Assessment of the Microbiological Quality of Vegetable from Urban Community Gardens in Korea

Jin-Won Kim¹, In-Wook Choi², Won-Seok Na¹, Enkhjargar Baljii¹, Yong-Man Yu³, Young-Nam Youn⁴, and Young-Ha Lee⁵*

¹Department of Environmental Horticulture, The University of Seoul, Seoul 130-743, Korea
²Department of Infection Biology, Chungnam National University School of Medicine, Daejeon 301-131, Korea
³Department of Applied Biology, College of Agriculture and Life Sciences, Chungnam National University, Daejeon 305-764, Korea

(Received August 3, 2013/Revised December 2, 2013/Accepted March 10, 2014)

ABSTRACT - Many community gardens in large cities worldwide grow vegetables; however, no information regarding the levels of sanitary indicator bacteria and prevalence of foodborne pathogens in vegetables grown in urban community gardens is available. To evaluate the microbiological quality of vegetables from urban community gardens in Korea, 530 samples (nine types of vegetable, including Chinese cabbage, lettuce, radish leaves, spinach, mustard leaves, crown daisy, leek, Korean cabbage, and chicory) were collected at 11 urban community gardens in Seoul, Korea from September through October 2012. The levels of total aerobic bacteria, Escherichia coli, total coliforms, Salmonella spp., Listeria monocytogenes, and E. coli O157:H7 were evaluated quantitatively and/or qualitatively. The mean numbers of total aerobic bacteria and coliforms were 6.3 log CFU/g (range 3.8-8.1 log CFU/g) and 4.3 log CFU/g (range 2.1-6.4 log CFU/g), respectively. Total coliforms were detected on 67% of whole vegetables. Chicory showed the highest number of total aerobic bacteria and coliforms, whereas the lowest number of coliforms was detected on leeks. E. coli was detected on 2.3% of whole vegetables, including lettuce, radish leaves, mustard leaves, and chicory; however, foodborne pathogenic bacteria were not detected on any of the vegetable samples using this highly sensitive and validated procedure. Based on these findings, the presence of coliforms and E. coli demonstrates that opportunity for improvement of microbiological safety exists throughout the produce production chain, although no major foodborne pathogens were present in vegetables grown in urban community gardens.

Key words: Community garden, Vegetable, Microbial safety, Foodborne pathogens

Introduction

Sources of produce contamination include soil, feces, irrigation water, inadequately composted manure, wild and domestic animals, dirty equipment, and human handling. Fresh fruits and vegetables can be a vehicle for transmission of bacterial, parasitic, and viral pathogens that can cause human illness. Several reports have referred to raw vegetables harboring potential foodborne pathogens, including Bacillus cereus, Clostridium perfringens, Salmonella spp., Escherichia coli O157:H7 and Listeria monocytogenes. According to a report of foodborne disease outbreaks in the United States during 2008, the commodities associated with the most outbreak-related illnesses were fruits and nuts (1,755 illnesses) and vine-stalk vegetables (1,622), and the pathogen-commodity pair responsible for the most outbreaks was norovirus in leafy vegetables (18 outbreaks). In Korea, the number of food-poisoning outbreaks associated with fruits and vegetables rose from 119 (4,577 patients) in 1998 to 271 (7,218 patients) in 2010. As the consumption of minimally processed vegetable produce rises, the importance of the food safety to public health concerns increases.

Community gardens are increasingly part of the urban fabric worldwide. These gardens, often built on under-utilized land, are seen as having several positive health benefits. Additionally, many urban community gardens in Seoul, Korea have been created for citizens to improve their quality of life and enjoy their leisure time. Some reports focused on the health impact of urban community gardens, however, to our knowledge no microbiological assessment of vegetables grown in urban community gardens has been conducted. Here, to obtain baseline information regarding the occurrence of indicator bacteria (total aerobic bacteria, E. coli, and total coliforms) and bacterial foodborne pathogens
(Salmonella spp., L. monocytogenes and E. coli O157:H7) in vegetables grown in urban community gardens in Seoul, a total of 530 samples (9 types of vegetable) were collected from 11 urban community gardens, and microbiological contamination levels and the presence of foodborne pathogens were analyzed using quantitative methods and qualitative techniques.

