Joint FAO/WHO Expert Meeting on the Prevention and Control of Microbiological Hazards in Fresh Fruits and Vegetables

Part 4: Commodity-specific interventions
(Virtual meeting, 16 May to 3 June 2022)

SUMMARY AND CONCLUSIONS

Issued in September 2022

The virtual Joint FAO/WHO Expert Meetings on Microbial Risk Assessment (JEMRA) on the Prevention and Control of Microbiological Hazards in Fresh Fruits and Vegetables was convened to provide scientific advice on commodity-specific measures for control of microbiological hazards in fresh fruit and vegetables from the primary production to point-of-sale.

If conditions had permitted, this meeting would have been held at FAO headquarters in Rome, Italy. Because of the travel restrictions and lockdowns due to the COVID-19 pandemic in many countries, the joint FAO/WHO secretariat was unable to convene a physical meeting. Therefore, the meeting was held as a videoconference using a virtual online platform.

Dr Elizabeth Bihn served as Chairperson. Dr Pascal Delaquis served as Rapporteur. This document summarizes the conclusions of the meeting on commodity specific interventions for the control of microbiological hazards and is made available to facilitate the deliberations of the upcoming Codex Committee on Food Hygiene (CCFH). The full report will be published as part of the FAO and WHO Microbiological Risk Assessment (MRA) Series.

The meeting participants are listed in Annex 1 of this summary report.

More information on this work is available at:

http://www.fao.org/food-safety/en/

and

https://www.who.int/foodsafety/en/

1. Background and objective

In 2019, following a request from the CCFH, the Codex Alimentarius Commission (CAC) approved new work at its 42nd Session on the development of guidelines for the control of Shiga toxin-producing *Escherichia coli* (STEC) in leafy vegetables and in sprouts (FAO and WHO, 2018).

To support the work of CCFH and to update and expand the information available in MRA14 (FAO and WHO, 2008), JEMRA convened a series of expert meetings on preventing and controlling microbiological hazards in fresh fruits and vegetables.

In September 2021, the JEMRA meeting on the Prevention and Control of Microbiological Hazards in Fresh Fruits and Vegetables reviewed relevant measures for control of microbiological hazards from primary production to point-of-sale in fresh, ready-to-eat, and minimally processed fruits and vegetables, including leafy vegetables, and identified problem areas and subsequent measures to address and avoid potential microbiological contamination (FAO and WHO, 2021).

In November 2021, a subsequent meeting was held with a subset of the JEMRA Expert Committee to collect, review, and discuss relevant measures for the control of microbiological hazards in sprouts, from the production of seeds for sprouting to the production of sprouts and point-of-sale (FAO and WHO, 2022).

The purpose of this final meeting was to reconvene the Expert Committee to collect, review, and discuss relevant commodity-specific interventions in all other fresh fruits and vegetables from the primary production to point-of-sale.

2. Scope

The objective of the meetings was to evaluate commodity-specific interventions used at all stages of fresh fruit and vegetable production from primary production to postharvest activities, transportation, point-of-sale, and consumer use. Emphasis was placed on the identification and evaluation of interventions used throughout the world to reduce microbiological hazards on fresh fruits and vegetables that contribute to the risk of foodborne illnesses, taking into consideration their effectiveness, practicality, and suitability.

The Experts addressed four sub-divided commodity groups: 1) leafy vegetables and herbs; 2) berries and tropical fruits; 3) melons and tree fruits; and 4) seeded and root vegetables. These commodities were grouped based on similar physical characteristics, intervention measures, and the potential volume of published literature to be reviewed. Interventions were identified for specific commodities against various target pathogens (including bacteria, parasites, and viruses) and indicator organisms in the following categories:

- Intervention stage (primary production (open field or protected facilities), postharvest handling, minimal processing, distribution, retail and consumer handling).
- Intervention type (physical, chemical, or biological)
    - Physical interventions included: Ultrasound, UV, high pressure processing, irradiation, pulsed light, plasma, and others.

- Chemical interventions included: Natural antimicrobials, chlorine-based chemicals, chlorine alternatives (e.g. organic acids, peracetic acid), modified atmosphere packaging (MAP), gas treatments (e.g. ozone, chlorine dioxide), and others.
- Biological interventions or biocontrols included: Bacteriophage, protective cultures, and others.

The scientific literature assessed included studies published between 2008 and early 2022 that were aimed at the development of interventions meant to reduce levels of microbial contamination of fresh fruits and vegetables. The available studies describing physical, biological, chemical, and multiple hurdle technologies were identified using scoping review methodology. Relevant search terms, identified by the JEMRA Expert Committee, were used to develop a search algorithm consisting of fresh produce (68 terms), pathogen (49 terms), and intervention (143 terms) constructs. A full search in PubMed and limited searches of Web of Science and CABI abstracts databases was conducted. The identified records were deduplicated and imported into Covidence software for further screening and data extraction. After a review of 3 931 references at the title and abstract level, and 1 097 references at the full text level, a database of 488 relevant studies resulted. The database included studies on the effectiveness of physical/biological interventions in the fresh produce value chain and contained information about intervention, studied pathogens, commodity groups, and types of produce. Given the large number of studies on chemical interventions in the scientific literature, recently published comprehensive reviews were used in the assessments.

