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Bacterial contamination of lettuce and associated risk factors at production sites, markets and street food restaurants in urban and peri-urban Kumasi, Ghana

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There is increasing evidence that urban grown vegetables in developing countries can be contaminated with pathogenic microorganisms. This is particularly true when wastewater is used in irrigation. The microbiological quality of wastewater grown lettuce on farms, markets and at street food vendor sites were evaluated for thermotolerant coliforms, enterococci and *Salmonella* using standard methods. Farm irrigation water and market refreshing water (water used in keeping the lettuce fresh) samples were also analysed. Thermotolerant coliforms on lettuce varied from 2.3×10^3 to 9.3×10^8 on farm, 6.0×10^1 to 2.3×10^8 on market and 2.3×10^6 to 2.4×10^9 at street food vendor sites. Indicator bacterial numbers on farm lettuce were higher compared to the irrigation water (1.5×10^3 to 4.3×10^6) used on the farms. Thermotolerant coliform numbers in market refreshing water (9.0×10^3 to 4.3×10^{10}) were higher compared to that on the market lettuce. Enterococci numbers on lettuce were lower and ranged from 3.9×10^1 to 1.0×10^6 on farm, 6.0×10^1 to 9.0×10^4 on market and 5.1×10^3 to 2.5×10^6 at street food vendor sites. *Salmonella* numbers recorded at food vendor sites ranged from 1.5×10^1 to 9.3×10^2. In general, thermotolerant coliforms numbers increased by 18% while enterococci numbers reduced by 64% from the farms to the street foods. Bacterial counts on farm lettuce and irrigation water, market lettuce and refreshing water and street foods all exceeded the recommended World Health Organization (WHO) and International Commission on Microbiological Specifications for Food (ICMSF) standards of 10^3. Wastewater use on farms and refreshing water in markets could be the main contributors to lettuce contamination and that education on use of effective de-contamination or washing methods before eating will contribute to reducing the risk associated with the consumption of such contaminated foods.

Key words: *Salmonella*, irrigation water, thermotolerant coliforms, enterococci, lettuce.

INTRODUCTION

Urbanization in the developing world is proving to be one of the greatest challenges of the 21st century with an annual growth rate of 5.8% in Sub-Saharan Africa (World Bank, 2000). In Ghana, the urban population is growing at an estimated annual rate of 4.4%, with only 4 - 5% of the population linked with sewage systems and sewerage treatment plants. Most untreated wastewater ends up in storm water gutters, streams and other water bodies (Keraita et al., 2002).

Urbanization coupled with population growth and increase in food demand especially perishable vegetables in major Ghanaian cities has resulted in increased demand for resources such as land and water. This demand is unseasonal and necessitates all year round production that is heavily dependent on wastewater use.

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In Kumasi, 90% of all lettuce and spring onions consumed are produced from open-space vegetable farming with shallow hand dug-wells, rivers and streams polluted with domestic wastewater as the main sources of irrigation water. Studies in Kumasi by Keraita et al. (2003a) have shown that the microbiological contaminants in irrigation water sources in most cases exceed the WHO (1989) guidelines significantly. Other sources of potential health risk are the use of organic manure especially poultry litter (Amoah et al., 2005), methods of transportation of produce to the markets and handling at the markets and consumption points (Drechsel et al., 2000; Sonou, 2001). This therefore raises public health concerns due to possible crop contamination with pathogens such as certain strains of *Escherichia coli* or Thermotolerant coliform and *Salmonella*, among others especially where vegetables are eaten uncooked (Sonou, 2001; Amoah et al., 2006).

Despite the associated health risks, urban and peri-urban farming contributes significantly to some of the millennium development goals relating to poverty alleviation, job creation and employment and food security. In Kumasi, this farming practice has contributed remarkably to food supply and is an important source of livelihood not only for the farmers but also for vegetable sellers and others in the post-harvest chain (Danso et al., 2002).

