44.5 °C for 24 h and plates of PDA were incubated at 25 °C for 48–72 h. Colonies of aerobic bacteria on TSA, yeasts and molds on acidified PDA, presumptive enterococci on EA, and presumptive fecal coliforms on MAC were enumerated after the incubation. Enterococcus colonies were confirmed by culturing selected colonies in tryptic soy broth (Becton, Dickinson and Company) with 6.7% NaCl (Fisher Scientific, Pittsburgh, PA, USA) and fecal colonies were confirmed by growth in EC broth (Oxoid Ltd, Basingstoke, Hampshire, England) with inverted fermentation tubes and incubated at 44.5 °C (Becton, Dickinson and Company).

2.3. Salmonella isolation

For *Salmonella* isolation, a leafy vegetable sample (25 g) was rinsed in 225 ml 0.1% peptone water by shaking on a platform shaker at 100 rpm for 30 min at room temperature. The rinsing buffer was incubated at 37 °C for 24 h and followed by selective enrichment in Rappaport-Vassiliadis (RV) broth with incubation at 42 °C for 24 h. Subsequently, 0.1 ml of RV broth was inoculated on XLT4 agar with supplement (Becton, Dickinson and Company) for isolation of presumptive *Salmonella* colonies. The colonies were confirmed by growth, on triple sugar iron agar (Becton, Dickinson and Company) and lysine iron agar slants (Becton, Dickinson and Company), and slide agglutination test using *Salmonella* O antiserum poly A- I and VI (Becton, Dickinson and Company).

2.4. Statistical analysis

One-way analysis of variance test was performed, and Fisher's Least Significant Difference test was used to compare the means ($p \le 0.05$) using the Statistical Analysis Software (Version 9.4). The effect of sample source (farm or market) and vegetable type on vegetable-borne microbial counts were determined.

3. Results

The mean aerobic bacteria counts on all sampled leafy green vegetables ranged from 8.30 to 9.20 log CFU/g. The mean yeast and mold counts were from 4.25 to 5.73 log CFU/g (Table 2). Mean fecal coliform counts ranged from 4.28 to 5.81 log CFU/g and enterococcus counts from 2.93 to 4.53 log CFU/g. Cabbage samples had the highest mean aerobic bacteria count. Lettuce samples, nevertheless, had the lowest mean aerobic bacteria count which was significantly ($p \le 0.05$) different from the mean aerobic bacteria counts from the other five types of leafy green vegetables sampled in the study (Table 2). Lettuce samples also had the lowest mean yeast and mold count while *C. olitorius, H. sabdariffa*, and *S. macrocarpon* samples had higher yeast and mold counts. *C. olitorius* and *S. macrocarpon* samples also had higher fecal coliform counts and enterococcus counts compared to other types of vegetables sampled in the study. Cabbage and lettuce samples had the lowest mean fecal coliform and enterococcus counts, respectively. In general, the indigenous leafy vegetables sampled in the study had higher yeast and mold, fecal coliform, and enterococcus counts than lettuce and cabbage, except the counts on *Amaranthus* sp. which were comparable to those from the two exotic vegetables.

There were significant differences in the microbial counts on vegetables collected from various farming areas or market centers (Table 2). Vegetables from farming areas 1, 3, and 11 had lower

Fig. 1. Vegetables sampled in the study. A: African spinach (*Amaranthus* sp.); B: jute leaves (*Corchorus olitorius*); C: roselle leaves (*Hibiscus sabdariffa*); D: African eggplant leaves (*Solanum macrocarpon*); E: green leaf lettuce (*Lactuca sativa*); F: cannonball cabbage (*Brassica oleracea var capitata*).

($p \leq 0.05$) mean aerobic bacteria counts. Yeast and mold counts were higher ($p \leq 0.05$) on vegetables from all the market centers and farming area 3, 4, 6, 7, 11, and 12. Vegetables from farming areas 2, 3, 4, and 5, and markets centers 2, 3, and 4 had significantly ($p \leq 0.05$) higher fecal coliforms counts. Vegetables from market centers 2, 3, and 4 also had higher ($p \leq 0.05$) enterococcus counts and those from farming area 11 had the lowest ($p \leq 0.05$) enterococcus counts.

