Effectiveness of common and improved sanitary washing methods in selected cities of West Africa for the reduction of coliform bacteria and helminth eggs on vegetables

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Summary

OBJECTIVE To analyse and improve the effectiveness of common indigenous washing methods for the reduction of faecal coliform (FC) populations on the surface of wastewater-irrigated vegetables and to determine simple factors affecting their efficacy.

METHODS Questionnaire interviews were used to gather information on common methods used for washing vegetables in seven West African countries. The efficacy of the most common decontamination methods was measured in terms of log reductions in FC populations on homogenised contaminated lettuce, cabbage and spring onion samples.

RESULTS The large majority of urban households and restaurants in the subregion are aware of vegetable-related health risks and wash vegetables before consumption. Methods used vary widely within and between Ghana and neighbouring francophone West African countries. However, several of the most common methods do not reduce the contamination to any desirable level. Significantly, different log reductions are achieved depending on the washing method, contact time and water temperature. Tests to improve the apparent ineffective methods were especially promising in view of the relatively expensive vinegar. However, up to 3 log units reduction is also possible at a much lower price with ‘Eau de Javel’ (household bleach), which is commonly used in francophone West Africa.

CONCLUSION Washing vegetables before consumption is an important component of a multiple barrier approach for health risk reduction. The high risk perception among consumers demands that more information be made available on the appropriate use of these washing methods. Any washing method will need complementary efforts to reduce contamination before the vegetables enter the kitchen, such as safer irrigation practices.

KEYWORDS faecal coliforms, pathogen removal, wastewater, washing, vegetables, Africa

Introduction

Raw and minimally processed fruits and vegetables are an essential part of people’s diet around the world but in recent years, fresh produce consumption has increased with increased urbanisation, urban diets and health awareness (Beuchat 1998). However, present cropping practices in many developing countries, where sanitation in general and wastewater treatment in particular remain challenges, cannot assure vegetables that are free from pathogens.

Many West African studies have shown high levels of pathogen contamination in irrigation water; on both farm and market vegetables (Cisse 1997; Olayemi 1997; Armar-Klemesu et al. 1998; Niang 1999; Faruqui et al. 2004; Amoah et al. 2005, 2006) far exceeding the ICMSF standards (ICMSF 1974).

In recent years, the frequency of outbreaks epidemiologically associated with raw fruits and vegetables have increased in some industrialised countries as a result of change in dietary habits and increased import of food (Altekruse et al. 1997), and use of marginal water for vegetable production (Blumenthal et al. 2000). However, in developing countries with poor sanitary conditions and a larger range of risk factors, many food-related outbreaks probably remain undetected (Beuchat 1998).
Market and street food surveys in Accra estimated that every day, about 200 000 urban dwellers consume (fast) food containing raw vegetables produced with wastewater in urban and peri-urban agriculture (Obuobie et al. 2006; Amoah et al. 2007). This street food is increasingly consumed especially by the urban poor and has been cited as cause for high incidence of diarrhoeal diseases (Tjoa et al. 1977; Mensah et al. 1999; King et al. 2000).

Although most contamination occurs through irrigation, post-harvest contamination especially in the markets is possible (Amoah et al. 2005, 2007).

Based on the exposure scenarios of vegetable consumption and relevant epidemiological evidence, WHO recommends a performance target of 6–7 log units reduction in order to achieve the tolerable additional disease burden from wastewater use of $10^{-6}$ Disability Adjusted Life Years (DALY) per person per year (WHO 2006). This performance target can easily be achieved by effective wastewater treatment using high-technology tertiary treatments and disinfection systems (WHO 2006). But these processes are difficult and costly as they have high energy, infrastructure and maintenance requirements, and require skilled labour; hence, they are less feasible in low-income countries (Carr & Strauss 2001).

In view of these difficulties, the WHO proposes the use of a comprehensive risk assessment and management approach that encompasses all steps in the process from generation and use of wastewater to produce consumption. This can be carried out by constructing multiple barriers along the process pathway by using various risk management strategies and interventions, so that they can have a combined resultant effect. For instance, to protect produce consumers, WHO (2006) proposes wastewater treatment, crop restrictions, use of application techniques that reduce produce contamination, prevention of cross-contamination, improved food hygiene and better cooking of food. Effective pathogen decontamination processes, especially at the food preparation points, are crucial components of a multiple barrier approach as supported by the new WHO (2006) guidelines to minimise health risks associated with consumption of contaminated vegetables. However, few studies have tested indigenous practices in developing countries and the potential of possible improvements.

