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Hydroponic Production of Edible Crops: Food Safety Considerations

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Introduction

Consumers often perceive greenhouse-grown produce as being fresher, tastier, longer lasting, and safer—attributes that have been historically used in branding and marketing. In fact, marketing blurbs on many hydroponic websites and product labels state that the product is "safe" or "safer" than their field-grown counterparts (Drotleff 2018). Although greenhouse systems do provide a more protected environment than field-grown systems, it is important to understand that products grown in any environment, even indoor hydroponic systems, are not inherently safer (Sparks 2020a, c; United States Food and Drug Administration 2022). There are still unique food safety risks and possible sources of contamination when growing produce in these systems, even though growers certainly aim to provide the safest product (Sparks 2020b, c; CEA Food Safety Coalition 2021). Identifying food safety hazards are necessary to implement best practices that reduce the risk of contamination during the pre-plant, production, harvest, and post-harvest handling stages (Bardsley et al. 2022a-c; Murphy et al. 2022).

With the increasing number of controlled environment agriculture (CEA) farms, Virginia Cooperative Extension (VCE) is working closely with specialty crop growers to address the challenges of establishing and managing CEA operations. This publication will look at specific important food safety factors to consider when growing edible crops in hydroponic greenhouses. A helpful checklist at the end of this publication can be used as a guide to make sure you have assessed risks and taken steps as a part of your food safety program.

Where to Start

One of the best ways to begin identifying potential hazards in your hydroponic greenhouse operation is to first map out and sketch the layout of your site and overall greenhouse facility (Bardsley et al. 2022a). It is helpful to start with a general map of the entire site, and then to create more detailed sketches that outline system components and the flow of product (Figure 1). If you grow multiple crops, especially if systems used for growing these crops are different, make sure you also show these in your sketches.

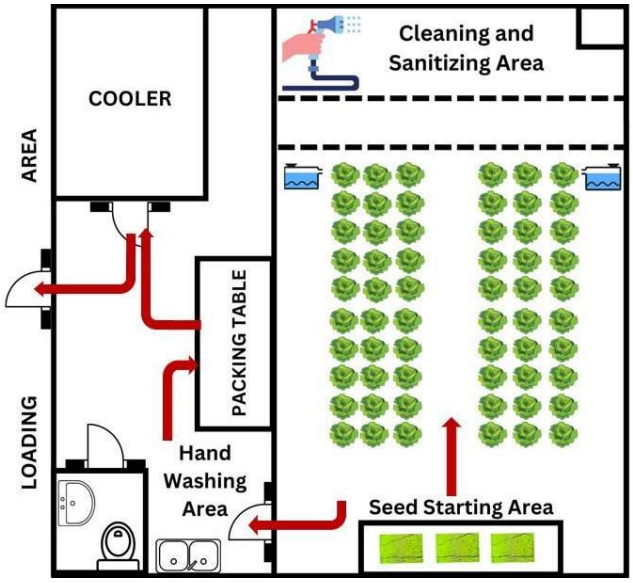

Figure 1. An example diagram outlining greenhouse system components and the overall flow of product as indicated with red arrows. (Toni Sperry, Virginia Tech)

Identifying Food Safety Hazards and Assessing Risks

When conducting your hazard analysis and assessing risks, it is important to look at the "big picture" context (e.g., overall site, general management and operations), then drill down to the specific details. This overarching tip can help you determine what practices can mitigate any identified risks. Using your map/sketch, outlined notes, and any other relevant documentation about your system, focus on three primary questions:

- What are the potential hazards (biological, chemical, physical) overall and at each stage in your process flow?
- What are the sources or routes of contamination?
- What practices can be implemented to minimize hazards?

As you read through each of the sub-sections below, please also refer to the "Assessing On-Farm Risks" factsheet series (Bardsley et al. 2022a-c; Vallotton et al. 2022a-c). While the content of those factsheets focuses primarily on field-grown produce, the overall principles have a lot of application here.