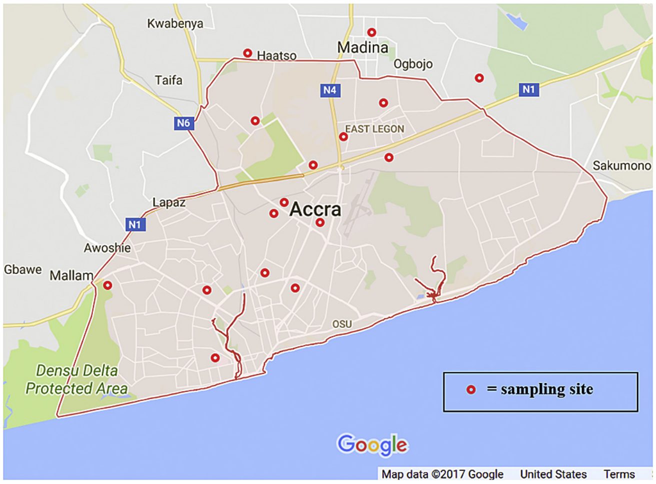

Fig. 2. Vegetable farming area and market center sampling sites in Accra metropolis, Ghana (modified from a google map).

Mean aerobic bacteria counts on leafy green vegetables collected from the farms *vs.* markets were not significantly ($p \geq 0.05$) different, although most of the counts from market vegetables were relatively higher (Table 3). Farm samples had significantly ($p \leq 0.05$) lower fecal coliform and enterococcus counts compared to the market samples, with the exception of cabbage. Indigenous vegetables collected from the farms had lower yeast and mold counts compared to those from the markets. The yeast and mold counts on cabbage and lettuce collected from farms *vs.* market centers were not significantly different.

Amaranthus sp. and lettuce from the farms had lower ($p \leq 0.05$) mean aerobic bacteria counts compared to the other farm vegetables, and there were no significant ($p \geq 0.05$) differences in the aerobic bacteria counts on different vegetables collected from the market centers (Table 3). Lettuce from the farms had the lowest ($p \leq 0.05$) yeast and mold count and *C. olitorius, H. sabdariffa* had the highest ($p \leq 0.05$) counts. Among the vegetables collected from the market, cabbage and lettuce had lower ($p \leq 0.05$) yeast and mold counts while *C. olitorius, H. sabdariffa* had higher ($p \leq 0.05$) counts. No significant ($p \geq 0.05$) difference in enterococcus counts was observed on vegetables collected from the farms. Lettuce and cabbage from the market were lower ($p \leq 0.05$) in fecal coliform and enterococcus counts than the indigenous vegetables.

Table 2
Mean microbial counts recovered from leafy green vegetables collected from vegetable farming areas and market centers in Accra metropolis, Ghana.

