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Development, Implementation, and Analysis of an On-Farm Food Safety Program for the Production of Greenhouse Vegetables

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ABSTRACT

Fresh fruits and vegetables are increasingly recognized as vectors for foodborne illness. Consequently, an on-farm food safety program was developed, implemented, and analyzed for the Ontario Greenhouse Vegetable Growers in Ontario, Canada, during a 2½-year period. This hazard analysis critical control point–based system was designed to reduce the potential of microbial contamination along the entire production and distribution process. Through the use of microbiological testing, on-site visits, and producer surveys, it was determined that the program has increased grower knowledge, understanding, and awareness of microbial risks associated with fresh produce and caused improvements in practices used within the greenhouse and packing sheds.

In recent years, there has been a continued rise in reported outbreaks of foodborne illness associated with the consumption of fresh fruits and vegetables worldwide *(8).* Laboratory studies have found that produce can support the growth of *Salmonella* and other enteric bacterial pathogens such as *Shigella* and *Escherichia coli* O157:H7 *(7).* Consequently, methods of growing, handling, processing, packaging, and distributing fresh produce are receiving increasing attention in terms of identifying and minimizing microbiological hazards. The produce industry has now focused on developing and implementing programs aimed at preventing foodborne disease and illness. These hazard analysis critical control point (HACCP)–based systems help to reduce the potential of microbial contamination along the entire production and distribution process to avoid recall campaigns, adverse publicity, loss of sales, or even food scares, all of which ultimately end in reduced sales and/or profits *(7, 8).* Each food producer and ultimately all participants in a farm-to-the-fork food safety system have a responsibility to ensure the safety and quality of their products. This preventive, proactive role played by the produce industry is a safeguard for the health and safety of the consumer.

The objectives of this study were to design, implement, and conduct an analysis on a set of practical and comprehensive safety guidelines used by the Ontario Greenhouse Vegetable Growers (OGVG) in their daily operations. The On-Farm Food Safety Program was based on a systematic approach to identify potential sources of microbiological hazards associated with greenhouse fresh produce, and the objectives were accomplished through the use of microbiological testing, food risk perception surveys, and on-site visits.

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MATERIALS AND METHODS

Food safety guidelines and manual. A set of written general guidelines for the safe production and distribution of greenhouse vegetables was researched, developed, and compiled in a comprehensive manual. The guidelines focused on prevention and control of microbiological hazards at each point in the greenhouse processing chain and were comparable to those published by the U.S. Food and Drug Administration (FDA) *(9).* The manual was presented to producers at the annual meeting of the OGVG in 1998, and comments and suggestions were used to write a final draft.

Each member of the OGVG received a copy of the *On-Farm Food Safety Program Manual* through the mail. In summer 1999, food safety coordinators began on-site visits to assist the producers with the implementation of the guidelines outlined in the manual. A food safety coordinator reviewed the manual with each member, any questions or problems were addressed, and members began applying the guidelines to their individual operations. In fall 2000, a second on-site visit was conducted to assess and analyze how the OGVG members were progressing with the program and to determine next steps.

Food risk perception surveys. A food risk perception survey (Fig. 1) composed of 12 questions was designed in spring 1998. The surveys contained some questions that were taken from the annual survey on consumer shopping by the Canadian Council of Grocery Distributors and the Food Marketing Institute *(6).* The survey was revised in 1999 and 2000 to include 10 questions that reflected the changes in the program over time. All surveys included prompted (participants must choose answers from options given) and unprompted (participants are not given answer options) questions regarding perceived threats to food safety, confidence and responsibility for food safety, and other questions on food

Ontario Greenhouse Vegetable Growers' Association Survey (2000)

1. How confident are you that the food in your supermarket is safe?
(Please circle your answer on the following five-point scale)

1	2	3	4	5
Completely confident	Mostly confident	Somewhat doubtful	Very doubtful	Not Sure

2. What, if anything, do you feel are the greatest threats to the safety of the food you eat?
3. How much do you rely on the following groups to ensure that the food products you buy are safe?
(Please circle your answer)