As adequate wastewater treatment infrastructure is not likely in the near future and wastewater continues to play a major aspect of irrigated urban and peri-urban agriculture, with adequate treatment to reduce health risks, wastewater use for irrigation is a realistic policy option (Pescod, 1992). Though efforts have been made towards interventions to produce safer vegetables and reduce health risk associated with the production and consumption of vegetables along the production-consumer chain in Ghana, most of these studies ended at the market (whole sale and retail) with little on street foods and associated production-consumer health risk factors (Armar-Klemesu et al., 1998; Sonou, 2001; Amoah et al., 2007).

This study was designed to assess indicator bacterial numbers (*E. coli* and *Enterococci*) on farm and market lettuce leaves as well as irrigation and refreshing water samples. The presence of *Salmonella* in ready to eat chopped lettuce leaves at food vendor sites were also analysed in addition to indicator bacteria to ascertain the effectiveness of decontamination interventions before lettuce leaves are served.

MATERIALS AND METHODS

Sampling sites

The study was conducted in Kumasi. It is the second largest city with a population of 1.2 million and an annual growth rate of 2.6% (Ghana Statistical Service, 2002). It is located centrally in Ghana between latitude N06416°41'N (6° 40" 26' North) and longitude W01371°37'W (1° 35" West) and lies approximately 260 m above sea level. Two urban and one peri-urban farm sites, three market sites and twelve food vendor restaurants within urban Kumasi were

selected for sampling. All the farm sites had similar land use history in terms of poultry manure use and have been under cultivation for not less than six years. The two urban farms, Gyenyase and Karikari which covered an irrigated area of 12.7 and 2.8 ha respectively used water from shallow wells and polluted streams for irrigation while the Deduako farm (Peri-urban) with an irrigated area of 9.3 ha used water from an impounded stream.

Sampling

Lettuce and water samples were obtained from the farms, markets and street food restaurants on a weekly basis for 12 months (June 2005 to May 2006).

Lettuce sampling

On a sampling date, six cultivated beds were randomly selected at each of the three farm sites and three lettuce heads harvested across the diagonal of the beds just before harvesting for the markets. In the markets, three lettuce heads were collected from each of the selected sellers at the market, at mid day to ensure that the vegetables had received enough splashing with the refreshing water. At each food vendor site, about 20 g of chopped lettuce ready to be sold with street food, was collected from each seller. Each of these samples at all stages was placed separately into labelled sterile plastic bags and immediately sent to the laboratory in cool boxes and analyzed for the selected bacteria contaminants

Water sampling

Irrigation water samples were taken from three different irrigation ponds on each farm site, but for the peri-urban site where stream water was used samples were taken at the point where the farmers draw water using sterile Duran Schott glass bottles.

In the markets, 'refreshing' water samples were aseptically collected from their vessels using sterile bottles and transported to the laboratory in a cool box for microbiological analysis.

Microbiological analysis

Thermotolerant coliforms were estimated using a three-tube Most Probable Number (MPN) method according to standard procedures (Anon, 1992). Ten grams of the lettuce was placed in a stomacher bag and pulsified in 90 ml of 0.9% NaCl MQ-water for 30 s using a pulsifier (PUL 100E; Stuart Scientific Co. Ltd, U.K). Serial dilutions of 10^{-1} to 10^{-11} were prepared from 1 ml of the stomacher bag content. One millilitre of each dilution was inoculated in triplicate into 5 ml of mineral modified Glutamate medium. Tubes showing acid and gas production after incubation for 24 h at 44°C were confirmed by transferring a drop of liquid from positive tubes into 5 ml test tube of tryptone water and incubated at 44°C for 24 h. A drop of Kovacs' reagent was then added to the tube of tryptone water. All tubes showing a red ring colour development after gentle agitation were recorded as positive for thermotolerant coliforms. Estimated counts were obtained from MPN tables (APHA-AWWA-WEF, 2001) and results expressed in per gram wet weight for lettuce and 100 ml for irrigation and refreshing water.