	APC	Y&M	Fecal coliforms	Enterococcus
			(Log CFU/g)	
Leafy green vegetables				
Amaranthus sp.	8.78^{a}	4.79^{c}	4.72^{bc}	3.57^{c}
Cabbage	9.20^{a}	4.63^{c}	4.28^{c}	3.66^{c}
Corchorus olitorius	9.00^{a}	5.73^{a}	5.81^{a}	4.53^{a}
Hibiscus sabdariffa	8.95^{a}	5.55^{a}	4.89^{b}	3.68^{c}
Lettuce	8.30^{b}	4.25^{d}	4.51^{bc}	2.93^{d}
Solanum macrocarpon	8.87^{a}	5.21^{b}	5.48^{a}	4.13^{b}
Sampling area				
FA 1	7.47^{cd}	4.34^{de}	4.66^{cde}	2.35^{def}
FA 2	9.37^{ab}	3.99^{e}	5.17^{abcd}	2.19^{ef}
FA 3	7.36^{d}	5.01^{abc}	5.54^{abc}	3.50^{bc}
FA 4	9.28^{ab}	4.95^{abcd}	5.67^{abc}	3.24^{cd}
FA 5	9.20^{ab}	4.42^{cde}	5.01^{abcd}	3.44^{bc}
FA 6	8.73^{ab}	5.32^{a}	3.49^{ef}	2.52^{cde}
FA 7	8.61^{ab}	4.88^{abcd}	4.01^{def}	2.92^{cde}
FA 8	8.91^{ab}	4.62^{bcde}	3.48^{ef}	3.24^{cd}
FA 9	9.62^{a}	4.30^{de}	2.88^{f}	2.91^{cde}
FA 10	8.50^{bc}	4.63^{bcde}	3.05^{f}	2.98^{cde}
FA 11	6.91^{d}	5.06^{abc}	3.01^{f}	1.49^{f}
FA 12	9.05^{ab}	5.21^{ab}	4.02^{def}	2.89^{cde}
MC 1	8.57^{abc}	5.08^{ab}	4.78^{bcd}	4.48^{ab}
MC 2	9.26^{ab}	5.43^{a}	5.62^{abc}	4.57^{a}
MC 3	8.99^{ab}	5.50^{a}	6.23^{a}	4.89^{a}
MC 4	9.02^{ab}	5.02^{abc}	6.05^{ab}	4.72^{a}
Sampling site				
FA	8.68^{a}	4.65^{b}	4.31^{b}	2.88^{b}
MC	8.94^{a}	5.29^{a}	5.57^{a}	4.58^{a}

Means followed by different lowercase letters within a column are significantly different ($p \leq 0.05$).
FA: Farming area; MC: Market center.
APC: aerobic plate counts.
Y&M: yeast and mold counts.

In total, 75.4% of the vegetables from 96.0% of the vegetable farms and 84.3% of the vegetables from 97.3% of the vegetable sellers tested positive for enterococci, and 81.1% of the vegetables from 96.0% of the farms and 83.7% of the vegetables from 94.6% of the vegetable sellers tested positive for fecal coliforms. Prevalence of enterococci and fecal coliforms was 50% or greater in vegetables collected from all the farming areas or market centers (Fig. 3). Over 80% of the *Amaranthus*, *C. olitorius*, and *H. sabdariffa* collected from

Table 1
Number of leafy green vegetable samples collected from individual farming areas and market centers in Accra metropolis, Ghana.

Source	Number of leafy green vegetables collected						
	Amaranthus	Cabbage	*C. olitorius*	*H. sabdariffa*	Lettuce	*S. macrocarpon*	Total
FA 1	2	5	2	0	17	0	26
FA 2	2	1	2	2	6	2	15
FA 3	0	0	0	2	0	2	4
FA 4	0	0	2	2	6	1	11
FA 5	6	0	6	6	9	10	37
FA 6	4	2	0	6	4	4	20
FA 7	4	0	0	2	8	2	16
FA 8	2	4	0	2	4	0	12
FA 9	0	0	0	0	2	0	2
FA 10	5	5	2	2	6	2	22
FA 11	0	0	0	0	2	0	2
FA 12	2	0	2	2	2	0	8
MC 1	4	12	10	4	10	8	48
MC 2	7	10	10	6	2	10	45
MC 3	6	8	10	5	2	10	41
MC 4	1	6	4	2	2	4	19
Total	45	53	50	43	82	55	328

Table 3
Effect of sampling site (farm *vs*. market) on the mean microbial counts on leafy green vegetables.

