

9. Quality of vegetables in urban markets¹

This chapter shows results obtained from analyzing samples of vegetables taken at farm gate and from selling points in Accra, Kumasi and Tamale. Due to the common practice of irrigating with polluted water, the focus was on the microbiological quality of the vegetables using faecal coliforms as main indicator. In addition, some information is provided on helminth contamination, heavy metals and pesticide residues.

9.1 Sampling and analyses

Where overhead irrigation with polluted water is common, like in Ghana, consumers of irrigated crops are at risk, especially if it concerns crops which are consumed uncooked. On the pathway from farm to fork, crops pass through various hands and it is important to analyse post-harvest contamination. To get a complete picture, pesticides and heavy metals also have to be considered. However, compare to wastewater irrigation, pesticide use is not a particular characteristic of urban and peri-urban agriculture.

This first study on pathogens was conducted over three months, October to December 2002. A total of 180 vegetable (*lettuce, cabbage and spring onion*) samples were collected from nine major markets and twelve specialized individual vegetable and fruit sellers in Accra, Kumasi and Tamale. On each market, samples were collected under normal purchase conditions, from three randomly selected sellers. A minimum of three composite samples (*each containing two whole lettuces*), three bunches of spring onions (*each containing two bunches*) and three cabbages were collected, put in sterile polythene bags and transported on ice to the laboratory where they were analyzed immediately or stored at 4° C until analysis within 24-48 hours. Samples from individual sellers were collected in the same way.

The second pathogen survey addressed 886 randomly selected farmers, sellers (wholesalers and retailers) and consumers/food vendors of irrigated lettuce in both cities. Over a period of 12 months from May 2003 to April 2004 a total of 1296 lettuce samples were collected at different entry points from farm to the final retail outlet. Twice every month, at least three composite samples (*each containing two whole lettuces*) from each selected farm site were randomly collected just before harvesting by a wholesaler. The wholesaler was followed to the wholesale market where another sample from the same original stock was collected before being finally sold to a retailer. At the final retail point, three composite samples were again

¹ This chapter is in large parts an extract from the forthcoming PhD thesis by Philip Amoah (IWMI-KNUST).

sampled after vegetables had been displayed on the shelves for at least two to three hours, which is a typical turnover period at the retail point.

The samples were analyzed quantitatively for total and faecal coliform (Most Probable Number method) and helminth eggs according to standard procedures (APHA, 1989, Schwartzbrod, 1998). Faecal and total coliform populations were normalised by log transformation before analysis of variance (ANOVA). Results of analysis are quoted at $p < 0.05$ level of significance (5%). For details of the pathogen analysis see Amoah et al. (2006b, 2007). Pesticide analysis considered *lindane*, *endosulfan*, *lambda cyhalothrin*, *chlopyrifos* and *p,p'-DDT*. Sample peaks were identified by their retention times compared to the retention times of the corresponding pesticide standard obtained from the International Atomic Energy Agency (IAEA). The ability of the laboratory used (Water Research Institute, Accra) to identify these substances has been verified by cross-tests in Ghana and Europe. For details of the analysis see Amoah et al. (2006a). Heavy metal sampling and analysis were carried out in an independent project by the Department of Soil Science, University of Ghana, Legon.

9.2 Coliform counts

Table 9.1 shows the faecal coliform contamination levels of lettuce at different entry points starting from farm to the final retail outlet. Irrespective of the irrigation water source, mean faecal coliform levels exceeded the recommended standard. There were no significant differences in the average lettuce contamination levels at different entry points (farm, wholesale market and retail outlet). Also the analysis of individual samples followed from farm to retail on the various sampling dates confirmed that the contamination of lettuce with pathogenic microorganisms does not significantly increase through post-harvest handling and marketing (Amoah et al., 2006b). This is good news as the hygienic conditions, including washing habits, clean display and handling of food as well as availability of sanitation infrastructure on market sites is not very supportive. Only 31% of the markets in Accra have a drainage system, 26% have toilet facilities and 34% are connected to pipe-borne water as shown by a survey some years ago (Nyanteng, 1998). While it appears as if the initial contamination on-farm is so high that it hides any possible post-harvest contamination, the latter also remains less significant in those cases where lettuce was irrigated with piped water,

thus making it significantly less contaminated. These results question earlier statements, for example by Armar-Klemesu *et al.* (1998)².