	Rely heavily				Don't rely on
Federal government	1	2	3	4	5
Consumer organizations	1	2	3	4	5
Provincial governments	1	2	3	4	5
Retailers	1	2	3	4	5
Manufacturers/Food processors	1	2	3	4	5
Farmers	1	2	3	4	5
Self	1	2	3	4	5
Other (please specify)	1	2	3	4	5

4. How important are the following information sources in increasing your knowledge of food safety issues? (Please circle your answer)

	Extremely Important				Extremely Unimportant
Consumer organization	1	2	3	4	5
Farm organization	1	2	3	4	5
Environmental organizations	1	2	3	4	5
Government agency (CFIS, OMAFRA)	1	2	3	4	5
University scientists	1	2	3	4	5
Family and friends	1	2	3	4	5
Media (newspapers, T.V. radio)	1	2	3	4	5
Specialized magazines	1	2	3	4	5

5. Do you feel food safety is an important issue for your industry?
Yes___ No___ Not sure___
6. Please give reasons for your answer.
7. Below is a list of food items that may or may not constitute a health hazard. For each one, please rank the hazard.

	Serious Hazard	Something of a Hazard	Not a Hazard at All	Not sure
a. Artificial coloring	1	2	3	4
b. Residues (pesticides/herbicides)	1	2	3	4
c. Irradiated foods	1	2	3	4
d. Bacteria/microorganisms	1	2	3	4
e. Antibiotics/hormones	1	2	3	4
f. Nitrites in foods	1	2	3	4
g. Additives and preservatives	1	2	3	4
h. Foods produced by biotechnology	1	2	3	4

8. Do you think the On-Farm Food Safety Program improves the safety of your products?
Yes___ No___Not sure___
9. If yes, how? If no, why not?
10. What motivates you to implement the On-Farm Food Safety Program?
Retailers_______Consumers_______Government_______Own Peace of Mind_______Other____

FIGURE 1. *Food safety perception survey mailed to OGVG growers in 2000.*

safety improvements. A total of 100, 220, and 238 surveys were mailed to members of the OGVG in 1998, 1999, and 2000, respectively. The surveys were conducted with the promise of anonymity to enhance the response rate. Those questions left unanswered were totaled separately, and for questions where multiple answers were given, only the first response was included in calculations. For all questions, percentages were obtained by dividing the total number of responses for a particular choice (yes/no, 1, 2, 3, 4, etc.) by the number of valid responses for the question. For those questions with open answers, responses are detailed below.

Collection of produce samples. Different tomato varieties and cucumber samples were collected from individual packing sheds affiliated with the OGVG in 1998, 1999, and 2000. The samples collected in 1998 were from unannounced visits, whereas the other samples were taken during scheduled appointments. Samples were randomly collected from crates before processing or at the end of the packing line, and samples from each shed were considered one lot (10 tomatoes or 10 cucumbers). Sampling plans (Table 1) for fresh vegetables recommended by the International Commission on Microbiological Safety of Foods *(5)* were followed. A three-class plan was followed to detect *E. coli*, whereas a two-class plan was adopted for *Salmonella* spp. The samples were labeled from 1 to 10 along with a code number representative of the shed.

Collection of water samples. Dump tank water samples were collected from individual packing sheds affiliated with the OGVG in 1998, 1999, and 2000. The samples collected in 1998 were from unannounced visits, whereas the others were taken during scheduled appointments. Water samples were randomly collected and each shed's sample was considered as one lot. Sampling plans (Table 1) for water recommended by the International Commission for the Microbiological Safety of Foods *(5)* were followed in 1998. A three-class plan was followed for the determination of total aerobic bacteria and total coliforms in the water. In 1999 and 2000, two samples were taken from each shed and recommended microbiological limits were the same as above. Samples were numbered accordingly along with a code number representative

TABLE 1. *Sampling plans and recommended microbiological limits for vegetable products and water (per lot)*[a]