This study tried (i) to assess existing risk awareness and risk mitigation in households and (street) restaurants in different parts of West Africa, (ii) to analyse the effectiveness of common methods on the reduction of faecal coliform (FC) and helminth egg populations on the surface of fresh vegetables and factors affecting their efficacy and (iii) to see if further improvements could increase the efficacies of these methods.

**Methods**

**Exploratory surveys**

A first exploratory survey carried out between June and August 2005 targeted a cross-section of 210 restaurants of different standards and 950 randomly selected household consumers. The survey was conducted with assistance of CREPA by local teams in the cities of Cotonou, Porto-Novoo and Sémé-podji (Benin), Ouagadougou (Burkina Faso), Niamey (Niger), Lomé (Togo), Bamako (Mali), Dakar (Senegal) and Accra, Kumasi and Tamale (Ghana). City selection was based on intensity of wastewater-irrigated urban vegetable production and proximity of markets for irrigated crops. Data collection was mainly by both structured and semi-structured questionnaire interviews supplemented by direct observation by trained interviewing teams. To harmonise the survey across countries, study terms of reference and questionnaires were developed, pre-tested and discussed with the various city teams.

Interviews were designed to cover a broad spectrum of the population. Inner-urban sites were stratified based on wealth (high-, medium- and low-class areas) and at least two communities from each stratum were randomly selected for the survey. The purpose of the interviews was to assess the general risk awareness and to identify prevalent washing methods used for pathogen decontamination of vegetables during preparation for consumption.

**Efficacy trials for common washing methods used in pathogen decontamination of lettuce**

These trials were based on the results of participant interviews on common washing methods for vegetables. In laboratory analyses, we determined their efficacy in FC decontamination, measured in terms of log reductions. The impact on helminth egg populations was also explored. The effects of selected factors (e.g. temperature, pH, sanitiser concentration and contact time) on the efficacy of the methods were assessed.

Lettuce samples from wastewater-irrigated farms in Accra (Ghana) were randomly collected into sterile polythene bags and transported on ice to the laboratory for analysis. These samples were pooled and homogenised. Vegetable samples used for each of the microbial decontamination trials were derived from the same pool of lettuce.

Lettuce samples were washed under running cold tap water: in a bowl of water, in bowls with different salt (NaCl) solutions (7, 23 and 35 ppm); in vinegar (Vinegar) solution of 6818 ppm and in a combined salt/vinegar solution of 6818 ppm and in a combined salt/vinegar solution of 6818 ppm.
solution at 7/6818 ppm. A powdered laundry detergent (OMO©) was used at a concentration of 200 ppm before washing and rinsing in clean water. In addition, household bleach products were used at the concentration of 1 ml on 1 l (a tea spoon on 5 l); different chlorine bleach brands with unspecified compositions (Eau de Javel™, Thick Bleach™, Power Zone™, etc.) purchased from local shops in Lomé and Accra were tested. All concentrations were calculated based on descriptions by users; in addition, chlorine tablets containing sodium dichloroisocyanurate (NaDCC) as now sold in Ghana for salad decontamination (Foodsaf©; Hydrachem Ltd, Sussex, England, UK) were used at the prescribed concentration of 100 ppm. Potassium permanganate (KM) from PHARMAQUIC S. A., Cotonou, Benin, USP 24, was used following common practices (about 100 ppm) and manufacturer’s instructions (200 ppm).

Measuring effect of temperature, sanitiser concentration and contact time

The effect of temperature on the sanitising efficiency of common methods was tested by using relatively low concentrations of various sanitisers at varying temperatures. Clean tap water, solutions of salt (7 ppm), vinegar (6818 and 11 904 ppm) and potassium permanganate (100 ppm) were each prepared in a bowl. Fifty grams of lettuce was submerged in each of the washing media at temperature of 25º, 30º and 40ºC for 2 min, washed for another 2 min and rinsed in cold water. All washed lettuce samples were analysed for FC populations after another 2 min and then rinsed in cold water. All washed lettuce samples were analysed for FC populations after rinsing in a bowl of clean water for about 10 s. Analyses of washed vegetables and temperature treatment combinations (25, 30 and 40 ºC) for each washing method were repeated eight times.