Site and Infrastructure Characteristics

When considering the site, it is important to understand the site topography, water sources, drainage, sewage system, and all fixed infrastructure such as buildings and roads, and adjacent land use (Bardsley et al. 2022c; CEA Food Safety Coalition 2021) (Figure 2). This includes the actual greenhouse structure (glass, plastic, framing supports, lighting, ventilation, heating, cooling, and sensors), the greenhouse system (benches, ponds, towers, permanent irrigation and fertigation systems, pumps, and robotics), the headhouse space, packing and storage areas, office areas, restrooms, and doors. It also includes the condition of materials used for walls, ceilings, floors, and drains, especially for repurposed and retrofitted CEA facilities. Site plans, blueprints, greenhouse system specifications, and other records can provide information to help with assessing the risks.

Figure 2. Site and infrastructure characteristics to consider, including site layout and adjacent land use (top left); well water system (top right); structural framing, supports, and lighting (middle images); packing areas (bottom left); and restroom facilities (bottom right). (Amber Vallotton, Virginia Cooperative Extension)

Pre-Plant Stage

Before beginning production (i.e., growing activities), consider the potential risks related to the propagation tasks of germination and transplanting (e.g., source of plant materials, the ways seeds are germinated and transplants are grown, the method for watering, and the overall propagation area).

When sourcing seeds and plant materials, make sure to request documentation to show how they have been handled by the vendor before and during shipment (Bardsley et al. 2022c). Make sure plant materials are stored properly on site. Seed starting trays, flats, and containers should be treated as food contact surfaces, and should be new and/or cleaned and sanitized before each use. Sanitizer should be labeled for use with produce and food contact surfaces. If trays or containers are re-used, there should be a schedule for the life cycle of these materials since they can break and degrade with use (CEA Food Safety Coalition 2021, 7). Tables, work areas, and any tools used for seed propagation also need to be regularly cleaned and sanitized.

Just like seeds and transplants, any substrate used for

germination and/or media systems, should have paperwork to document how the product has been manufactured and handled to ensure the materials are free of plant and animal pathogens and heavy metals (CEA Food Safety Coalition 2021, 10-11). Animal-based amendments should not be used or stored in the facility. Substrate materials should be stored, protected, and handled in such a way as to prevent contamination.

Figure 3. Cleaned and sanitized seed trays stored upside down on a metal shelf unit (top left); seed starting area with easy to clean tables (top right); seedling tray after seeds have germinated (bottom left); and bags of substrate stacked on pallets in seeding area (bottom right). (Amber Vallotton, Virginia Cooperative Extension)

As with hand-seeding, automated seeding equipment should be monitored for any hazards and mechanical issues including physical hazards from parts. Procedures should be in place for how often the equipment is cleaned, sanitized, and maintained (CEA Food Safety Coalition 2021, 9). Seeding rafts used for deep water culture that are machine-seeded, should have a regular schedule for being cleaned and sanitized. Avoid rafts that are constructed of porous material and are difficult to clean, especially if making your own rafts. Any rafts showing signs of excessive wear or damage should be discarded.

Spray wands, emitters, or foggers used to apply water during germination should be maintained and not a source of contamination. Water quality will be discussed in the next sub-section.

Production Stage

Think through the possible ways contamination may occur for crops being grown in your specific hydroponic growing system(s) (Mullins et al. 2022a-c). Evaluate specific risks posed such as the crop characteristics (Bardsley et al. 2022b, 4); condition and ability to clean and/or sanitize channels, rafts, pots, bulk containers, and benches; water delivery mode, recycling, quality, and nutrient application; and pest issues (CEA Food Safety Coalition 2021, 7).

When using a nutrient film technique (NFT) system or a media system, you should have procedures in place for regularly cleaning and sanitizing growing channels (gutters), plastic Dutch buckets, bulk growing containers, or vertical stack containers. Cleaning and sanitizing should be conducted between each rotation. Growing channels and containers that have been cleaned and sanitized should be stored properly between uses (Figure 4). Plastic bags should not be re-used since they cannot be easily cleaned and sanitized.