**Materials and Methods**

**Collection of vegetable samples**

Vegetable samples were obtained from 11 urban community gardens located in Seoul, Korea between September and October 2012. A total of 530 samples (nine types of vegetable: Chinese cabbage, lettuce, radish leaves, spinach, mustard leaves, crown daisy, leek, Korean cabbage, and chicory) were collected directly from fields and immediately transported to the laboratory without being washed. Microbial analyses were initiated within 6 h of sample collection.

**Enumeration of total aerobic bacteria, E. coli, and coliforms**

Samples were analyzed according to the Korea Food and Drug Administration Food Code (2008). Each vegetable sample (25 g) was weighed and mixed with 225 mL of sterilized peptone buffer. After homogenizing for 2 min at 230 rpm in a Stomacher machine (BagMixer, Interscience, Rockland, MA, USA), 1 mL of homogenized sample was serially diluted with 9 mL of sterilized peptone water. To calculate the total aerobic bacteria and coliforms, 1 mL of diluted sample was spread onto Petrifilm™ Aerobic Count Plates (3M, St Paul, MN, USA) and Petrifilm™ E. coli/coliform plates (3M) under aseptic conditions, and plates were incubated for 24 h at 37°C.

For detection of E. coli, 25-g samples were mixed with 225 mL of EC broth (Oxoid, Hampshire, England) and pre-incubated at 37°C for 24 h. A loop of the pre-enriched culture was plated onto Eosin Methylene Blue agar (EMB, Oxoid) and then incubated at 37°C for 24 h. The presence of E. coli was determined by the appearance of metallic green-colored colonies on the EMB plates.

**Detection of foodborne pathogenic bacteria**

Three subsamples (25 g each) were weighed and prepared for detection of Salmonella spp., L. monocytogenes, and E. coli O157:H7 according to the Korea Food and Drug Administration (2008) Food Code and commercial immunoassays (BioSign™ antigen detection test, PBM, Princeton, NJ, USA).

For detection of Salmonella spp., samples (25 g each) were incubated in 225 mL of buffered peptone water, followed by incubation at 37°C for 24 h. An aliquot (100 µL) was then transferred to 10 mL of Rappaport-Vassiliadis R10 broth (Difco Laboratories, Detroit, MI, USA) and incubated at 37°C for 24 h. After incubation, samples were streaked on xylose lysine desoxycholate (Oxoid) and incubated at 35°C for 24 h. Presumptive Salmonella isolates were confirmed using a BioSign™ Salmonella antigen detection kit (PBM) and VITEK-2 system (bioMérieux, Marcy l’Etoile, France).

For detection of L. monocytogenes, vegetable samples (25 g) were incubated in Listeria enrichment broth at 30°C for 24 h, and 100 µL of cultured supernatant were transferred to Fraser Listeria broth (Difco Laboratories), and then incubated at 30°C for 24 h. Listeria colonies are brown-green with a black halo on the media. When typical colonies were present, they were confirmed using a BioSign™ Listeria antigen detection kit (PBM), and using the VITEK-2 system.

For detection of E. coli O157:H7, vegetable samples (25 g) were incubated in 225 mL of mEC broth (Oxoid) at 37°C for 24 h, and then transferred to sorbitol-MacConkey agar (Oxoid), supplemented with potassium tellurite and cefixime, and incubated at 37°C for 24 h. When presumptive colonies were present, they were assayed using the BioSign™ E. coli O157 antigen detection kit (PBM) and identified using the VITEK-2 system.

The following S. typhimurium, L. monocytogenes, and E. coli O157:H4 strains were used as positive controls: ATCC 13314, ATCC 15313, and ATCC 43894 (ATCC, Manassas, VA, USA), respectively.