Vinegar concentrations between 12 500 and 33 300 ppm were prepared by diluting vinegar (5%) with clean tap water and pH measured. Concentrations below 12 500 ppm, which produced less than 1 log reduction during initial trials, were not included. Fifty grams of lettuce was submerged in 1 l of each of the solutions for 2 min and washed for about 2 min in a bowl. The washed lettuce was then rinsed with cold tap water before analysis. The cut-off point of vinegar concentration at which maximum FC reduction occurred was determined.

Samples (50 g) of lettuce were held in a bowl for different contact times between dipping and 10 min of washing in a vinegar solution with a concentration of 21 400 ppm (cut-off point for FC reduction). Other sanitisers tested for 5 and 10 min were KM (100 ppm), Chlorine (200 ppm), OMO™ washing powder and different bleach brands. The efficacy of vinegar solution at a lower concentration of 12 500 ppm on FC contamination of lettuce, cabbage and spring onions with a contact times of 5 and 10 min was also tested. Each test had 9 repetitions.

The decline of efficacy of vinegar solution when used over a long period of time was determined by washing 50 g of lettuce leaves in 12 successions using 1 l of vinegar at a concentration of 21 400 ppm. The pH of the solution was determined before and after every 50 g of lettuce washed.

Both outer and inner leaves of lettuce and cabbage samples were cut into pieces with a sterilised knife and held for about 2 min in vinegar solution (concentration 12 500 ppm), washed for at least 2 min and rinsed with clean water before analysis. The FC levels of the unwashed vegetables (both outer and inner leaves) were also analysed. These tests were repeated with the inner leaves of both lettuce and cabbage after the outer leaves had been removed.

Microbiological examination of washed vegetables

Samples were analysed quantitatively for total and FC and helminth eggs. Coliforms counts were estimated in about 20 g of vegetables (both washed and unwashed), which was weighed into 180 ml of phosphate-buffered saline and rinsed vigorously. Further 10-fold serial dilutions were made and triplicate tubes of MacConkey broth (Merck KGaA 64271, Darmstadt, Germany) were inoculated from each dilution and incubated at 44 ºC for FCs for 24–48 h (APHA-AWWA-WEF 2001). Positive tubes (acid or gas production or both) were selected and the corresponding numbers of FCs obtained from most probable number (MPN) tables.

Helminth eggs were enumerated using the concentration method (Schwartzbrod 1998). This is a modified US-EPA method, but the same principle (floatation/sedimentation) compared with Ayres and Mara (1996) in that both use similar reagents e.g. ZnSO₄ solution (specific gravity, d = 1.2), ether or ethyl acetate, detergent solution (e.g. Tween) and a buffer solution. However, the buffers are different, acetoacetic buffer (Ayres and Mara) and acid/alcohol buffer solution (H₂SO₄ at 0.1 N at 35% ethanol; Schwartzbrod 1998); different centrifugation speeds are used and the ZnSO₄ solutions are applied at different stages in both methods. About 100 g of lettuce leaves were thoroughly washed in about 1 l of sterile distilled water containing two to three drops of Tween 20. The washed leaves were rinsed with sterile distilled water and rinsings added to the washing water in a 2-l container and allowed to stand overnight to enable the eggs to settle completely. As much of the supernatant as possible was sucked up and the sediment transferred into 15-ml
centrifuge tubes. The 2-l containers were rinsed two to
three times with deionised water and the rinses were
transferred into the centrifuge tubes. The tubes containing
the sediments were then centrifuged at 1450 rpm for
3 min. The sediments in the centrifuge tubes for each
sample were pooled into one centrifuge tube and centri-
fuged again at 1450 rpm for 3 min.

The supernatant was poured away and the deposit was
re-suspended in about 150 ml ZnSO₄ solution (specific
gravity = 1.2). The mixture was homogenised with a sterile
spatula and centrifuged at 1450 rpm. At a specific gravity
of 1.2 (ZnSO₄), helminth eggs float leaving other sediments
at the bottom of the centrifuge tube. The ZnSO₄ super-
natant (containing the eggs) was poured into a 2-l flask and
diluted with at least 1 l of distilled water. This was
allowed to stand overnight or for at least 3 h for the eggs to
settle again. As much supernatant as possible was sucked
up and the deposit was re-suspended by shaking. The
deposit was then transferred into centrifuge tubes. The 2-l
container was rinsed two to three times with de-ionised
water and the rinsed water added to the centrifuged tubes
and centrifuged at 1600 rpm for 3 min. The deposit was
pooled into one tube and centrifuged again at the same
speed and time.