Figure 4. Methods for cleaning and sanitizing NFT channels: plastic sawhorses (top left); a large PVC pipe cut in half for placing channels sprayed with a pressure washer (top middle); a plastic-lined trough for soaking dirty channels (top right); and sanitized channels stored on a large shelving unit (bottom). (Amber Vallotton, Virginia Cooperative Extension)

Use your maps and sketches to detail your water delivery (irrigation) system including pumps, reservoirs, water tanks, lines, emitters, foggers, and other related equipment. The water delivery system should be regularly maintained and monitored. If water is reused, it is important to make sure the water does not become a source of contamination. Monitor and document conditions such as flow rate, filtration, antimicrobial treatment, and the water change out

schedule (CEA Food Safety Coalition 2021, 7, 9). Regardless of the type of hydroponic system or water delivery system used, water is obviously a central component to the entire operation, not just for production, but for all stages including germination, irrigation and nutrient delivery, cleaning and sanitizing procedures, post-harvest washing, and handwashing. Water quality is critical to prevent the introduction of any human pathogens and subsequent contamination of produce. Water should be regularly tested to determine its quality, and corrective actions taken if it does not meet quality standards (e.g., zero generic *E. coli*). If water is treated to remediate it, the water should be re-tested to verify that the treatment has been effective (see Vallotton et al. 2022a, 6-8).

Product labels and safety data sheets (SDS) for all chemical materials should be readily available. Training and procedures for the proper handling, mixing, applying, storing, and disposing of agricultural chemicals (nutrients, acids, plant protection products) should be developed to prevent accidents and contamination of produce. Secondary and bulk containers with concentrated chemicals, and nutrient mixes and acids, feeding into the water delivery system, should be well labeled to indicate the contents of the containers (Figure 5) (Vallotton et al. 2022a, 8-9).

Figure 5. Labeled secondary containers with nutrient concentrated nutrients (top) and nutrient solutions (bottom). (Amber Vallotton, Virginia Cooperative Extension)

A pest management program should be in place to exclude and control rodents, flies, and any other pests (Vallotton et al. 2022c, 10).

Harvest Stage

The harvest stage comprises all processes taken just before, during, and immediately following the gathering and cutting of the crop. It is important to consider and identify any risks associated with your harvest methods, the harvesting tools and equipment used, containers or packaging in which produce will be placed immediately after harvest, and the storage of the harvested produce (Vallotton et al. 2022b, 2). Using your assessment, you can outline your harvesting steps to develop specific operating procedures.

Your procedures should always include a pre-harvest assessment to identify any observed signs of contamination in the production areas, as well as any contamination related to harvest equipment, tools, containers, packaging, and storage areas (Vallotton et al. 2022b, 3). Examples include water quality concerns in the growing channels or ponds; cross-contamination by agricultural chemicals; shattered glass or dripping moisture from ceilings over growing areas; leaking equipment lubricants on food contact surfaces; and rodent droppings in and on harvest tools, bins, and packaging.

Actual harvesting of the product can take various forms, depending on your operation. As is true of the other stages, harvesting tools, equipment, carts, containers, and bins should always be cleaned and sanitized prior to use, and properly stored to minimize cross-contamination (Vallotton et al. 2022b, 3-4). All packaging should be new, single-use materials and stored to protect them from contamination (Vallotton et al. 2022c, 6).

If product is harvested and placed directly into packaging in the growing area, care should be taken to make sure the packaging does not show signs of dirt, debris, pests, soiling, or damage. Examples of this kind of harvesting are NFT-grown lettuce harvested with roots intact placed into clamshells and recirculating, hydroponically grown strawberries into specialized cartons (Figure 6).

Figure 6. Strawberries being directly hand-harvested into specialized cardboard containers (top), and NFT-grown lettuce harvested directly into clamshells. (Amber Vallotton, Virginia Cooperative Extension)

If product is harvested by hand or with tools into a container or larger bulk bin, e.g., plastic wheel barrel, to be re-packed, these containers and bins should never be used for other purposes like storing new substrate or waste media and culls. It is always a good idea to have dedicated tools and containers that get used for specific tasks and are labeled accordingly. Examples of this would be NFT-grown lettuce harvested into a plastic bin and lettuce harvested from a vertical stack system into a large plastic wheelbarrow (Figure 7).

If product is mechanically harvested, the machine conveyers, cutting blades, chutes, and other equipment parts should be inspected regularly and in good repair. Lubricants and any fluids, grease, etc., should be monitored to make sure they do not drip or get onto the product during harvesting. All food contact surfaces should be cleaned and sanitized prior to use. An example of this is using an automated harvesting machine in which lettuce grown on rafts with deep water culture (DWC) are cut mechanically (Figure 8).