**Statistical analysis**

The data are presented as the means ± standard deviation (S.D.). Statistical significance was determined by ANOVA (StatView; Abacus Concepts Inc., Berkeley, CA, USA). Differences were deemed to be significant at P-values less than 0.05.

**Results and Discussion**

Community gardens are perceived by gardeners to exert psychological benefits through agricultural experience, produce fresh vegetables, and promote social health and community cohesion. Baseline data regarding the microbiological quality of vegetables grown in urban community gardens located in major cities, including Seoul, Korea, are difficult to ascertain. Therefore, we evaluated the general microbiological qualities of such vegetables.

Aerobic colony count is an indicator of the overall microbial quality and shelf-life of a food product. As shown in Table 1, the mean number of total aerobic bacteria was 6.3 log CFU/g, ranging from 3.8-8.1 log CFU/g. Chicory showed the highest mean number of total aerobic bacteria (6.9 log
Assessment of the Microbiological Quality of Vegetable from Urban Community Gardens in Korea

3 CFU/g, while the lowest number was detected in mustard leaves (5.3 log CFU/g). Significant differences were noted between the numbers of total aerobic bacteria of chicory and mustard leaves \( (P < 0.01) \). Compared with previous reports, these data suggest similar levels of total aerobic bacteria on leafy green vegetables collected from both farms and retail stores \(^3-5,13\). It was reported that total aerobic bacteria levels ranged from 5.2-6.9 log CFU/g in several types of leafy greens and herbs, including green Swiss chard, turnip greens, collards, cabbage, kale, cilantro, and parsley at packing sheds \(^13\). In Korea, mean total aerobic bacteria counts of sesame leaf, dropwort, Chinese cabbage, Korean leek, lettuce, crown daisy, *Pimpinella brachycarpa*, and chicory from whole markets ranged from 2.5-9.4 log CFU/g \(^4\) or \(2.2 \times 10^6\) to \(6.0 \times 10^7\) CFU/g \(^5\).

Total coliforms and *E. coli* represent additional sanitary indicators and/or spoilage level indices. In the present study, coliforms were detected on 67% of whole vegetables, and the mean coliform count was 4.3 log CFU/g, ranging from 2.1-6.4 log CFU/g. Chicory showed the highest mean number of total coliforms (5.1 log CFU/g), and leek showed the lowest (3.4 log CFU/g) (Table 2); this difference was statistically significant \((P < 0.01)\). The present results of total coliform counts were comparable to those reported elsewhere; i.e., 3.0-5.0 log CFU/g for fresh produce and minimally processed vegetables \(^4-6,13-15\). In Korea, mean coliform counts were 5.8 log CFU/g, and ranged from 1.0-7.8 log CFU/g from lettuce, sesame leaves, spinach, chicory, dropwort, crown daisy and fruit \(^4,16\). These studies indicated a higher contamination level than found in similar vegetables reported here. The variation observed may be attributed to methodological differences in the collection conditions of each study. In this investigation, samples were collected immediately from community gardens, thus minimizing additional sources of contamination. In contrast, the previous studies were performed with vegetables collected from markets \(^4,16\), thereby increasing the opportunities for contamination.

We also evaluated *E. coli* contamination, which is currently the best-available indicator of fecal contamination \(^7\). *E. coli* was isolated from 2.3% of the samples, including chicory, radish leaves, mustard leaves, and lettuce. The mean number of *E. coli* detected was 2.6 log CFU/g, ranging from 2.1-

---

### Table 1. Total aerobic bacteria levels in nine types of vegetable collected from 11 urban community gardens in Seoul, Korea