The deposit was re-suspended in 15 ml acid/alcohol
buffer solution (H₂SO₄ at 0.1 N at 35% ethanol, i.e.,
350 ml ethanol and 5.16 ml H₂SO₄) after sucking up much
of the supernatant, about 5 ml ethyl acetate was added.
The mixture was shaken and the centrifuge tube occa-
sionally opened to let out gas before centrifuging at
2200 rpm for 3 min. After the centrifugation, a diphasic
solution (aqueous and lipophilic phase representing the
acid/alcohol and ethyl acetate, respectively) solution was
formed. With a micropipette, as much of the supernatant
as possible (starting from the lipophilic and then the
aqueous phase) was sucked up leaving about 1 ml of
deposit. The deposit was observed on a Sedgwick-Rafter
cell under the microscope and the eggs counted. The eggs
were identified by shape, size and colour. The Bench Aid
for the Diagnosis of Intestinal Parasites (WHO 1994) was
used for preliminary identification.

Data handling and analysis
Data were analysed using spss for Windows 10 (SPSS Inc.,
Chicago, IL, USA). Faecal coliform populations (MPN)
were normalised by log transformation before analysis of
variance (ANOVA). ANOVA (multiple comparisons) was used
to compare FC levels on different vegetables washed.
T-tests were also used where appropriate. Results of
analysis are quoted at $P < 0.05$ level of significance or
$P < 0.01$.

Results

Treatment of vegetables by food vendors and consumers
before consumption

There was generally a high level ($>90\%$) of awareness of
potential health risks from consuming raw vegetables and
the corresponding unanimous application of risk mitiga-
tion measures, ranging from water to sanitisers in all the
cities. Measures differed greatly between cities and
between the francophone country group and Ghana.
Quantities of disinfectant used per quantity of product or
water varied strongly.

In general, 56%–90% of the households and
80%–100% of the restaurants used some kind disinfectant
for washing leafy vegetables to be eaten raw, the rest used
only water. The most common disinfectants used in
francophone restaurants were bleach (55%) and potassium
permanganate (31%), followed by salt/lemon or soap
(both 7%). In households, the prevalent method was the
use of bleach (50%), followed by potassium permanganate
(22%), salt (14%) and water only (12%). Every second
recipient rinsed the leaves after washing. Bleach and
potassium permanganate were both practically unknown
as food disinfectants in Ghana. In francophone cities, the
lower classes tended to use water only or water with salt,
soap and lemon juice; in middle- and upper-class house-
holds and restaurants, the use of bleach or permanganate
appeared to be prevalent (Figure 1).

In Cotonou and Dakar, for example, 5%–12% of the
restaurants used only water, 30%–35% used water and a
sanitiser and 53%–65% in addition rinsed the leaves after
washing. In the corresponding households, 28%–42% used
only water. The most common disinfectants used in
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permanganate (31%), followed by salt (14%) and water only (12%). Every second
recipient rinsed the leaves after washing. Bleach and
potassium permanganate were both practically unknown
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sanitiser and 53%–65% in addition rinsed the leaves after
washing. In the corresponding households, 28%–42% used
only water, 27%–33% a disinfectant and 31%–40%
rinsed finally. In Ghana, various salt and vinegar solutions

![Figure 1](image)

**Figure 1** Types of disinfectants used according to the category of restaurants in Cotonou.
are dominantly used besides cleaning in water only (Table 1). Salt is preferred to vinegar for because it is cheaper (Rheinländer 2006).

Efficacy of common methods used in Ghana

Washing vegetables, irrespective of the methods and concentrations commonly used, reduced FC levels in lettuce. For the common methods tested, FC population reductions under a contact time of 2 min ranged from 1.0 to 2.2 log units, whereas reductions of 0.2–1.1 log units were observed when vegetables were just dipped into the solution (Table 2).

Significant coliform reductions (P < 0.05) were recorded for all methods at a contact time of 2 min, and for dipping in a 35 ppm NaCl solution for the same time period. Increasing the salt concentration from 7 to 35 ppm improved its efficacy from 1.4 to 2.1 log units (2 min contact). However, at high concentration (35 ppm), the quality of the lettuce leaves was greatly reduced. The combination of vinegar and salt at low concentration (7/618 ppm) did not perform better than salt alone. Washing lettuce 2 min under running tap water achieved the highest log reduction of 2.2 units.