Sampling Area	Microbial counts (Log CFU/g)					
	Amaranthus	Cabbage	*C. olitorius*	*H. sabdariffa*	Lettuce	*S. macrocarpon*
Aerobic bacteria counts						
Farm	$8.61^{b, A}$	$9.65^{a, A}$	$8.90^{ab, A}$	$8.94^{ab, A}$	$8.20^{b, A}$	$8.86^{ab, A}$
Market	$9.03^{a, A}$	$8.99^{a, A}$	$9.00^{a, A}$	$8.96^{a, A}$	$8.70^{a, A}$	$8.87^{a, A}$
Yeast and mold counts						
Farm	$4.54^{bc, B}$	$4.71^{abc, A}$	$5.20^{a, B}$	$5.18^{a, B}$	$4.22^{c, A}$	$4.89^{ab, B}$
Market	$5.16^{b, A}$	$4.60^{c, A}$	$5.97^{a, A}$	$6.21^{a, A}$	$4.36^{c, A}$	$5.40^{b, A}$
Fecal coliform counts						
Farm	$3.96^{b, B}$	$4.11^{ab, A}$	$5.02^{a, B}$	$4.15^{ab, B}$	$4.33^{ab, B}$	$4.63^{ab, B}$
Market	$5.85^{ab, A}$	$4.36^{c, A}$	$6.17^{a, A}$	$6.18^{a, A}$	$5.26^{b, A}$	$5.98^{a, A}$
Enterococcus counts						
Farm	$2.89^{a, B}$	$3.13^{a, A}$	$3.01^{a, B}$	$3.02^{a, B}$	$2.71^{a, B}$	$2.91^{a, B}$
Market	$4.59^{b, A}$	$3.91^{c, A}$	$5.24^{a, A}$	$4.86^{ab, A}$	$3.87^{c, A}$	$4.84^{ab, A}$

Means followed by different lowercase letters within a row are significantly different ($p \leq 0.05$).
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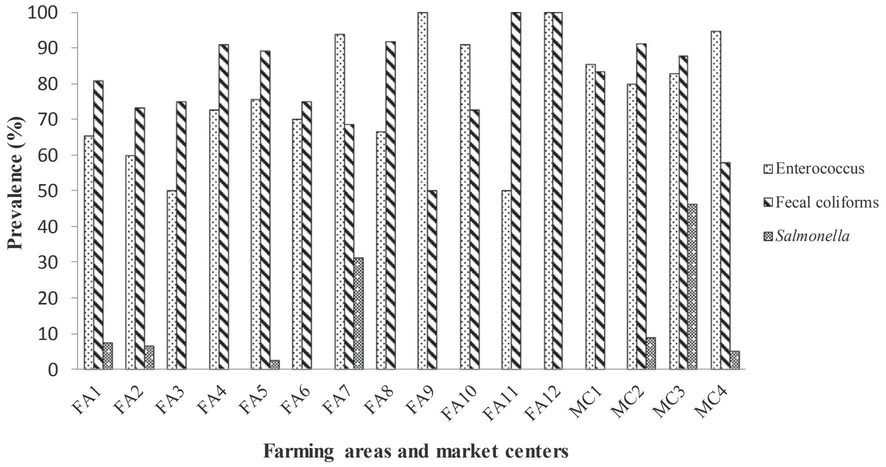

Fig. 3. Prevalence of enterococcus, fecal coliforms, and *Salmonella* on all vegetable samples collected from individual farming areas and market centers.

the farms, and *C. olitorius*, *H. sabdariffa*, lettuce, and *S. macrocarpon* collected from the market centers tested positive for enterococci (Fig. 4). With the exception of *Amaranthus*, there were high incidences of enterococci on vegetables collected from the markets than those from the farms. More samples of *Amaranthus*, *C. olitorius*, lettuce, and *S. macrocarpon* collected from the markets tested positive for fecal coliforms than those from the farms (Fig. 5).

Salmonella was isolated from 9 vegetable samples (5.1%) collected from 8 farms (16%) in 4 farming areas (33.3%) and 24 vegetable samples (15.7%) collected from 9 sellers (24.3%) in 3 markets centers (75%). Approximately 7.7, 6.7, 2.7, and 31.2% of the vegetables from farming areas 1, 2, 5, and 7 carried *Salmonella* whereas 8.9, 46.3, and 5.3% of the vegetables from market centers 2, 3, and 4 tested positive for the pathogen (Fig. 3). The prevalence of *Salmonella* among farm-collected lettuces, cabbage, *C. olitorius*, and *H. sabdariffa* were 7.6, 5.9, 12.5, and 3.8%, respectively and 20.6% and 41.2% of the *C. olitorius* and *H. sabdariffa* samples collected from the market centers carried *Salmonella* (Fig. 6).