<table>
<thead>
<tr>
<th>Sample names</th>
<th>Numbers (%)</th>
<th>Samples in the indicated interval (%)</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 5</td>
<td>5-6</td>
<td>6-7</td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>80 (100.0)</td>
<td>14 (17.5)</td>
<td>54 (67.5)</td>
<td>9 (11.2)</td>
</tr>
<tr>
<td>Lettuce</td>
<td>100 (100.0)</td>
<td>17 (17.0)</td>
<td>62 (62.0)</td>
<td>13 (13.0)</td>
</tr>
<tr>
<td>Radish leaves</td>
<td>100 (100.0)</td>
<td>13 (13.0)</td>
<td>68 (68.0)</td>
<td>12 (12.0)</td>
</tr>
<tr>
<td>Spinach</td>
<td>50 (100.0)</td>
<td>8 (16.0)</td>
<td>27 (54.0)</td>
<td>12 (24.0)</td>
</tr>
<tr>
<td>Mustard leaves</td>
<td>40 (100.0)</td>
<td>13 (32.5)</td>
<td>19 (47.5)</td>
<td>7 (17.5)</td>
</tr>
<tr>
<td>Crown daisy</td>
<td>50 (100.0)</td>
<td>8 (16.0)</td>
<td>32 (64.0)</td>
<td>9 (18.0)</td>
</tr>
<tr>
<td>Leek</td>
<td>40 (100.0)</td>
<td>6 (15.0)</td>
<td>21 (52.5)</td>
<td>8 (20.0)</td>
</tr>
<tr>
<td>Korean cabbage</td>
<td>40 (100.0)</td>
<td>2 (5.0)</td>
<td>8 (20.0)</td>
<td>23 (57.5)</td>
</tr>
<tr>
<td>Chicory</td>
<td>30 (100.0)</td>
<td>0</td>
<td>6 (20.0)</td>
<td>15 (50.0)</td>
</tr>
<tr>
<td>Total</td>
<td>530 (100.0)</td>
<td>81 (15.3)</td>
<td>294 (56.0)</td>
<td>108 (20.4)</td>
</tr>
</tbody>
</table>

\( ^{a} \) Counts are expressed as log CFU/g of vegetable

### Table 2. Total coliform levels in nine types of vegetable collected from 11 urban community gardens in Seoul, Korea

<table>
<thead>
<tr>
<th>Sample names</th>
<th>Numbers (%)</th>
<th>Samples in the indicated interval (%)</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ND(^{b})</td>
<td>2-4</td>
<td>4-5</td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>80 (100.0)</td>
<td>23 (28.8)</td>
<td>16 (20.0)</td>
<td>24 (30.0)</td>
</tr>
<tr>
<td>Lettuce</td>
<td>100 (100.0)</td>
<td>37 (37.0)</td>
<td>17 (17.0)</td>
<td>36 (36.0)</td>
</tr>
<tr>
<td>Radish leaves</td>
<td>100 (100.0)</td>
<td>24 (24.0)</td>
<td>18 (18.0)</td>
<td>35 (35.0)</td>
</tr>
<tr>
<td>Spinach</td>
<td>50 (100.0)</td>
<td>18 (36.0)</td>
<td>17 (34.0)</td>
<td>12 (24.0)</td>
</tr>
<tr>
<td>Mustard leaves</td>
<td>40 (100.0)</td>
<td>24 (60.0)</td>
<td>7 (17.5)</td>
<td>6 (15.0)</td>
</tr>
<tr>
<td>Crown daisy</td>
<td>50 (100.0)</td>
<td>8 (16.0)</td>
<td>22 (44.0)</td>
<td>19 (38.0)</td>
</tr>
<tr>
<td>Leek</td>
<td>40 (100.0)</td>
<td>22 (55.0)</td>
<td>9 (22.5)</td>
<td>6 (15.0)</td>
</tr>
<tr>
<td>Korean cabbage</td>
<td>40 (100.0)</td>
<td>8 (20.0)</td>
<td>8 (20.0)</td>
<td>16 (40.0)</td>
</tr>
<tr>
<td>Chicory</td>
<td>30 (100.0)</td>
<td>11 (36.7)</td>
<td>4 (13.5)</td>
<td>6 (20.0)</td>
</tr>
<tr>
<td>Total</td>
<td>530 (100.0)</td>
<td>175 (33.0)</td>
<td>118 (22.3)</td>
<td>160 (30.2)</td>
</tr>
</tbody>
</table>