The removal of helminth eggs requires first of all a physical process. Independently of the method or disinfectant, washing in a bowl reduced the helminth egg population by half or more (Figure 2). Washing under a running tap (without any sanitiser) appeared even more effective, reducing helminth egg contamination levels from about 9 to 1 egg per 100 g wet weight.

Effect of temperature, vinegar concentration and contact time on the efficacy of common washing methods used

The efficacy of salt (7 ppm) and vinegar (6188 and 11 904 ppm) solutions increased significantly when temperature was raised from 25 to 40 °C. This resulted in 1 log reduction for NaCl solution to 2 log unit reduction for vinegar (Figure 3). However, the reductions did not change significantly with temperature when ordinary water and salt (7 ppm) solutions were used.

Increases in vinegar concentration improved its performance on FC levels by up to 4.5 log units. Maximum reductions occurred at a vinegar concentration of 21 400 ppm and beyond corresponding with a pH below 2.8 (Figure 4). Further test showed that at this concentration (21 400 ppm), a contact time of about 20 s is enough to achieve the observed reductions in FC levels.

At the lower vinegar concentration of 12 500 ppm, increasing the contact time from 2 to 5 or 10 min significantly (P < 0.05) increased efficacy (Table 3). Significant FC reductions were also observed for cabbage (1.6 log units) and spring onions (2.8 log units; Table 4).

Table 1 Vegetable washing methods practiced in Accra, Kumasi and Tamale

<table>
<thead>
<tr>
<th>Vegetable washing method</th>
<th>Percentage respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap water in a bowl</td>
<td>Accra (n = 235)</td>
</tr>
<tr>
<td></td>
<td>Kumasi (n = 117)</td>
</tr>
<tr>
<td></td>
<td>Tamale (n = 100)</td>
</tr>
<tr>
<td>(no sanitizer)</td>
<td>28</td>
</tr>
<tr>
<td>Running tap</td>
<td>0</td>
</tr>
<tr>
<td>Salt solution</td>
<td>40</td>
</tr>
<tr>
<td>Vinegar solution</td>
<td>30</td>
</tr>
<tr>
<td>Potassium permanganate</td>
<td>2</td>
</tr>
<tr>
<td>solution</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2 Efficacy of common methods at different exposure times (n = 10 for each treatment)

<table>
<thead>
<tr>
<th>Contact time</th>
<th>Treatment†</th>
<th>FC population (log MPN)</th>
<th>Log reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipping (3–4 s)</td>
<td>Unwashed</td>
<td>5.5 ± 1.1</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Cold water</td>
<td>4.5 ± 1.4</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>NaCl7</td>
<td>5.0 ± 1.2</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>NaCl23</td>
<td>4.7 ± 0.8</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>NaCl35</td>
<td>4.4 ± 0.9</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Running tap</td>
<td>5.2 ± 1.1</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Vin618</td>
<td>5.3 ± 1.2</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>NaCl7 + Vin618</td>
<td>5.2 ± 1.4</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>KM100</td>
<td>4.8 ± 1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>2-min contact</td>
<td>Unwashed</td>
<td>6.1 ± 1.0</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Cold water</td>
<td>4.7 ± 1.0</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>NaCl7</td>
<td>4.7 ± 0.8</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>NaCl23</td>
<td>4.6 ± 1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>NaCl35</td>
<td>4.0 ± 1.2</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Running tap</td>
<td>3.9 ± 0.8</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Vin618</td>
<td>5.1 ± 1.5</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>NaCl7 + Vin618</td>
<td>4.7 ± 1.0</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>KM100</td>
<td>4.9 ± 1.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Vin: vinegar; KM: potassium permanganate. †Subscripts represent concentration in ppm.

pH changes of vinegar solution used repeatedly in washing lettuce

The pH of the washing solution increased as lettuce was successively washed in one washing solution without changing the solution after each use (Figure 5). The efficacy of the sanitiser decreased after washing a total 450 g lettuce (in nine cycles at 50 g per cycle) in one solution.
Using eau de javel, potassium permanganate, laundry detergent and chlorine tablets

Faecal coliform reductions of about 2.6 and 2.4 log units were obtained when lettuce leaves were kept for 5 and 10 min, respectively, in a detergent (OMO™ laundry powder) solution, for 2 min and then rinsed with clean water. These reductions were both significant ($P < 0.01$). The difference in FC reduction levels between the two holding times were, however, not significant.