Product	Organism	Plan class	*n*	C	Limit per g m	Limit per g M
Fresh vegetables	*E. coli*	3	5	2	10 CFU/g	100 CFU/g
	Salmonella	2	10	0	Absent	NA
Water	Aerobic plate count	3	5	2	100 CFU/ml	10,000 CFU/ml
	Total coliforms	3	2	0	<1 CFU/100 ml	10 CFU/100 ml

[a] *n*, number of sample units; C, maximum allowable of defective sample units; m, marginally acceptable quality; M, defective quality; NA, not applicable.

of the shed. All produce and water samples were placed in coolers with ice packs and transported to the Laboratory Services Division (University of Guelph, Guelph, Ontario, Canada) for microbiological analysis.

Microbiological analysis. Tomato and cucumber samples were stored at 4°C until processed. Sterile forceps and scalpels were used to aseptically weigh 25 g of sample into a stomacher bag (Fisher Scientific, Nepean, Ontario, Canada) containing 225 ml of buffered peptone water (Oxoid Unipath Inc., Nepean, Ontario, Canada) and stomached for 2 min. The 25-g sample, taken from different sections of the product, was representative of both the surface and core of the product. Samples 1 through 5 were tested individually for *E. coli* and as one composite for *Salmonella* (i.e., 5 g from each was used to compose the 25 g), and samples 6 through 10 were used as the second composite for *Salmonella.* Tenfold dilutions in 0.1% peptone diluent (Difco Laboratories, Detroit, Mich.) were then prepared immediately from the samples.

A total of 1 ml of each dilution (up to 10^{-3}) was dispensed onto *E. coli* Petrifilm (3M Petrifilm, London, Ontario, Canada). Plates were incubated at 35 to 37°C for 24 h. Plates that had 15 to 150 of the typical coliform (red with one or more gas bubbles) colonies were selected and enumerated along with any showing *E. coli* colonies (blue with gas bubbles) *(3).*

The 1:10 food homogenate was incubated in buffered peptone water (Oxoid) for 18 to 24 h at 35 to 37°C. First, 1 ml of this preenrichment broth was inoculated with 9 ml of tetrathionate brilliant green broth (Difco) (after adding 0.2 ml of potassium iodide [Oxoid]). Second, 1 ml of the broth was inoculated with 9 ml of selenite cystine broth (Difco). The tetrathionate brilliant green broth was incubated at 43°C and the selenite cystine at 35 to 37°C for 24 h. A loopful from each selective enrichment broth was streaked onto brilliant green sulfadiazine (Difco) and bismuth sulfite (Difco). The selective plates were incubated at 35°C and observed for typical *Salmonella* colonies at 24 and 48 h of growth. Biochemical confirmation was performed on selected colonies using triple sugar iron agar (Difco) and urea agar (Difco) slants *(2).*

Water samples were stored at 4°C until processed. A sterile, 0.45-μm membrane filter (QA Life Sciences Inc., San Diego, Calif.), grid side up, was centered on a filter holding base. A total of 100 ml of sample was poured into the filter and vacuumed from the surface of the filter. The filter was aseptically placed on a petri plate (Fisher) of 4-methylumbelliferyl-β-D-galactopyranoside indoxyl-β-D-glucuronide (Difco) and incubated at 35°C for up to 24 h. First, the colonies that appeared blue under ambient light were counted; these were *E. coli.* Second, the colonies that appeared fluorescent under long-wave UV light (366 nm) were counted. The addition of these two counts was the total number of coliforms per 100 ml of sample *(10).*

RESULTS AND DISCUSSION

Microbiological analysis. Reasons for conducting microbiological tests varied among the 3 years evaluated. In 1998, test results were used to determine where critical control points should be within the greenhouse, help construct the guidelines, and establish a microbiological baseline for greenhouse produce. Microbiological testing was performed in 1999 to determine necessary operation changes and better understand exact testing procedures to meet the goals of the food safety program. In 2000, appropriate testing was conducted to build and expand a microbiology database and to verify that the procedures outlined in the *On-Farm Food Safety Program Manual* were effectively managing the risks associated with the growing and harvesting of greenhouse product.