Another interesting result was that on-farm crop contamination also takes place under irrigation with piped water. Sources of contamination in these cases included the already contaminated soil (FC levels of 1×10^4 10g^{-1} in the upper 5 cm) and the frequent application of improperly composted (poultry) manure (Amoah *et al.*, 2005; Drechsel *et al.*, 2000).

Table 9.1: Mean faecal coliform contamination levels of lettuce at different entry points along the production - consumption pathway of lettuce (Amoah *et al.*, 2006b)

City	Irrigation water source	Statistics	Log faecal coliform levels (MPN* 100g ⁻¹)		
			Farm	Wholesale market	Retail
Kumasi	Well (n=216)	Range	3.00 - 8.30	3.10 - 8.50	3.20 - 7.00
		Geometric mean	4.54	4.44	4.30
	Stream (n=216)	Range	3.40 - 7.10	3.60 - 7.20	3.50 - 7.20
		Geometric mean	4.46	4.61	4.46
	Piped water (n=216)	Range	2.30 - 4.80	2.60 - 5.30	2.40 - 5.10
		Geometric mean	3.50	3.69	3.65
Accra	Drain (n=216)	Range	3.40 - 6.00	3.00 - 6.80	3.00 - 6.50
		Geometric mean	4.25	4.24	4.48
	Stream (n=216)	Range	3.20 - 5.70	3.10 - 5.90	3.20 - 5.50
		Geometric mean	4.22	4.29	4.37
	Piped water (n=216)	Range	2.90 - 4.70	2.90 - 4.80	2.80 - 4.50
		Geometric mean	3.44	3.46	3.32

* MPN, Most Probable Number;

9.2.1 Faecal coliform levels in vegetables in Accra

In Accra, lettuce, cabbage and spring onion samples were taken from Makola, Agbogbloshie, Dome and Kaneshie markets and from some individual sellers. In all markets and selling points, lettuce had the highest levels of faecal coliforms population (Figure 9.1). Agbogbloshie is the main depot for vegetables from within and outside Accra, where vegetables are not washed as they are mainly sold to other vendors who are expected to wash them before selling (Figure 9.2).

² However, the often-cited statement of the authors that contamination of vegetables in markets was higher than at farm gate was later amended. At farm and market, the levels appeared comparable, which could also mean no further contamination.