Significant ($P < 0.01$) log reductions were also observed between unwashed lettuce and treatments with potassium permanganate, chlorine tablets or bleach (Table 5). Reductions as a result of increased contact time ranged between 2–3 log units. However, variations between bleach brands appear to be more important than the time.

Discussion

Nearly all households and restaurants interviewed in the pilot surveys in 11 cities of the subregion showed that there is a high awareness of the need to wash vegetables to be eaten raw. Although this result will need further verification from a more stratified survey, it is highlighting one important avenue for food safety campaigns where a comprehensive wastewater treatment is unlikely. Despite...
the general awareness, disease transmission pathways are generally unknown and many factors were related to health risks besides the irrigation water (dust, soil, manure, pesticides, insects, etc.).

The surveys showed that various solutions at different concentrations and for different contact times are used but with very limited information on washing procedures. In Ghana, salt solutions, water and vinegar are the dominant means used for washing vegetables, whereas in the cities of all its francophone countries surveyed, chlorine bleach (commonly known as ‘Eau de Javel’) and potassium permanganate are well-established disinfectants. The permanganate sold at the market is a usually pulverised product, whereas the permanganate sold in pharmacies is formulated in the form of tablets, the dosage of which can be one tablet for 1 or 5 l of water. Except for permanganate tablets and Foodsaf™ chlorine tablets (locally promoted in Ghana), there are no guidelines available on how to use any of the other disinfectants. Respondents were unaware of any particular recommendation and therefore used their own judgement on dosages and contact times.

To assess the efficacy of the observed ‘indigenous’ washing methods, they were repeated in the laboratory. In further steps, factors (concentration, temperature and contact time) possibly influencing their efficacy were modified to see how with maybe minor changes with respect to financial, time and labour constraints of the users, the methods could be optimised. Table 6 is summarising the results of the washing tests so far conducted.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unwashed</td>
<td>10</td>
<td>3.65</td>
<td>0.24</td>
</tr>
<tr>
<td>5 min</td>
<td>10</td>
<td>1.87</td>
<td>1.09</td>
</tr>
<tr>
<td>10 min</td>
<td>10</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 5 Quantity of lettuce washed in 1 l vinegar solution (21 4000 ppm) and effect on pH and faecal coliform levels (cycle 0 shows the start concentration).

Table 5 Faecal coliform and log reduction levels in lettuce after washing in different sanitisers at different contact times

<table>
<thead>
<tr>
<th>Treatment†</th>
<th>n</th>
<th>Mean faecal coliforms‡ (log)</th>
<th>Log reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw (unwashed)</td>
<td>12</td>
<td>6.39 ± (0.20)</td>
<td>–</td>
</tr>
<tr>
<td>KM₅</td>
<td>12</td>
<td>4.36 ± (0.25)</td>
<td>2.03</td>
</tr>
<tr>
<td>KM₁₀</td>
<td>12</td>
<td>3.86 ± (0.16)</td>
<td>2.53</td>
</tr>
<tr>
<td>Cl₅</td>
<td>12</td>
<td>4.07 ± (0.34)</td>
<td>2.32</td>
</tr>
<tr>
<td>Cl₁₀</td>
<td>12</td>
<td>3.69 ± (0.57)</td>
<td>2.70</td>
</tr>
<tr>
<td>EdJ₅</td>
<td>12</td>
<td>3.25–4.17 ± (0.29)</td>
<td>2.12–3.14</td>
</tr>
<tr>
<td>EdJ₁₀</td>
<td>12</td>
<td>3.17–3.96 ± (0.15)</td>
<td>2.43–3.13</td>
</tr>
</tbody>
</table>

KM: Potassium permanganate (200 ppm); Cl: Chlorine tablets (100 ppm); EdJ: ‘Eau de Javel’ (bleach), three different brands with unspecified compositions.
†Subscripts represent contact time in minutes.
‡Figures in parentheses represent standard deviation.