For each intervention, the Experts reviewed available published literature and data, and assessed if the intervention showed efficacy for different commodities. If an intervention showed efficacy, experts identified how much efficacy was shown and considered factors such as consistency in levels of reduction, prevention of growth if the pathogen is likely to grow on target commodity, and likelihood of being used alone or in combination with other interventions. Several criteria were considered in the assessment of the interventions, including the scale at which research was performed (e.g. laboratory, pilot plant, commercial scale), rigor of both experimental design and data analysis, and practical merit of the proposed approach or technology.

Factors considered in the assessment of practical merit included potential cost, availability of resources, environmental impact, difficulties in performing the task, training needs, regulatory hurdles, consumer acceptance, and recognition that each of the factors are likely to vary across geographies. Applicability to similar commodities or pathogens, when no data was available, was also assessed.

3. Conclusions derived from an assessment of published research on commodity-specific interventions used at all stages of fresh fruit and vegetable production

3.1 All fruits and vegetables

- The application of preventive measures such as Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP) during primary production remains the most effective means of reducing the risk of contamination with human pathogens in all fruit and vegetable commodities during cultivation. Postharvest activities require GHP, Good Manufacturing Practices (GMP), and a Hazard Analysis and Critical Control Point (HACCP) based system to prevent microbiological contamination, reduce cross-contamination, or avoid pathogen growth during different postharvest handling steps. These preventive measures include effective training, personal hygiene of those that handle fresh produce, and sanitary facilities and food safety resources that must be provided so all workers can reduce risks (FAO and WHO, 2021).

- Irrigation water of poor or variable microbiological quality is a major risk factor during fruit and vegetable production. Treatment may be advisable to ensure the consistent removal of microbiological hazards if there is a need for this water to contact the harvestable part of the crop and there are known risks. Where a sufficient supply of water treated by conventional methods (e.g. nutrient removal, chlorination) is unavailable, alternative means to ensure consistent water quality may be needed. For example, treatment using UV or filtration-based systems can reduce populations of bacterial pathogens by up to 6 log in irrigation water, thereby reducing the risk of contaminating the growing plants. While such treatments are effective, practical considerations have hampered their application, notably restrictive access to electricity in field settings, controlling flow rates, or the cost of the technologies.
- The microbiological quality of process water is of critical importance due to risks associated with potential cross-contamination during the postharvest washing, conveyance, or processing of fresh produce. Extensive research on chemical sanitizers to inactivate microorganisms at each production or processing step has been conducted. Where there is a reliance on sanitizers, validation of treatments for process water under pilot or commercial conditions is desirable but rare.
- Several physical methods (e.g. UV, plasma, pulsed light, ultrasound) have been evaluated alone or in combination with other processes or antimicrobial compounds to assess their potential for the disinfection of process water. Some of this research has led to the identification of promising treatments that not only inactivate spoilage microorganisms and/or human pathogens in process water but also on the surface of produce. However, most of this work has remained experimental and there is scant evidence of industry uptake.
- Lack of industry uptake of interventions indicates a need for future research to more carefully address the practicality of new technologies, and to examine their performance under conditions that either closely simulate in field production, on-farm packing, commercial processing, or by experimentation in commercial processing facilities. This should include more thorough examination of treatment effects on shelf-life and sensory quality, which are often overlooked in laboratory-based research.
- Of note, public health data indicates that outbreaks of illness caused by viral or parasitic pathogens are common, but that research on interventions disproportionately addresses control of bacterial pathogens. Survival of viral and parasitic pathogens is typically very different than for bacterial pathogens, so additional research focused on pathogens that are indicated in outbreaks would be valuable to assessing the effectiveness of interventions.

3.2 Leafy vegetables and herbs

- None of the postharvest interventions intended for the treatment of whole produce immediately after harvest (e.g. washes, post-processing chemical and physical treatments) reliably deliver significant reductions in human pathogens.

- Irradiation (i.e. gamma, electron beam, X-ray) is the most effective postharvest treatment against human pathogens on fresh-cut leafy vegetables. Reductions in excess of 5 log or complete eradication have been reported with a range of fresh-cut commodities. There are few technological limitations to the use of irradiation, but the cost and adverse consumer response continue to hinder commercial applications.