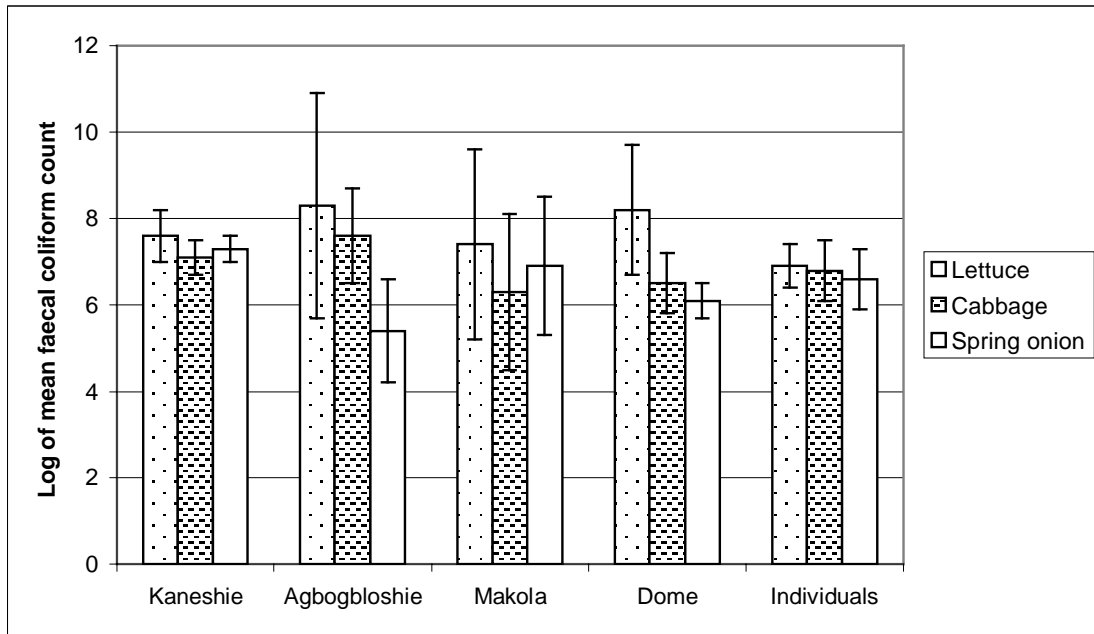


Figure 9.1: Faecal coliform populations on selected vegetables from some markets in Accra.



Figure 9.2: A section of Agboglobshie market showing vegetables displayed on the ground.

For both cabbage and lettuce, there were no significant differences in either faecal or total coliform levels when comparing these vegetables across markets. The same applies to spring onions, except higher levels in Kaneshie than Agbogbloshie.

9.2.2 Faecal coliform levels in vegetables in Kumasi

In Kumasi, vegetable samples were collected from three markets ('White' (opposite Post Office), Asafo and Central) and from some individual sellers. Samples collected from individual sellers had less contamination compared to the formal markets (Figure 9.3). However, these levels are still higher than the International Commission on Microbiological Specification for Food (ICMSF) recommended levels of 1×10^3 100 g^{-1} fresh weight³. Mensah et al. (2001) observed that on the smaller "White" markets where (expatriate) consumers asked frequently about produce quality, the sellers changed the water to wash their produce more often than on other markets and reduced indeed the pathogen level.

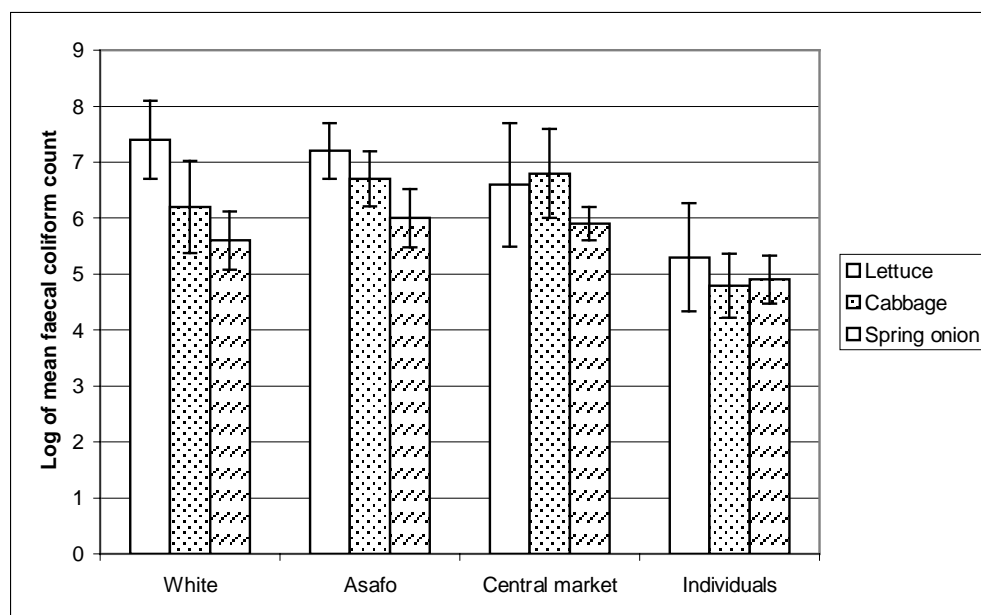


Figure 9.3: Faecal coliform populations on selected vegetables from markets in Kumasi.