Enterococci were enumerated by placing 1 ml volume of the same serial dilutions prepared for the thermotolerant coliforms directly onto set plates of Slanetz and Bartley agar. These were allowed to dry and then incubated for 4 hr at 37°C and for 44 h at 44°C. Red, maroon or pink colonies were counted as presumptive Enterococci. Presumptive colonies were confirmed on MacConkey No. 2 (Scharlaw 02 - 120). All counts were expressed as colony

forming units (cfu) per gram wet weight for lettuce leaves and per 100 ml for water.

Salmonella was enumerated by the MPN technique (Anon, 1992) using Buffered Peptone water (BPW) as a pre-enrichment medium (Moringo et al., 1989). Ten grams of the lettuce was placed in a stomacher bag and pulsified in 90 ml of 0.9% NaCl MQ-water for 30 s using a pulsifier (PUL 100E; Stuart Scientific Co. Ltd, U.K). From the 1/10 stock solution, volumes of 10, 1 and 0.1 ml of the liquid were directly inoculated into BPW tubes and incubated for 24 h at 37°C. From each BPW tube, 100 µl were inoculated into Rappaport-Vassiliadis Soya Broth (RVS) (Oxoid) and incubated at 42°C for 48 h (Vassiliadis, 1983). Each enrichment broth was subsequently streaked onto Salmonella-Shigella media (SS) (Oxoid) and incubated for 24 h at 37°C. Transparent colonies, with or without black centres (typical salmonella morphology) were tested by standard biochemical procedures (Le Minor, 1984). Counts were expressed as MPN g^{-1} (Collins et al., 1989). All salmonella-like colonies were tested by slide agglutination using commercial antisera (Difco) Edwards and Ewing, 1972).

Perceptions of health risk

Perceptions of health risk information at the farm and market sites were gathered through focus group discussions and informal interviews as well as personal observations. Semi-structured questionnaires, also with open-ended questions, were administered and observation check list used at the street food vendor sites of the sampling process. This was used to assess perceptions of health risks factors or agents to consumers and the food vendors. The questionnaire was administered randomly to twenty four street food vendors to capture information including personal data, source of vegetables, washing methods, source of washing water and general and personal hygienic conditions.

Data handling and analysis

Laboratory and survey data were analyzed using SPSS Windows version 11.0. In order to eliminate zero data points, the value 1 was added to each count (x) of thermotolerant coliforms, enterococci and *Salmonella* and the x + 1 value transformed into $\log_{10}$. A one-way randomized analysis of variance (ANOVA) was used to analyse the transformed data. Mean data is however reported as untransformed values.

RESULTS

Bacterial indicator numbers at production (farm) sites

Geometric mean bacterial numbers at the three farm sites ranged from 2.30×10^3 to 9.30×10^8 MPN/g wet weight for thermotolerant coliforms and from 3.9×10^1 to 1.0×10^6 cfu of enterococci per g wet weight of lettuce leaves. However, significantly (p ≤ 0.05) lower bacterial numbers were recorded in irrigation water samples ranging from 1.5×10^3 to 4.3×10^6 MPN/g wet weight for thermotolerant coliforms and from 9.6×10^1 to 8.6×10^4 cfu/g wet weight for enterococci (Table 1).

There were varied differences in bacterial numbers between all the three farms. Table 1 compares thermotolerant coliform numbers on lettuce leaves with their corresponding irrigation water from the same farm. The recorded differences were very highly significant (p ≤

0.000) for the Karikari farm site and highly significant at the Deduako (p ≤ 0.003) and Gyenyase (p ≤ 0.008) farms. Relationships between thermotolerant coliform load in irrigation water and irrigated lettuce at the three farm sites were generally linear; the correlation was positive (r = 0.331, p ≤ 0.008) for Gyenyase and negative for the Karikari (r = -0.531, p = 0.000) and Deduako (r = -0.388, p = 0.003) farm sites.