4. Discussion

The levels of aerobic bacteria counts recovered from leafy green vegetables in this study are comparable to findings of previous studies from certain geographic areas. A study in Lebanon found 9.41 and 8.78 log CFU of aerobic bacteria per gram of lettuce (Halablab, Sheet, & Holail, 2011). Abdullahi and Abdulkareem (2010) and Manjunath, Yadava, Rai, and Singh (2017) reported an aerobic bacteria count of 8.36 log CFU/g of cabbage and 7.83 log CFU/g of *Amaranthus*, respectively. Mngoli and Ngongola-Manani (2014) reported fecal coliform counts of 5.08–5.84 log CFU/g of lettuce sampled in Malawi. Fecal coliform counts observed by Cobbina, Kotochi, Korese, and Akrong (2013) were 3.7, 3.5, and 3.1 log CFU/g of lettuce, *Amaranthus*, and cabbage, respectively. Some of these reported fecal coliform counts are lower than the results of the present study. Amoah, Drechsel, Abaidoo, and Ntow (2006) found that lettuce sampled from some cities in Ghana had higher fecal coliform counts than those from cabbage samples, a finding which is similar to the observation of this study. The recovery of fecal coliforms and enterococci from leafy green vegetables indicates possible fecal contamination and potential presence of enteric pathogens (Boehm & Sassoubre, 2014; New Hamspire Department of Environmental Services, 2003).

Le Quynh Chau et al. (2014) reported a *Salmonella* incidence of 17.6% on fresh leafy vegetables sold in Vietnam. Nma and Oruese (2013) detected *Salmonella* in 42.7% of the cabbage and lettuce samples purchased from markets in Nigeria. Uyttendaele, Moneim, Ceuppens, and Tahan (2014) found that 38.9% and 43.3% of the lettuce collected from farm or retail outlets in Egypt carried *Salmonella*. Although the *Salmonella* incidence observed in this study was relatively lower compared to the incidences reported in some