³ Ready-to-eat foods are considered to be of "acceptable" quality in England if they contain <100 *E. coli* per gram wet weight (i.e., $<10^4$ per 100 g) (Gilbert *et al.*, 2000). This guideline value is used in many other countries, including Australia, Canada and New Zealand. Since lettuce is a common component of many ready-to-eat foods, it makes little sense for the wastewater used to irrigate lettuce to be treated to a higher quality than is required of the lettuce itself (WHO, 2006).

9.2.3 Faecal coliform levels in vegetables in Tamale

Tamale has few vegetable markets and selling points, as it has a smaller population compared with Accra and Kumasi. Sampling was done in two markets (Aboabo and the main market), while some samples were also taken from individual sellers. Faecal coliforms ranged from 4.0×10^5 to 7.5×10^8 while total coliforms were between 1.5×10^7 and 1.6×10^{10} (see Figure 9.4). There was no significant difference in both total and faecal coliform counts for the three vegetables across markets.

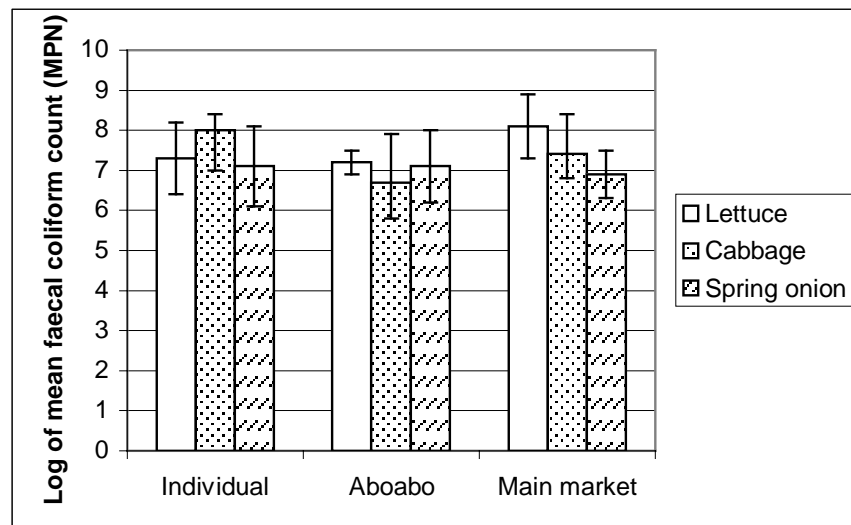


Figure 9.4: Faecal coliform populations on selected vegetables from some markets in Tamale

9.2.4 Inter-city comparison of the total and faecal coliform levels in vegetables

Lower levels of both total and faecal coliform populations were recorded for vegetable samples from Kumasi compared to those from Accra and Tamale (Figures 9.5 and 9.6).

The reason for this could be both on-farm and post-harvest handling of crops. Previous studies done in Kumasi (Cornish et al. 1999, Keraita et al. 2002b) show that many farmers use shallow wells along the streams with better water quality for irrigation compared with Accra and Tamale where water from urban drains is mostly used. There is no scarcity of water in Kumasi and vegetables are washed on the farms (though with the same irrigation water), before they are taken to the market.