Differences in enterococci numbers on lettuce leaves from the three farm sites were not significant at p ≤ 0.05 except between Gyenyase and Deduako where the differences were significant at p = 0.020. Similarly, enterococci numbers in irrigation water samples from the three farms showed some variation. Enterococci load in irrigation water at Gyenyase was significantly higher (p ≤ 0.006) than at Karikari but differences between Karikari and Deduako and between Gyenyase and Deduako were not. Enterococci numbers in irrigation water samples compared closely with numbers on lettuce samples from the same farm site (Karikari p ≤ 0.347; Deduako, p ≤ 0.501; and Gyenyase p ≤ 0.073). Relationships between enterococci load on lettuce and in irrigation water were weakly linear. For Karikari farms, the relationship was positive (r = 0.121, p ≤ 0.347) but negative for Deduako (r = -0.091, p ≤ 0.501) and Gyenyase farms (r = -0.227, p ≤ .073).

Bacterial indicator numbers on lettuce and refreshing water samples at the market sites

Thermotolerant coliform numbers in lettuce ranged from 4.0×10^3 to 2.3×10^8 MPN/g wet weight and enterococci from 6.0×10^1 to 9.0×10^4 cfu/g wet weight for all the market sites (Table 2). Generally, thermotolerant coliform numbers on lettuce at the different markets showed significant (p ≤ 0.000) variation although differences between the European/French line and Asafo markets were not significant (p ≤ 0.639). There was a strong positive correlation (r = 0.629, p = 0.00) in thermotolerant coliform numbers on lettuce and in the 'refreshing' water samples from the European/French line markets but the relationship was negative (r = -0.255, p = 0.134) for the Railways market.

There were statistically significant differences in enterococci numbers on lettuce from the three markets. Comparing enterococci numbers in 'refreshing' water samples to the lettuce from the same market, there was a negative correlation (r = -0.499, p = 0.002) at the Railway but there was a positive correlation (r = 0.477, p = 0.001) at the European/French line market.

Bacterial indicator numbers on chopped lettuce at street food vendor sites

Irrespective of the street food vendor site, bacterial numbers on ready-to-serve lettuce were higher than the recommended level of 1 × 1000 per 100 g fresh weight by

Table 1. Bacterial counts (geometric means and ranges) on lettuce and in irrigation water on vegetable farm sites within urban and peri urban Kumasi.

Sample	Bacteria	Sampling site	Geometric mean (log S.D.)	Range
Lettuce[1]	Thermo. coliform[3]	Gyenyase (urban)	$4.8 \times 10^4 (0.65)$	$4.0 \times 10^3 - 4.2 \times 10^6$
		Karikari(urban)	$5.9 \times 10^4 (0.93)$	$4.0 \times 10^4 - 9.3 \times 10^8$
		Deduako(peri-urban)	$5.3 \times 10^4 (1.06)$	$2.3 \times 10^3 - 2.4 \times 10^8$
	Enteroccoci[4]	Gyenyase (urban)	$3.6 \times 10^4 (0.83)$	$3.9 \times 10^1 - 1.0 \times 10^5$
		Karikari(urban)	$3.9 \times 10^4 (0.95)$	$8.5 \times 10^1 - 1.0 \times 10^6$
		Deduako(peri-urban)	$3.4 \times 10^5 (0.76)$	$1.5 \times 10^2 - 4.1 \times 10^5$
Water[2]	Thermo. coliform	Gyenyase (urban)	$4.9 \times 10^4 (0.72)$	$7.0 \times 10^3 - 4.3 \times 10^6$
		Karikari(urban)	$4.4 \times 10^4 (0.47)$	$4.0 \times 10^3 - 9.3 \times 10^4$
		Deduako(peri-urban)	$3.4 \times 10^4 (0.22)$	$1.5 \times 10^3 - 4.3 \times 10^3$
	Enteroccoci	Gyenyase (urban)	$3.1 \times 10^4 (0.61)$	$1.2 \times 10^2 - 5.7 \times 10^3$
		Karikari(urban)	$4.2 \times 10^4 (0.94)$	$9.6 \times 10^1 - 8.6 \times 10^4$
		Deduako(peri-urban)	$3.6 \times 10^4 (0.88)$	$1.2 \times 10^3 - 5.7 \times 10^3$

[1]Lettuce, n = 54 for all sites; [2]Irrigation, water = 9 for Karikari and Gyenyase and 3 for Deduako. [3]Thermotolerant coliform results are average geometric means of MPN per g wet weight of lettuce and MPN per 100 ml of water; [4]Enterococci results are average geometric means of cfu per g wet weight of lettuce and cfu per 100 ml of water.