Washing lettuce, irrespective of the methods used for a least 2 min contact time reduces bacterial contamination. Indeed, already the removal of outer lettuce leaves reduces the FC contamination level by 0.5–0.9 log units (Table 6). However, in most cases considerably high bacteria load still remains on the vegetables. As food decontamination before consumption is the last barrier of a multiple barrier

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Log FC</th>
<th>Log reduction</th>
<th>P-value</th>
<th>Log FC</th>
<th>Log reduction</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unwashed</td>
<td>5.35 ± (0.03)†</td>
<td>–</td>
<td>–</td>
<td>5.40 ± (0.26)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>5 min</td>
<td>4.03 ± (0.75)</td>
<td>1.32</td>
<td>0.114</td>
<td>3.76 ± (0.47)</td>
<td>1.64</td>
<td>0.001</td>
</tr>
<tr>
<td>10 min</td>
<td>2.52 ± (1.68)</td>
<td>2.83</td>
<td>0.004</td>
<td>3.86 ± (0.58)</td>
<td>1.54</td>
<td>0.001</td>
</tr>
</tbody>
</table>

†Figures in parenthesis represent standard deviation.
<table>
<thead>
<tr>
<th>Method</th>
<th>Use</th>
<th>Contact time</th>
<th>Mean log10 FC levels before and after treatment</th>
<th>Log reduction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Mean FC levels before and after treatment</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>95% CI of mean Before</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Cold water</td>
<td>I</td>
<td>3–4 s t</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>2 min</td>
<td>6.1</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Running tap</td>
<td>I</td>
<td>3–4 s s</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>2 min</td>
<td>6.1</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>NaCl t</td>
<td>I</td>
<td>3–4 s s</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
</tr>
<tr>
<td>NaCl3</td>
<td>I</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
<td>4.7</td>
</tr>
<tr>
<td>NaCl6</td>
<td>I</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
<td>4.4</td>
</tr>
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<td>NaCl12</td>
<td>I</td>
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<td>4.9</td>
<td>6.1</td>
<td>4.7</td>
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<td>NaCl15</td>
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<td>2 min</td>
<td>6.1</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>NaCl7</td>
<td>I</td>
<td>2 min</td>
<td>6.1</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>NaCl + Vin6818</td>
<td>I</td>
<td>3–4 s s</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>2 min</td>
<td>6.1</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Vinegar6818</td>
<td>I</td>
<td>3–4 s s</td>
<td>5.5</td>
<td>4.9</td>
<td>6.1</td>
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<tr>
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<td>C</td>
<td>2 min</td>
<td>6.1</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Vinegar21400</td>
<td>C</td>
<td>5 min</td>
<td>3.7</td>
<td>3.4</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>10 min</td>
<td>3.7</td>
<td>3.4</td>
<td>3.8</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>5 min</td>
<td>4.7</td>
<td>3.8</td>
<td>5.6</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>10 min</td>
<td>4.7</td>
<td>3.8</td>
<td>5.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Removal of outer leaves</td>
<td>C</td>
<td>5 min</td>
<td>4.3</td>
<td>3.8</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>10 min</td>
<td>4.3</td>
<td>3.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Laundry Omo™ (Detergent)</td>
<td>C</td>
<td>5 min</td>
<td>4.3</td>
<td>3.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Eau de javel™ (Bleach:16.5 μS/cm)</td>
<td>I</td>
<td>5 min</td>
<td>6.4</td>
<td>6.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Thick Bleach™ (248 μS/cm)</td>
<td>C</td>
<td>10 min</td>
<td>6.4</td>
<td>6.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Power Zone™ (Bleach:223 μS/cm)</td>
<td>C</td>
<td>5 min</td>
<td>6.3</td>
<td>5.7</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>10 min</td>
<td>6.3</td>
<td>5.7</td>
<td>6.9</td>
</tr>
</tbody>
</table>
approach, it requires special attention. According to Parish et al. (2003), the efficacy of the method used to reduce microbial populations is usually dependent on the type of treatment, type and physiology of the target microorganisms, characteristics of produce surfaces, exposure time and concentration of cleaner/sanitizer, pH and temperature.

Generally, the efficacy of all sanitizers (at relatively low concentrations) tested in this study increased with increasing temperature. For example, the efficacy of salt and vinegar solutions increased significantly between about 1 and 2 log reductions from 25 to 40 °C. However, the higher temperature can have a deteriorating effect on the appearance of lettuce leaves. In addition, higher salt concentrations of 23 and 35 mg/l had a considerable deteriorating effect on the lettuce leaves and therefore may not be desirable. Indeed, Parish et al. (2003) reported that there are no known mitigation strategies that will completely remove pathogens after contamination has occurred while completely maintaining produce freshness.