In a typical Ontario operation, greenhouses were emptied, cleaned, sanitized, and fumigated before each new crop was planted. Vegetables were grown on plastic mulch (very few still grow in the soil), stacked, and strung up to avoid contact with the ground. The climate inside the greenhouse was carefully controlled. The plants were fertilized by drip irrigation, and workers handpicked the product into sterile crates for transportation to a packing shed (some larger facilities both grow and pack on the same premises).

Tomatoes were placed into a dump tank (large stainless steel tank filled with water) that was normally treated with an approved method. Studies have found that tomatoes placed in water, cooler than the pulp of the tomato, will absorb water and *Salmonella* organisms into the core tissues through the stem scar. Additionally, these studies found that *Salmonella* can survive on the skin of tomatoes and multiply to high numbers on cut or sliced tomatoes held at room temperature *(4).* The importance of water quality maintenance in postharvest operations has been recognized *(7)*, and the washing of tomatoes has been found to promote the separation of cells adhering to the surface of tomatoes, resulting in bacterial removal in rinse water *(1).* Chlorination of water is a critical control point to prevent contamination of tomatoes from bird droppings, organic debris, or other contaminated tomatoes and must be maintained at sufficient chlorine-free levels *(4).* Cucumbers remained unwashed and were wrapped in plastic.

Tomatoes, cucumbers, and water from OGVG producers were tested for bacteria, and the results for 1998, 1999,

TABLE 2. *Microbial evaluation of greenhouse tomatoes, cucumbers, and water samples in 1998, 1999, and 2000*[a]

Product tested	Total no. of samples	Aerobic plate count, no. (%) positive	Total coliforms, no. (%) positive	*E. coli*	*Salmonella*
Tomatoes					
1998	2	—[b]	—	All negative	Absent
1999	28	—	4 (11)	All negative	Absent
2000	18	—	3 (17)	All negative	Absent
Cucumbers					
1998	1	—	—	All negative	Absent
1999	9	—	All negative	All negative	Absent
2000	4	—	All negative	All negative	Absent
Dump tank water					
1998	2	1 (50)	1 (50)	All negative	—
1999	6	—	3 (50)	—	—
2000	13	—	1 (8)	1 (8)	—

[a] Total no. of samples: 1998, $n = 5$; 1999, $n = 43$; and 2000, $n = 35$.
[b] Test was not performed.

and 2000 are summarized in Table 2. Cucumbers, although not washed during processing, have not been associated with microbiological hazards during the last 3 years. A few tomato samples were positive for bacteria in 1999 and 2000, whereas a small number of dump tank water samples were implicated in all 3 years for contamination. *E. coli* was found in one water sample in 2000; however, the tomatoes washed in this water were found to be negative for *E. coli.* An investigation determined the cause of the high bacteria counts to be inadequate water treatment of the dump tanks (i.e., chlorinating, etc.) and insufficient sanitation along the packing lines. In 2000, those packing sheds found to have unacceptable results were retested after they improved their treatment methods and sanitized appropriately.

The microbiological results helped to educate the grower on identifying the critical control points required to effectively reduce bacterial counts on greenhouse product. The purpose or goal of the program is to achieve consistent grower education; future testing will show negative results.