Table 2. Bacterial counts (geometric means and ranges) in lettuce and refreshing water from three selected market sites within urban Kumasi.

Sample	Bacteria	Sampling site	Geometric mean (log S.D.)	Range
Lettuce[1]	Thermo. coliform[3]	Euro/French line	$6.8 \times 10^4 (1.20)$	$1.5 \times 10^4 - 2.3 \times 10^8$
		Railways	$5.6 \times 10^4 (1.10)$	$4.0 \times 10^3 - 2.4 \times 10^7$
		Asafo	$6.6 \times 10^4 (0.74)$	$2.3 \times 10^5 - 9.3 \times 10^7$
	Enteroccoci[4]	Euro/French line	$3.7 \times 10^4 (0.79)$	$6.0 \times 10^1 - 9.2 \times 10^4$
		Railways	$4.4 \times 10^4 (0.59)$	$4.6 \times 10^2 - 8.4 \times 10^4$
		Asafo	$3.1 \times 10^4 (0.92)$	$8.1 \times 10^1 - 9.0 \times 10^4$
Water[2]	Thermo. coliform (Refershing)	Euro/French line	$8.8 \times 10^4 (0.82)$	$2.3 \times 10^7 - 4.3 \times 10^{10}$
		Railways	$5.0 \times 10^4 (1.05)$	$9.0 \times 10^3 - 9.3 \times 10^6$
		Asafo	-	-
	Enteroccoci	Euro/French line	$4.6 \times 10^4 (0.28)$	$1.3 \times 10^4 - 8.3 \times 10^4$
		Railways	$3.6 \times 10^4 (0.67)$	$4.8 \times 10^2 - 2.7 \times 10^4$
		Asafo	-	-

[1]Lettuce n = 27 for Asafo and Railways and 36 for European/French market; [2] Refreshing water n = 9 for Railways and 12 for European/French market; [3] Thermotolerant coliform results are average geometric means of MPN per g wet weight of lettuce and MPN per 100 ml of water; [4]Enterococci results are average geometric means of cfu per g wet weight of lettuce and cfu per 100 ml of water.

the ICMSF (1998). Bacterial numbers ranged from 2.3×10^4 to 1.5×10^9 for thermotolerant coliforms, 5.1×10^3 to 2.5×10^6 for enterococci, and 1.5×10^1 to 9.3×10^2 for *Salmonella* (Table 3). Mean prevalence of salmonella ranged between 0 to 8%. Bacterial indicator numbers generally increased from the production (farm) sites to the street food vendor sites. Thermotolerant coliform numbers on lettuce leaves sold in the markets (6.26×10^4) were 16% higher than counts (5.29×10^4) obtained from farm sites. Also, there was a linear increase of 18% from production (farm) to consumption points but the increase was only 3% from the markets (6.3×10^4) to street foods sites (6.5×10^4). Enterococci numbers on market samples (3.7×10^4) were 3% lower compared to

Table 3. Bacterial counts (geometric means and ranges) from selected street food vendor sites in urban Kumasi.

Sample	Bacteria	Geometric mean (log S.D.)	Range
Lettuce	Thermo. coliform	$6.5 \times 10^4(1.28)$	$2.3 \times 10^4 - 1.5 \times 10^9$
	Enteroccoci	$5.1 \times 10^4(0.47)$	$5.1 \times 10^3 - 2.5 \times 10^6$
	Salmonella	$5.5 \times 10^1(1.50)$	$1.5 \times 10^1 - 9.3 \times 10^2$

Lettuce n = 32 for all sites. Thermotolerant coliform results are average geometric means of MPN per 100/g wet weight. Enterococci results are average geometric means of cfu per 100/g wet weight.

that on the farms (1.4×10^5).