Only a few of the methods usually applied in the selected West African cities achieved at least 2 log reductions while with some sanitizer, achievement of 3 logs or more was possible. Other studies have reported that approximately 1 and 2 log reductions (depending on nature of surface of leaves) can be achieved when washed vigorously in tap water (Beuchat 1998; Lang et al. 2004). In addition, washing and rinsing salad crops, vegetables and fruits with water reduces pathogens by 1 log unit, whereas washing with weak sanitizer solution and rinsing with clean water reduces pathogens by 2 log units (Olayemi 1997; WHO 2006).

At a vinegar concentration of 21 400 ppm (approximately one part vinegar in two parts water), for example, the efficacy of the sanitizer completely removed FC levels (>4 log units) in less than 1 min. In addition, lower concentrations (approximately one part vinegar in five parts water) combined with an increase in contact time (up to 10 min) could be equally effective. However, these are more expensive compared with the costs of potassium permanganate, chlorine tablets and ‘Eau de Javel’. For the same 5-l bowl (1:5 dilution), vinegar would cost in the above example more than 1 US$, whereas the other sanitizers would cost between 0.03 and 0.06 US$. These alternatives are, however, hardly available in Ghana while potassium permanganate and ‘Eau de Javel’ are among the most common disinfectants used in francophone West Africa.

The WHO has set a health protection level of 10⁻⁶ DALY per person per year. This could be achieved through an FC reduction of about 6–7 log units, which is

<table>
<thead>
<tr>
<th>Method</th>
<th>Use</th>
<th>Contact time</th>
<th>Mean log₁₀ FC levels before and after treatment</th>
<th>Log reduction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM₁₀₀</td>
<td>C</td>
<td>2 min</td>
<td>6.4 6.3 6.5 4.4 4.2 4.3 2.3</td>
<td>2.0</td>
<td>1) Effective but not commonly used in most West African countries. 2) Effect of higher concentrations on efficacy not tested in this study.</td>
</tr>
<tr>
<td>KM₂₀₀</td>
<td>C</td>
<td>5 min</td>
<td>6.4 6.3 6.5 4.4 4.2 4.3 2.3</td>
<td>2.0</td>
<td>1) Effective but not commonly used in most West African countries. 2) Effect of higher concentrations on efficacy not tested in this study.</td>
</tr>
<tr>
<td>CL tabs₁₀₀</td>
<td>C</td>
<td>10 min</td>
<td>6.4 6.3 6.5 4.4 4.2 4.3 2.3</td>
<td>2.0</td>
<td>1) Effective but not commonly used in most West African countries. 2) Effect of higher concentrations on efficacy not tested in this study.</td>
</tr>
</tbody>
</table>

Contact time of dipping vegetables in the washing solution. Subscripts represent sanitizer concentration in ppm.

Table 6 (continued)
easy to achieve through produce cooking. This, however, does not apply to salads. To contribute to the appropriate log reduction washing salad leaves is important, although it will require complementary pathogen barriers, such as safer irrigation practices on farm and improved hygienic handling in markets.

Conclusion

Because of widespread surface water pollution around its cities, contaminated vegetables are a common feature in most West African markets. The study revealed that there is a high general awareness potential in the subregion on the need for vegetable washing on which food safety campaigns could rely. Salad washing methods, however, vary widely and are often applied ineffectively without any information or instruction. Nevertheless, food vendors are usually confident that their treatment is sufficient (Rheinländ 2006), which could not be confirmed. An important recommendation is to remove the observed cultural divide and to promote potassium permanganate and ‘Eau de Javel’ in Ghana. Care has to be taken as common bleach brands vary in their composition without appropriate labelling.

Although it is possible to significantly improve most indigenous methods, none of them would completely remove FC populations on vegetables. A multiple barrier approach is required where complementary risk reduction strategies are applied at various entry points before the vegetables even enter the kitchen.

Acknowledgements

This study was made possible by financial support from IDRC’s International Graduate Research Awards in Urban Agriculture (AGROPOLIS), the Challenge Program on Water and Food (CPWF) projects CP38/51 and a capacity building grant of the International Water Management Institute (IWMI). We are grateful to CREPA for coordinating the city surveys in most of the countries. Mr. Osei Tutu of KNUST, Mark Akrong (IWMI) and Kwadwo Kusi Amoah supported the study with field data collection and laboratory analysis.

Conflicts of interest

All authors declare no conflicts of interest.

References


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