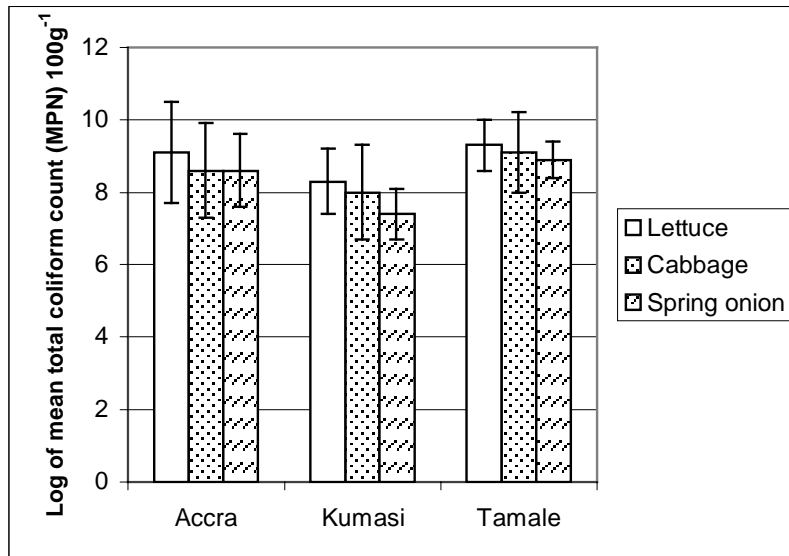


Figure 9.5: Total coliform levels in vegetables from Accra, Kumasi and Tamale

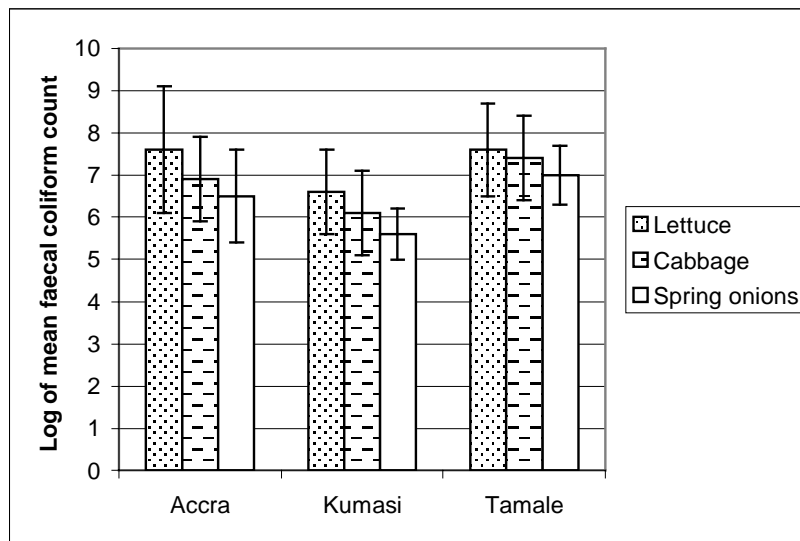


Figure 9.6: Faecal coliform levels in vegetables from Accra, Kumasi and Tamale

9.2.5 Inter-vegetable comparison of total and faecal coliform levels

Among the three vegetables, lettuce showed the highest level of contamination both in faecal and total coliform (Figure 9.7) with contamination levels ranging between 10^6 and 10^{11} for total coliforms and between 10^3 and 10^9 for faecal coliforms. These contamination levels are in line with recent studies on food contamination conducted in Accra (Akpedonu, 1997, Abdul-Raouf et al., 1993).