Perceptions of health risk

Farmers at all the three farm sites were males with most of them living close to their farms. Each farm had an average of fifteen farmers. During Focus Group Discussions it became apparent that all the farmers had experienced one health problem or the other. Eighty percent of farmers attributed their health problems to the exposure to wastewater used in vegetable irrigation while others pointed to the use of agrochemical and poultry manure. The perception of farmers on the nature of health problems also varied. Farmers ranked malaria and fever (95%); foot-rot, (50%); diarrhoea (10%) and occasional back ache. However, twenty percent of the farmers and their families were of the view that their health problems were neither the result of their consumption of the farm produce nor their exposure to wastewater.

The study identified on farm sources of contamination to include the indiscriminate disposal of waste in irrigation water channels and use of inappropriate protective clothing. It was observed that many farmers did not use Personal Protective Equipment and were in direct contact with the wastewater.

All the vegetables sellers at the three market sites were females and 63% of them displayed their produce in open basin receptacles with 'refreshing water'. Sellers acknowledged that the use of wastewater and agrochemicals in the production of the vegetables could increase the incidence of cholera and other diarrhoeal diseases amongst farmers, sellers, and consumers. 'Refreshing' water use could also be a major source of contamination as it is used for other activities such as the washing of hands before and after eating.

The fast-food vendors surveyed were made up of 71% females and 21% males and had been in the trade for between 4 to 6 years. Sixty-three percent of them were between the ages of 21 - 30 years and 79% had had primary education.

Most of the food vendors (96%) washed their lettuce with pipe borne water and 4% used well water. About 49% of the food vendors used salt solution, 13% used vinegar and 38% used plain water in washing vegetable,

in order to destroy any pathogen that may be present on the leaves, before serving. However, over 50% of the vendors served their vegetables with their bare hands.

DISCUSSION

The study shows that wastewater irrigated vegetable farming and produce handling practices increase bacterial loading on the vegetables. Bacterial numbers recorded in this study are above the ICMSF (1998) limit of 10^3 to 10^5 coliforms 100 g^{-1} wet weight of vegetables usually eaten raw. Cornish et al. (1999), Keraita et al. (2003a), Amoah et al. (2005) all reported high bacterial numbers on lettuce produced in farms within Kumasi.

Several reasons can be assigned to this: firstly, the level of bacterial loading on lettuce on the farms may result from the high levels of indicator bacterial numbers in the farm irrigation water. This agrees with reports of earlier workers (Mensah et al., 2001; Keraita et al., 2003b; Amoah et al, 2005; Obiri-Danso et al., 2005) that the bacterial quality of urban rivers and waterholes in Kumasi is low and most of these are the main sources of irrigation water for vegetable production. The water bodies in the Kumasi metropolis are often contaminated by diffused or non-point sources and point sources. These sources include run-off from agricultural lands and abattoirs and outfall pipes of breweries and wood processing industries.

Additionally, inputs from the faeces of wild birds and domestic animals, human excreta, market and household waste end up in the rivers and shallow wells. The shallow wells or dugouts on the vegetable farms are often not protected and easily receive pollutants from the surrounding farm environment (Drechsel et al., 2000; Amoah et al., 2005; Obiri-Danso et al., 2009). Secondly, the use of overhead irrigation technique and the general morphology of lettuce expose much of its surface area to the irrigation water and soil particles from the splashes and this could account for the high contamination (Amoah et al., 2005). Thirdly, the use of poultry manure by 75% of vegetable farmers as the main nutrient source for the lettuce and for the management of soil fertility contributes high numbers of faecal coliforms (Westcot, 1997). Animal manure is a well known source of foodborne pathogenic

bacteria and it's inappropriate use in vegetable crops contributes a risk to consumer health (Lau and Ingham, 2001; Locking et al., 2001; Riordan et al., 2001; Wachtel et al., 2002; Zschock et al., 2000). Drechsel et al. (2002) reported that fresh poultry litter samples used for vegetable production in Kumasi had high faecal coliform counts ranging from 3.6×10^4 to 1.1×10^7 and could be a possible source of lettuce contamination especially where farmers broadcast manure on standing crops.