- Experimental evidence suggests that electrolyzed water in combination with other physical treatments, including ultrasound or exposure to UV, can reduce bacterial pathogens by 3 to 5 log on the surface of leafy vegetables. Potential impediments to commercial applications include engineering complexity and cost. Moreover, little data is available regarding efficacy against viruses or parasites.

- Application of bacteriophage or phage lysins have been reported to reduce bacterial pathogens by > 3 log on fresh-cut leafy vegetables. However, the approach is relatively new and data are presently limited. Potential constraints on commercial application include narrow strain specificity, absence of effects against viruses and parasites, and cost.

- Research on alternative sanitizers for use in fresh-cut processing is scarce. Only one reference on novel sanitizers describing a nanoparticle preparation of silica particles was reviewed. Use of the novel sanitizer resulted in > 5 log reductions of some human pathogens on cut lettuce leaves. Trisodium phosphate was also very effective against some bacteria and viruses. Reasons for the scarcity of research on alternative sanitizers for use in fresh-cut processing are unclear, perhaps barriers to regulatory approval contribute to this situation.

3.3 Berries and tropical fruits

- Specifically, limited papers are available on the mitigation of protozoa on berries, while several papers exist on virus mitigation. Information is mostly on strawberries, blueberries, and raspberries, but it is uncertain how these data may translate to other berries (especially on a global scale). Publications on mitigation efforts for tropical fruits are less common than for berries.

- Water-assisted light treatments (e.g. UV, pulsed light) resulted in > 4 to 5 log reductions in some situations, however, the efficacy depends on how the berries are inoculated (e.g. spot vs dip, calyx vs skin). Some of the studies assessed the disinfection effect on the water to avoid cross contamination. Ultrasound treatment in combination with chemical sanitizer showed some efficacy, 2 to 3 log reductions in some situation, although some adverse effect on product quality was reported, such as reduced firmness in strawberries.

- Gaseous treatments (e.g. controlled-release pads, fumigation, fogging with chlorine dioxide or sulfur dioxide) had variable effects depending on the dose and pathogen assessed.

3.4 Melons and tree fruits

- The most important strategy for improving the safety of melons and tree fruits involves hygienic handling and hygiene control including environmental monitoring during the sorting and packing of these products. Keeping the packing environment and packaging equipment free from contamination is essential to reducing risks.

- Water management is a key strategy to maintain the microbiological quality of process water and prevent cross-contamination through the use of chemical disinfectants or UV-C light treatments of the water.

- There are many decontamination treatments currently available or in the research phase that aim to reduce the levels of pathogenic microorganisms on the surface of melons and tree fruits. However, the degree of reduction that can be expected from these technologies when applied by the industry is relatively low and will be affected by the characteristics of the rind or surface of the fruit as well as by many other factors. The degree of contamination reduction achieved is typically low. The treatment most commonly found in the literature are UV-C light (e.g. 254 nm, 11 kJ/m^2) and heat (e.g. 65 to 80 ˚C applied for times from 45 s to 5 min), which generally achieve 1 to 2 log reductions.

- Specific for pome fruit, the use of gaseous disinfectants in the atmosphere during prolonged refrigerated storage (e.g. controlled atmosphere of low oxygen and ultra-low oxygen) of selected fruits (i.e. pome) was a critical and effective intervention.

3.5 Seeded and root vegetables

- Irradiation doses were sufficient for 3 to 5 log inactivation of *Salmonella* on green onions, baby carrots and grape tomatoes. Treatment was not detrimental to quality and was able to slightly extend shelf life. Technology is likely to have similar results in other commodities, but doses will need to be developed for commodity and target pathogen (bacteria, virus, parasite). As previously noted, limitations exist with the availability of technology and consumer acceptance.

- Gas phase chlorine dioxide (ClO_2) treatment has shown efficacy ranging from 2 to 5 log reduction on vegetables contaminated with human pathogens. In-package aerosolized ClO_2 (400 ppm) reduced populations of human pathogens in the stem scar area of tomatoes and lower populations of human pathogens on washed carrots by 2 log units.

- UV-C shows promise for bacterial surface decontamination of vegetables (approximately 2 log reduction compared to controls) with evidence for inactivation on multiple crops (e.g. tomatoes, cucumber, jalapeno pepper). Crops with greater shadowing or porosity will have less efficacy. Integrated treatment using a low dose of UV-C light with sanitizers (e.g. organic acids (1 percent), hydrogen peroxide (3 percent), and a novel antimicrobial preparation containing hydrogen peroxide, EDTA and nisin) provided a greater than 4 log reduction in *Salmonella* populations on tomatoes.

- Delivery of chemical treatments can be improved by physical means. Incorporation of vacuum impregnation into a washing process (with 2 percent malic acid) reduced levels of human pathogens on paprika peppers and carrots. The extended processing time and necessity to make this a batch process will be drawbacks to commercial applications.

4 References

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Annex 1. List of Participants

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