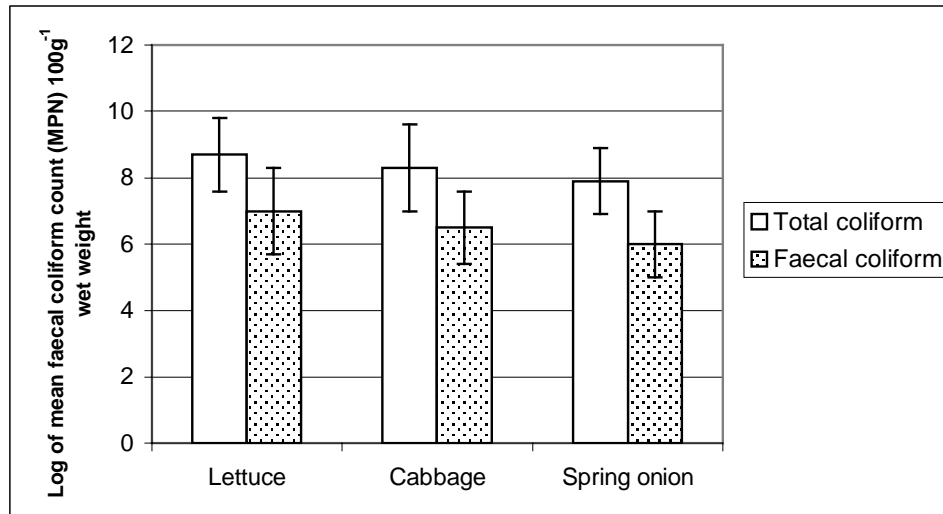


Figure 9.7: Faecal and total coliform populations on selected vegetables

The differences were significant for faecal coliform counts, which could be attributed to the larger leaf surface of lettuce offering a larger contamination surface. This foliage also protects microorganisms against exposure to environmental factors and prolongs microorganism survival (Shuval et al. 1986, Armon et al. 1994).

9.3 Helminth eggs

Table 9.2 shows helminth populations from the vegetables analyzed. The eggs identified include *Ascaris*, *lumbricoides*, *hookworm*, *Trichostrongylus*, *Schistosoma heamatobium* and *Trichuris trichiura*. *Strongyloides stercoralis* and nuaplius larvae were observed but not included in the counts. *S. stercoralis* had a high occurrence and was observed in all samples. *A. lumbricoides* was the most predominant among all the other organisms and was observed in 85% of the contaminated vegetables. This could be attributed to the high level of persistence of *S. lumbricoides*, hence high survival time. The presence of helminths, particularly *S. lumbricoides*, on the vegetables could pose a serious problem because of their high infective dose and low host immunity. For a better assessment of the potential threat it is required to determine egg viability. It can be assumed that many of the eggs found in streams and irrigation water are old and no longer viable.

Table 9.2: Mean helminth egg population on selected vegetables in Ghanaian markets

Vegetable	No. of samples	Average number of eggs/g
Lettuce	27	1.14 a
Cabbage	32	0.42 a
Spring onion	26	2.74 b

The mean difference is significant between a and b at the 0.5% level.

As shown in Table 9.2, cabbage had the lowest counts of helminth eggs and spring onions the highest ($p < 0.05$). The high helminth egg count in spring onion is surprising considering the low surface area of the leaves compared with lettuce and cabbage.

9.4 Heavy metals

In 2006, the University of Ghana started a pilot assessment of heavy metals in crops, water and soils on different urban vegetable production sites in Accra. The data so far available show that in the water, soil and crop samples at all the study sites (Marine Drive, Korle Bu, GBC, Dzorwulu and Alajo) the concentrations of Cadmium were well below international limits. However, the concentrations of lead in lettuce were in general above the standards. The major source of lead in the urban environment is usually traffic. A detailed and final evaluation of the variations in the concentrations of these and other metals in the different materials at the respective sites will be available soon (Dowuona, 2006).

9.5 Pesticides

The results on pesticide residues showed that vegetable producers in Ghana use a wide range of chemicals to control insects, fungi and other pests. Some of the used pesticides are restricted in application or even banned in Ghana. These include Lindane, Endosulfan, Karate (Lamba cyhalothrin), Chlorpyrifos and DDT. These chemicals have very powerful biologically active ingredients, which are highly toxic and persist in the environment posing a serious threat to the health of producers and consumers. This notwithstanding, farmers indiscriminately use them to cultivate vegetables. Observations revealed that majority of the farmers who apply these chemicals do not perceive the health risks (see also Chapter 4 for

pesticide use on tomatoes in peri-urban areas) or give it less importance than the risk of losing the harvest.