\( ^{a} \) Counts are expressed as log\(_{10}\) CFU/g of vegetable

\( ^{b} \) ND : Not detected, > \(10^2\)
4.2 log CFU/g; the sample positivity percentages ranged from 2.0% for lettuce to 13.4% for chicory (Table 3). These findings are consistent with the results of Sant’Ana et al\(^6\), who reported a 2.7% *E. coli* contamination rate in minimally processed vegetables at retail stores. However, a 2009 Alberta, Canada study found that 8.2% of fresh produce, including lettuce, spinach, carrots, and green onions were positive for *E. coli*\(^7\), and *E. coli* was detected in 12.5 and 22.2% of conventional and organic lettuce, respectively\(^8\).

In Korea, *E. coli* was isolated in 2.8% (ranging from 3.1-19.1%) of vegetables and fruits\(^6\), which was higher than our results. In the present study, the levels of total aerobic bacteria, coliforms, and *E. coli* were relatively low and similar to those in other reports. The large variation in counts between studies could be due to differences in microbiological methodologies, the types of produce tested, source of samples and/or geographical locations. Importantly, these sanitary indices usually increase from the field through cutting, shredding, slicing, and grating, are all potential sources of contamination that could further increase the microbial load\(^9\). Outbreaks of foodborne illnesses related to consumption of fresh produce have been documented by many authors\(^2,6,14,18\). In the present study, we also evaluated the prevalence of common foodborne pathogens that have been associated with vegetables using double-check systems, such as media culture systems and commercial immunoassay kits. All vegetables collected at 11 urban community gardens in Seoul had undetectable foodborne pathogens levels, possibly because the urban gardens were minimally contaminated by feces from wild animals and cattle due to the use of composted commercial organic fertilizer. Additionally, vegetables were harvested directly from farms, so no additional contamination occurred during vegetable processing. In recent reports, no *Salmonella*, *L. monocytogenes*, or *E. coli* O157:H7 were detected in lettuce, spinach, tomatoes, carrots, green onions, strawberries, sesame leaf, dropwort, Chinese cabbage, Korean leek, crown daisy, and chicory from markets or farms in Japan\(^4\), Canada\(^13\), and Korea\(^5,10\).

The microbiological quality of fresh produce is a concern not only from a food safety perspective, but also because of losses due to the shorter product shelf-life. A community gardening program can reduce food insecurity, improve dietary intake, and strengthen family relationships\(^19\). This is the first study to provide baseline information regarding the occurrence and levels of microbiological indicators and common foodborne pathogens in selected produce items from urban community gardens in a major city. No foodborne pathogens were detected, although coliforms and *E. coli* were detected in 67.0 and 2.3% of the samples, respectively. The microbial qualities of the examined vegetables were similar to those reported elsewhere. However, the presence of coliforms and *E. coli* demonstrates that opportunity for improvements in microbiological safety exist throughout the produce production chain.

**요 약**

도시 톱밥에서 재배되는 농산물의 대부분은 식탁에 바로 오르는 재소류로 안전성 확보가 요구되나 아직 이에 대한 자료가 없다. 본 연구는 도시 톱밥에서 재배되는 재소류의 생물학적 안전성을 평가하기 위한 기초 자료를 확보하기 위하여, 2012년 9월부터 10월 사이에 서울시내 11곳의 도시텃밭에서 채취한 9종 재소류(배추, 상추, 무,...)
시금치, 견과류, 과일, 과, 양배추와 치커리) 530 표본을 대상으로 총호기성 세균 (L. monocytogenes, Salmonella spp., E. coli O157:H7)을 양성과 음성으로 판정하였다. 대장균은 대장균 군에서 찾아졌고, 대장균군은 총 153개에서 검출되었다. 

 Acknowledgements

The present research has been performed according to the planning project of Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry, and Fisheries (ARPC, Project No. 608010-5) and the support of Rural Development Administration, Republic of Korea (Project No. PJ9071142012). 

References