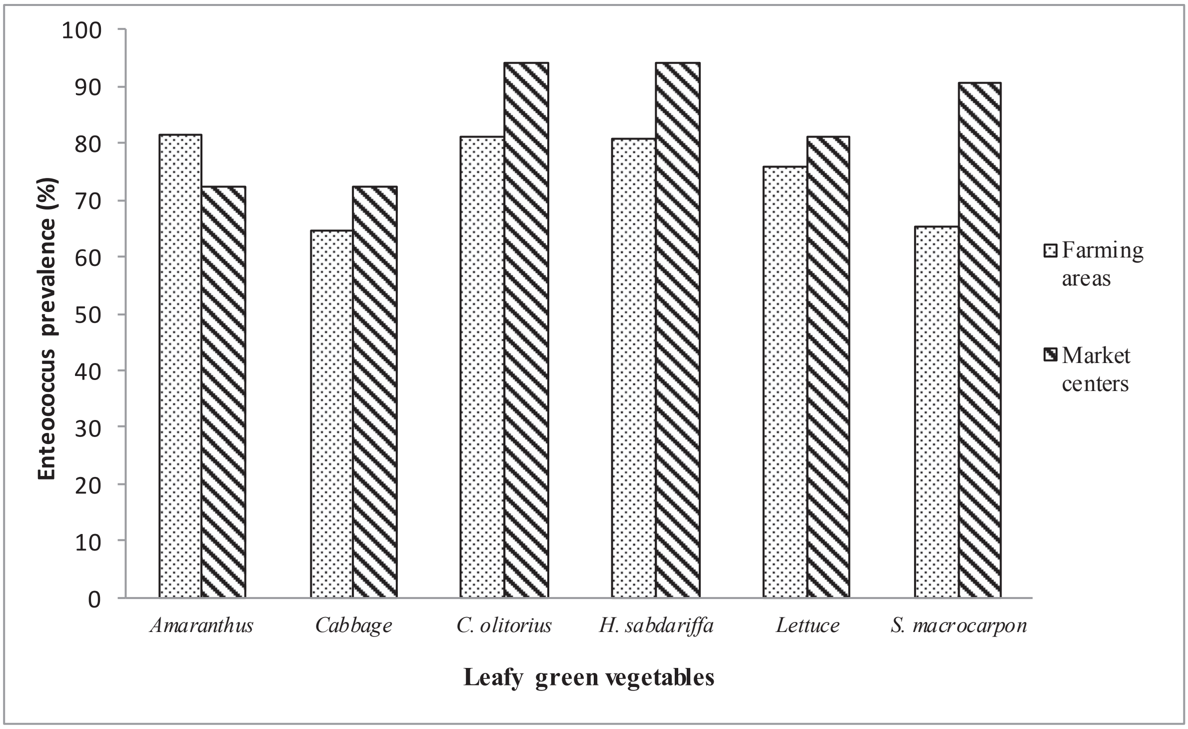

Fig. 4. Prevalence of enterococcus on individual types of leafy green vegetables collected from all farming areas and market centers.

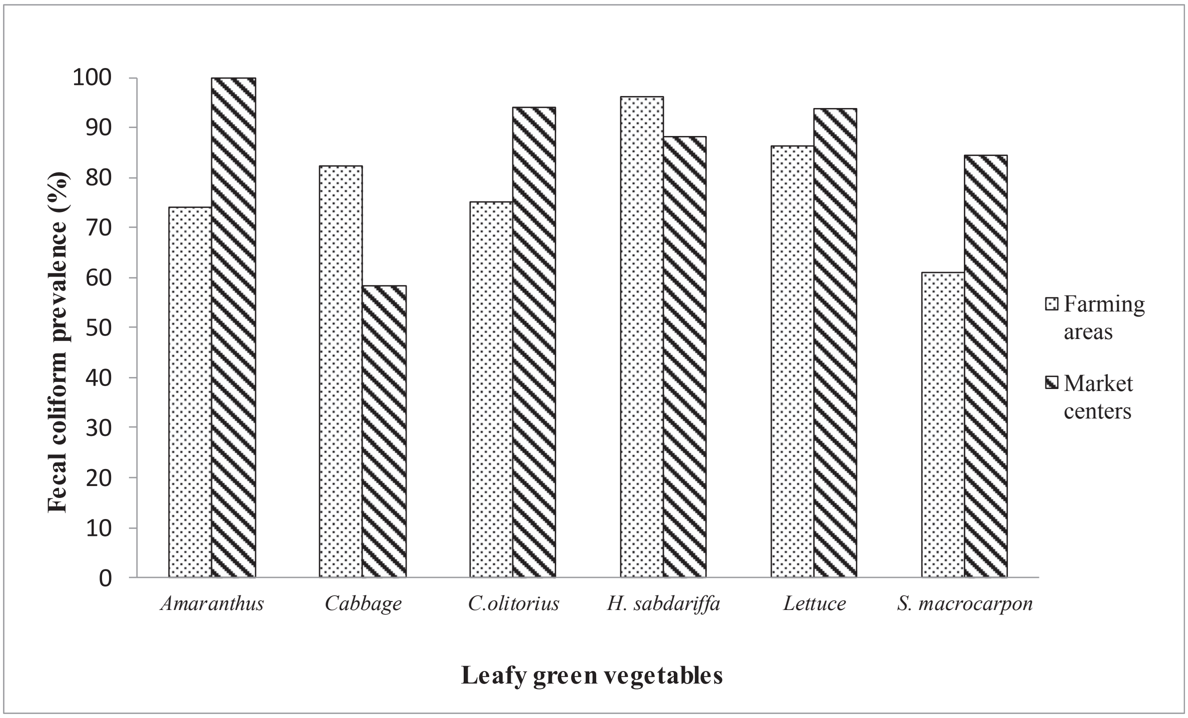

Fig. 5. Prevalence of fecal coliforms on individual types of leafy green vegetables collected from all farming areas and market centers.

of the developing countries, the presence of the pathogen on leafy green vegetables, especially on lettuce and cabbage which are usually consumed with minimal or no heat treatment is a major food safety concern.