Only lettuce was selected for the pesticide residue analysis due to financial constraints. Chlorpyrifos (Dursban) was detected in 78 % of the lettuce samples, which corresponds with a report by Okorley and Kwarteng (2002) who stated that Dursban is among the most widely sold pesticides in the central region of Ghana. Lindane and Endosulfan are among the pesticides restricted for the control of certain pests, like on cocoa and coffee. As shown in Table 9.3, Lindane, Endosulfan, and DDT were, however, each detected on 33% of the vegetables, showing how weakly these restrictions are enforced. All concentrations exceeded allowed standards.

Table 9.3: Percentage of lettuce showing pesticide residues.

Name of Pesticide	Percentage of lettuce with pesticide residues
Lindane	31
Endosulfan	33
Endosulfan	3
Lambda cyhalothrin	11
Chlorpyrifos	78
DDT	33

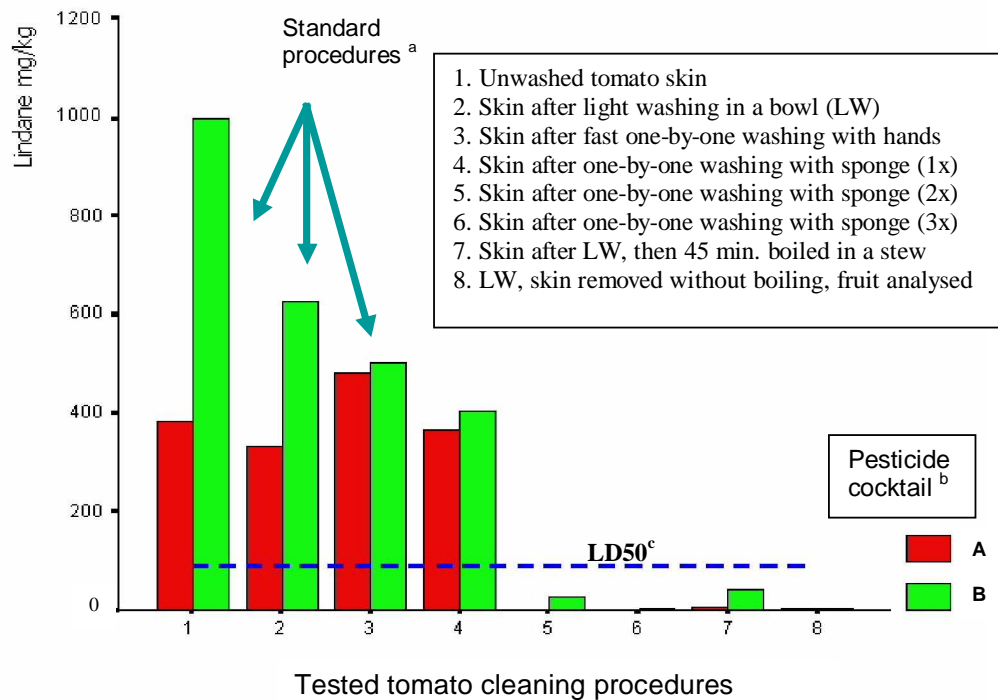
Our laboratory analysis showed that washing of food before eating can reduce or eliminate much of the pesticide residue, except when e.g. Lindane is used (Figure 9.8). In our case study, tomatoes from two farms (A and B) were analysed. On Farm A, they were treated with a cocktail of pesticides three weeks before harvesting while on Farm B they were still treated on the same day of harvesting with a similar cocktail. The cocktails were farmers' choice:

Farm A Diathane, Thionex, Kocide, Lindane

Farm B Diathane, Thionex, Kocide, Topsin, Karate, Lindane

Tomato cleaning was carried out under normal kitchen conditions in Ghana 72 hours after sampling with a number of treatments (see Figure 9.8).

With a melting point over 100°C, even boiling could not remove Lindane. In contrast, the tomato skin cracks when boiled and the pesticides in the water enter the fruit body. The safest way for consumers is to wash the fruit several times or to use only peeled tomatoes (Figure 9.8). An alternative could be to remove hydrophobic chemicals with soap, which was, however not tested due to the expected unfavorable local perception of the resulting taste.