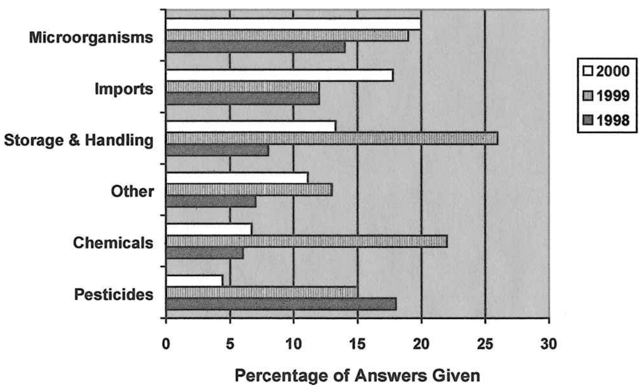


FIGURE 2. *Percentage of responses to the question, "What, if anything, do you feel are the greatest threats to the safety of the food you eat?" in 1998 (*$n = 53$*), 1999 (*$n = 68$*), and 2000 (*$n = 45$*).*

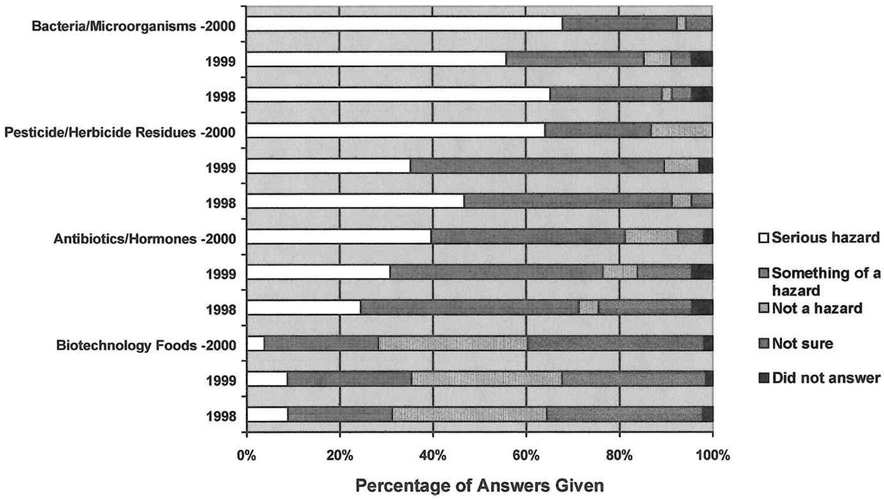
Food risk perception surveys. Only those questions that were relevant to the conclusions of the study will be discussed in this article. The purpose of the surveys was to obtain insight into how OGVG members perceived food safety issues and how these perceptions changed throughout the 3 years.

Growers were asked, "What, if anything, do you feel are the greatest threats to the safety of the food you eat?" Microorganisms ranked number 1 (Fig. 2) in this unprompted question, reflecting the primary concern of growers. The response suggests that, with the implementation of the program, OGVG members have become more aware of potential bacterial contamination. Bacteria was chosen third to storage and handling and chemicals in 1999 and second to pesticides in 1998. Storage and handling were important to growers in 1999 because this was the first year of implementation and growers were beginning to learn the areas where food safety played a role. Pesticides were ranked as least important when growers were unprompted in 2000, compared with being most important in 1998. Growers require proper education and certification for the use and control of pesticides; thus, they are more aware of the impact these can have when used improperly.

The prompted request, "Below is a list of food items that may or may not constitute a health hazard. For each one, please rank the hazard," further illustrates the increase in knowledge growers now have about microbial risks associated with their product. Figure 3 shows that OGVG members perceive bacteria and microorganisms as the number 1 hazard in all three surveys; however, a larger percentage of grower's chose it in 2000. Pesticides were ranked as second in the prompted question, most likely because of the same reasons as stated in the previous paragraph.

In 1999 and 2000, the question "Do you feel food safety is an important issue for your industry?" (data not shown) got a yes response rate of 92.6 and 97.8%, respec-

FIGURE 3. *Percentage of responses to "Below is a list of food items that may or may not constitute a health hazard. For each one, please rank the hazard" in 1998* (n = *53), 1999* (n = *68), and 2000* (n = *45).*



tively. When asked why, reasons included that "consumers demand a safe product and safety is required to ensure the growth and prosperity of the greenhouse industry."