Low microbial quality of leafy green vegetables is usually the results of poor farming practices such as the use of polluted irrigation water, improperly-composted manure, and inappropriate postharvest handling practice (Adetunde, Sackey, Dombirl, & Mariama, 2015; Amoah et al., 2006; Cobbina et al., 2013). Streams, shallow wells, and waste drains are common sources of irrigation water used in vegetable cultivation in Ghana. Wastewater from both households and industries are mostly released into the

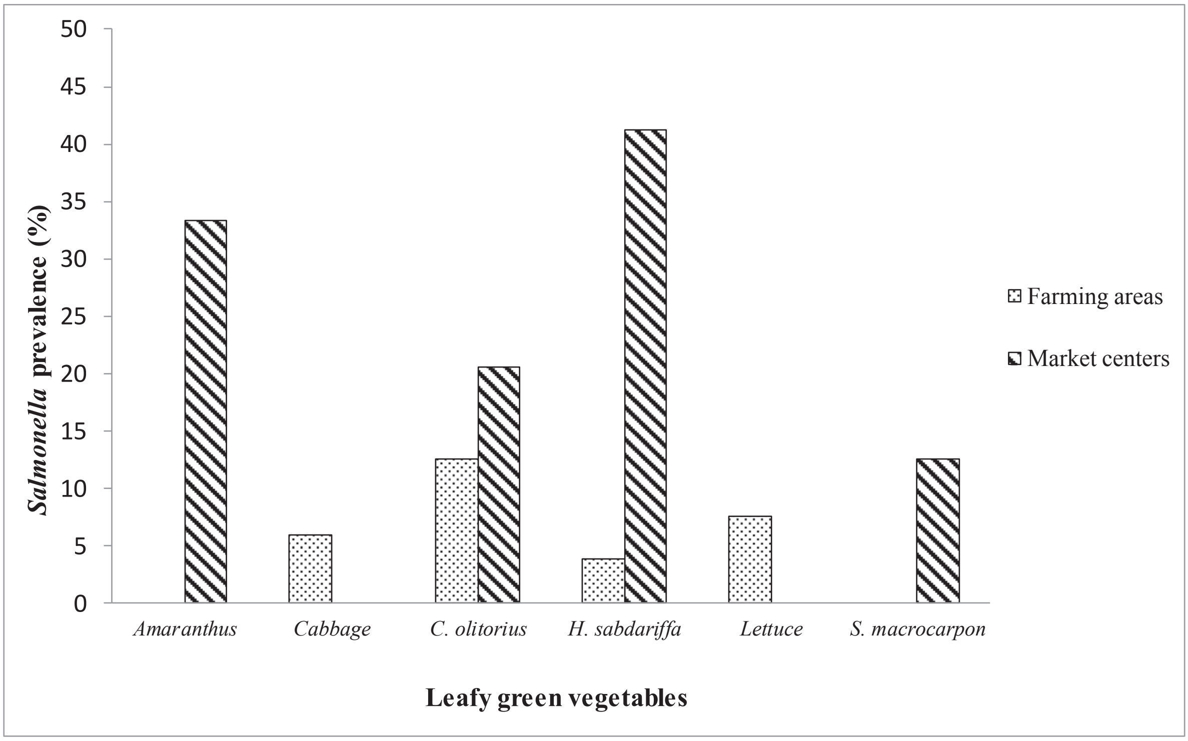

Fig. 6. Prevalence of *Salmonella* on individual types of leafy green vegetables collected from all farming areas and market centers.

environment untreated, and eventually ends into major streams or water bodies used in vegetable irrigation (Keraita, Silverman, Amoah, & Asem-Hiable, 2014). Random testing of irrigation water in the vegetable-growing areas in the present study revealed the presence of high microbial loads (data not shown), which makes it a possible source of vegetable contamination. Adetunde et al. (2015) and Cobbina et al. (2013) analyzed the microbial quality of irrigation water and irrigated leafy green vegetables and found a strong positive correlation between the microbial counts on vegetables and in irrigation water. Adetunde et al. (2015) observed that wild and domestic animals could be the source of irrigation water contamination.