- a. Standard washing procedures in Ghanaian households
- b. Two different “cocktails” of pesticides applied on two farms (A and B)
- c. LD₅₀ (lethal dose of lindane is >88 mg per kg bodyweight)

Figure 9.8: Effect of various forms of washing on the reduction of lindane residue concentrations on tomato skin. Source: Boadi, Abaidoo, Drechsel (unpublished)

9.6 Conclusions and recommendations

Both faecal and helminth contamination of vegetables (*lettuce, cabbage and spring onion*) produced and marketed at various selling points in Accra, Kumasi and Tamale exceeded the ICSMF recommended levels. Faecal contamination was about twice higher than the ICSMF recommended level of 10^5 faecal coliform/g fresh weight. Helminth contaminations were also high (0.42 – 2.74 eggs g^{-1}).

Results showed that except for piped water, all other sources of water used by urban farmers for irrigation showed FC levels exceeding common guidelines for unrestricted irrigation. The study identified the farm as the main point of microbiological lettuce contamination. Despite poor sanitary conditions in markets, post-harvest handling and marketing did not affect the farm-gate contamination levels. Although lettuce irrigated with piped water had the lowest FC

counts, contamination levels can still exceed common standards suggesting contamination through manure and the already contaminated farm soils, with post-harvest contamination being again the comparatively lower risk factor.



Figure 9.9: Awareness creation for appropriate pesticide removal in Ghana
(Source: IWMI)

Comparing vegetables, it was observed that lettuce had the highest levels of faecal contamination, which is to be expected because of its open leaf structure. However helminth eggs were surprisingly higher in spring onions in spite of lower area to volume ratio. Cross-market comparisons within cities showed in general no significant differences in contamination from faecal coliforms for lettuce and cabbage. Thus there is no particular market which could be recommended for the purchase of safe produce. This also concerns supermarkets. However, there was a tendency to safer produce where - based on consumers' demand - sellers changed the water they use to refresh their crops more often than in other markets.

Comparisons among cities showed that in general, the quality of vegetables in Kumasi was better than that in Accra or Tamale. This may be indicative of the water source (often shallow wells near streams) or better post-harvest handling (washing of vegetables still on farm) practices.

The main question of the authorities is where intervention should be placed to reduce health risks for consumers. The results suggest that during the sampling period post harvest contamination was not a major contamination source in contrast to contamination on farm. However, most sellers wash (or refresh) different vegetables before selling them with the same water again and again. This water could easily contaminate relatively cleaner vegetables. Thus, it is not sufficient to address only farm practices.

To reduce the health risk associated with the consumption of contaminated lettuce, it is evident from the study that the problem should first be tackled at the farm level through safer agricultural practices. This, however, is not as easy as often recommended. Changes in irrigation methods, timing and types of crops might not be possible for the farmers (Drechsel et al., 2002). Therefore, other options are currently under investigation in two projects of the Challenge Program on Water for Food. First trials by IWMI show that especially helminth counts can be reduced significantly with simple measures on farm, while it requires good washing practices at home to minimize the bacterial contamination. Thus, it will always be necessary to wash the crops in addition, also in view of heavy metals and pesticides. Kitchens of fast food sellers particularly should be addressed in a related campaign as shown in Chapter 5. Among food sellers, awareness of food safety is generally high and more than 90% of the food vendors and consumers wash salad, however, individual methods vary largely and seldom meet the required standards as our tests showed.

The same applies to the removal of pesticides. Many farmers use restricted and even banned pesticides for vegetable production resulting in residue much higher than the recommended thresholds. In fact, pesticides are considered as plant medicine and the perception of human health risks is very low (Danso et al., 2002b). Despite sufficient legislation, monitoring of pesticides residue on food is virtually non-existent in Ghana (Clarke et al., 1997). Alternative forms of pest control require more participatory technology development and skills training to become competitive (Okorley et al., 2002). Risk reduction should, however, also focus on households to create demand for safer crops and to educate about appropriate washing procedures. Figure 9.9 shows a related example.