In 1998 and 1999, OGVG members were asked, "Have you implemented any programs or steps that you feel would improve the safety of your products" (data not shown). The response was yes for 75.5% in 1998 and for 73.5% in 1999. The question was revised in 2000 to reflect the fact the growers should have been aware of the program at that time. Thus, the following question was asked: "Do you think the On-Farm Food Safety Program improves the safety of your products?" (data not shown). A yes response was received from 75.6%. Reasons why growers believed it improved safety was that "it increased awareness of potential problems and that it was a good standard for everyone to follow." Those growers (24.4%) who did not think the program improved food safety either left the answer blank or stated, "there has never been a problem with greenhouse product so how do we know?"

From the three surveys it was determined that, from the initiation of the On-Farm Food Safety Program in 1998, those OGVG members who responded to the survey have an increased awareness of food safety issues, a better comprehension of how important food safety is, and a greater knowledge of the potential microbial risks associated with fresh vegetables.

Food safety guidelines and manual. The HACCP-based systems for fresh fruits and vegetables help to identify potential contamination sources along the entire production and distribution process with each set of guidelines being specific. The OGVG *On-Farm Food Safety Program Manual* was researched, designed, and composed particularly for the OGVG operations. The guidelines were compared with those specifications outlined by the FDA since a large portion of greenhouse products is exported to the United States.

The guidelines were organized in a comprehensive manner based on grower feedback to improve ease of comprehension (http://www.plant.uoguelph.ca/safefood/on-farm/ogvga/manual.htm). A checklist format was decided on that each OGVG member could use to document the measures taken for food safety and to monitor those areas that presented a microbial risk. These included water quality, hygienic practices, pest control, and storage and distribution procedures. Each grower received the manual through the mail in summer 1999. They also attended two seminars that detailed foodborne illness outbreaks associated with contaminated produce and the impacts of unsafe, inadequate farming practices.

On-site visits began in July 1999, where individual growers had the opportunity to review the manual with the OGVG food safety coordinator. It was quickly determined that one-on-one visits were essential to such a program to allow any problems or questions to be addressed immediately. The coordinator does not act as an inspector but instead is support for the grower so together they can implement the program accurately and effectively. Ninety-five percent of the OGVG members received a first on-site visit. During these first visits, suggestions for improvement were made to each grower, and it was determined that these on-site calls would continue periodically to help the OGVG members in their food safety effort.

The second set of on-site visits began in fall 2000. Ninety-four percent of the members from Leamington, Ontario, Canada, where a large percentage of the overall OGVG production is located in large operations, received a visit from the food safety coordinator. During these visits, the manual was once again reviewed, growers received updates, and they were provided with English and Spanish hand washing signs to be posted in their establishments. An assessment of the improvements required to meet all aspects outlined by the program found that minor changes were necessary. These included stocking washrooms with paper towels and pump soap and washing crates more frequently. The importance of using the manual checklists to document the safety procedures used was also stressed to each grower.

From the on-site visits, it was determined that most OGVG members view the program positively, were actively working toward the program, and were implementing any necessary changes to fulfill its requirements successfully.

The primary activities undertaken in the OGVG On-Farm Food Safety Program are microbiological testing, on-site visits, and surveying. However, others forms of communications are used to inform and update growers, the media, consumers, industry, and government agencies about the risks associated with fresh greenhouse produce and the preventive steps being undertaken by producers. These include newsletters, annual reports, press releases, journal articles, magazine articles, television documentaries, presentations, and a Web site.

In the 2½ years since the commencement of the OGVG On-Farm Food Safety Program, the active collaboration with individual growers has proven extremely valuable to help determine what science-based protocols can be effectively implemented in an on-farm scenario. The next set of visits, to begin in spring 2001, will entail extensive microbiological testing; the number of sheds sampled will be doubled to ensure that no packer is overlooked, and a second employee will join the team. A wall checklist, requested by the OGVG members, will be printed before the next set of visits to simplify, yet still make meaningful, the documentation required for the program. Lastly, the most important aspect of ensuring that an on-farm food safety program is successful is to openly and frequently communicate with individual producers.

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