The use of composted and inadequately-composted manure is very common in vegetable production in Ghana and other African countries (Drechsel et al., 2014). Increase in temperature during the composting process inactivates most of the pathogens present (Jones & Martin, 2003). Properly-managed composting can reduce the number of pathogens like *E. coli* and *Salmonella* to non-detectable levels (Lung et al., 2001). However, fecal coliforms and human pathogens could remain viable in inadequately-composted manures, leading to the contamination of the soil and leafy green vegetables. Amoah et al. (2006) have isolated *Salmonella* from poultry fecal matters, dust, water, and feed samples in Accra and Kumasi, Ghana. Amoah, Drechsel, and Abaidoo (2005) observed that soils contaminated due to prior exposure to inadequately- or un-composted-manures could lead to vegetable contamination. Amoah et al. (2005) analyzed the fecal coliforms in inadequately-composted poultry manure and lettuce grown on soil enriched with the manure. The level of fecal coliforms in inadequately-composted poultry manure was found comparable to the level of the bacteria on leafy green vegetables.

Most indigenous leafy vegetables sampled in the present study had higher yeast and mold, fecal coliform, and enterococcus counts than the two exotic vegetables and this observation might be attributed to the use of pesticides, which often include fungicides (manganese ethylene-bis-dithiocarbamate and benzimidazole) and biocides (sodium sulfide and 1,2-benzisothiazolin-3-ones), during exotic vegetable production. Pesticides are more frequently used in the production of exotic vegetables, to control pests and diseases due to their high economic values or returns, than in the indigenous vegetable production. The use of pesticides especially at high concentrations has been shown to kill soil microorganisms (Ayansina & Oso, 2006; Kalia & Gosal, 2011) or temporally inhibit their growth (Filimon et al., 2015). Ottesen et al. (2015) observed lower counts of *Salmonella* and *Paenibacillus* on tomato leaves and fruits that were regularly sprayed with pesticides as compared to controls which received no spraying, although the difference in the bacterial counts was not statistically significant.

The present study found that leafy green vegetable samples collected from the market centers had higher yeast and mold, fecal coliform, and enterococcus counts than the farm samples, except cabbage (Tables 2 and 3). Higher percentages of market vegetables than farm vegetables tested positive for enterococci and fecal coliforms with a few exceptions (Figs. 4 and 5). *C. olitorius* and *H. sabdariffa* from the market had higher prevalence of *Salmonella* than those from vegetable farms (Fig. 6). Ensink, Mahmood, and Dalsgaard (2007) observed that leafy green vegetables collected from agricultural fields had lower *E. coli* counts compared to the counts of the same batch of vegetables transported to the markets. Unsanitary postharvest practices were reported by Ensink et al. (2007) as the major source of vegetables contamination. Unhygienic postharvest handling practices and improper storage conditions could be attributed to the poor microbial quality of market vegetables in this present study. Vegetables transported to the markets are stored under non-refrigeration temperatures in sacks or boxes kept in rooms or in the open at the markets centers. Some vegetables are washed to remove dirt before being displayed at the market for sale using water which is not changed regularly. This practice promotes cross contamination and microbial growth on vegetables. Different from the results of the present study, Amoah et al. (2007) observed no significant differences in the contamination levels on lettuce from the farm through the value chain to retail outlets in some cities of Ghana. The authors believed that the on-farm contamination levels were so high, which overshadowed additional contamination after harvest.

Other postharvest practices that could contribute to the poor microbial quality of leafy green vegetables include the activities of handlers and processers. It was observed during our study that vegetables were mostly handled with bare hands which were cleaned on the farms using polluted irrigation water. Furthermore, sanitation infrastructures are lacking in most of the market centers and vegetable farms in Ghana. Use of washrooms without running water for hand washing can also contribute to the contamination of leafy green vegetables.

5. Conclusion

High fecal coliform and enterococcus counts were found on leafy green vegetables sampled in the present study. On average, market vegetables had higher microbial counts than the vegetables collected from the farms. Indigenous leafy green vegetables with the exception of *Amaranthus* sp. had higher yeast and mold counts, fecal coliform counts, and enterococcus counts than lettuce and cabbage. *Salmonella* was isolated from both exotic and indigenous vegetables collected from the farms and markets. This study suggests that leafy green vegetables grown and sold in some urban areas of Ghana are associated with high microbial counts and some of them are contaminated with *Salmonella*. Consumption of fresh leafy green vegetables without sanitizing or heat treatment should be discouraged.

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