Generally, the shallow hand dug well water recorded significantly higher bacterial numbers compared to the stream water and this may suggest that use of streams in vegetable production may be relatively less risky to farmers and consumers. Cornish et al., (1999) also recorded higher faecal coliform numbers in shallow wells than in nearby streams in their study in Kumasi. This could be attributed to surface runoff from the farms and adjacent fields (Drechsel et al., 2000).

Enterococci numbers were found to be lower compared to the thermotolerant coliforms. This is because unlike coliforms, enterococci are more sensitive to variations in environmental conditions and are easily knocked-off by sunlight and temperature (Obiri-Danso et al., 2001; Beuchat, 1998).

Though it was expected that bacteria numbers would decrease from farm to market due to possible die-off resulting from the prevailing high temperatures and sunlight intensity, mean bacterial numbers on the market lettuce samples were 16% higher compared to the farm samples for thermotolerant coliform but decreased by 74% for enterococci. High bacterial numbers on market lettuce leaves have also been reported in earlier studies (Sonou, 2001; Keraita et al., 2003b). The use of irrigation water in washing the lettuce at the farm gate after harvesting before transporting to the markets increases the bacterial load (Drechsel et al., 2000). Poor handling, storage, transportation and cleaning practices at the market could add to the contamination (Beuchat, 1995; Sonou, 2001; De Rover, 1998). An additional potential source of contamination is the use of refreshing water which rarely gets changed and carries high microbial numbers (Feenstra et al., 2000; Blumenthal et al., 2000).

Ironically, although the Asafo market sellers do not use refreshing water, bacterial numbers were still high on their lettuce and comparable to the other markets. The use of cane baskets, dirty cover clothes and fertilizer sacks as carrying and transporting receptacles for the lettuce and the storage of the produce under tables and on the market floor in Asafo could account for the high level of contamination. The results of this study however contrast that of Maxwell et al. (1998) who reported that farm gate vegetable samples had significantly lower counts of all categories of bacteria than samples in the major wholesale markets.

Chopped lettuce sold together with rice on the streets of the Kumasi metropolis was contaminated with thermotolerant and enterococci bacteria. This is contrary to the perception that because these leaves are often deconta-

minated with either salt or vinegar they would be free of microorganisms. Our study indicates that bacterial numbers on the chopped lettuce leaves were 3% higher than that on the market. Mensah et al. (2001) and Johnson (2002) who studied bacterial loads on street foods sold in the city of Accra also reported high numbers. The high bacterial load on the chopped lettuce can be linked to poor handling such as the use of bare hands in serving the chopped lettuce and occasionally wiping these same hands on their dresses and rags. Mensah et al. (2002) identified serving of vegetables with bare hands by street food vendors as a source of contamination. Also, chopped lettuce were usually displayed in the same receptacle with other chopped vegetables, hence the possibility of cross contamination. Lettuce leaves were also washed in the same bowl of water, (water quality cannot be guaranteed) with other vegetables and displayed together. This confirms earlier reports by Feenstra et al. (2000) and Blumenthal et al. (2000).

Conclusion

The use of wastewater in vegetable production guarantees a secured livelihood for urban and peri-urban farmers but without any wastewater treatment, it poses serious health risks to farmers, sellers and consumers. Bacterial numbers along the production-consumer chain all exceeded both the WHO (1989) and ICMSF (1998) recommended levels making their consumption a health threat. The linear increase in bacterial counts from pro=uction to consumption was significant and could be due to poor handling practices.

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