Another important aspect of harvesting and packing is developing a traceability system. All produce should be labeled to facilitate traceability back to your farm once the produce is sold (Vallotton et al. 2022b, 5-6; Vallotton et al. 2022c, 6-7). When harvested crop is packed directly into containers and boxes in the production area, a traceability code should be affixed to each unit of product. If harvested crop is re-packed in a place other than the production area, it is important to keep track of the growing location of the crop in the greenhouse prior to adding the traceability code in the packing area. See Vallotton et al. 2022b-c for more information about traceability.

Figure 7. Dedicated wheelbarrow used for harvesting (top left and right), along with lettuce being sorted and packed into clamshells (bottom). (Amber Vallotton, Virginia Cooperative Extension)

Figure 8. Automated harvesting machine cutting lettuce from DWC rafts (top and bottom). (Amber Vallotton, Virginia Cooperative Extension)

Post-Harvest Handling Stage

It is vital to handle produce appropriately once it has been harvested. Regardless of whether the produce has been directly packed into containers or it will be washed and/or re-packed after harvest, it is important to maintain product safety and quality through minimal handling, holding it at optimal temperatures, and making sure best practices are followed during this stage. For full coverage of this topic see Vallotton et al. (2022c).

Worker Health and Hygiene and Training

All farms growing produce—whether field or greenhouse grown—need to have a good understanding of the effect of workers on food safety at all stages, already described previously (Bihn et al. 2021; Boyer et al. 2019). All workers should be trained in proper handwashing practices, restroom use, recognizing illnesses, how to handle injuries, cleaning, sanitizing, and any other policies related to worker best practices (Schonberger et al. 2021). Signage should be posted and readily understandable by all workers (Bardsley et al. 2022b).

Food Safety Assessment Checklist

The checklist provided on the next three pages will help you to identify hazards and assess risks at each stage of your operation. Along with your maps and sketches, it can be used as a record to document that you have conducted a hazard analysis, assessed risks, and your intention to adhere to preventive food safety practices. While the assessment is not a substitute for a complete food safety plan (which typically includes policies, standard operating procedures, records, and supporting documents), or other certification/inspections, the assessment is still a document demonstrating you have identified and understood potential risks. It is important to ask your buyers what they require to satisfy their food safety policies, as some buyers have more stringent food safety standards and audit requirements that must be met.

Check the boxes for the items or activities <u>you have performed/completed</u> as a part of your hydroponic greenhouse food safety program. Write N/A next to item/activities that do not apply to your operation.

Site and Infrastructure Characteristics

- ❑ Site plans have been used to explore overall site characteristics.
- ❑ All features such as water sources, drainage areas, sewage or septic systems, buildings, and roads have been noted.
- ❑ Current and adjacent land use has been determined.
- ❑ Greenhouse specifications for structural materials, lighting, ventilation, heating, cooling, and sensors has been reviewed and hazards identified.
- ❑ Walls, ceilings, floors, and drains used in headhouse, packing, and storage areas have been inspected to determine state of repair.
- ❑ Hydroponic greenhouse systems and all components have been assessed to determine any potential ‘hotspots’ posing risks.

Pre-Plant Stage

- ❑ All plant material used for plant propagation (i.e. seeds, transplants) has proper documentation from vendor.
- ❑ Procedures for starting seeds and/or growing transplants have been developed and include the following practices (check those all that apply):
    - □ Seeds are properly inventoried and stored on site.
    - □ Flats used for seed germination are either new or have been inspected, cleaned, and sanitized prior to use.
    - □ Containers used for transplants are new (bags) or cleaned and sanitized before use.
    - □ Sanitizer is labeled for use with produce and food contact surfaces, and labeled rates are being used.
    - □ The source, composition, and process used to manufacture all substrates are documented and kept in records.
    - □ Bulk and loose substrate are properly stored and handled before use.

- □ Work areas and tools used for seed starting are cleaned and sanitized before each use.
- □ All cleaned and sanitized flats, growing containers, tools, etc., are labeled to avoid confusion and inspected before use to ensure they have not become contaminated.
- □ Any equipment used to apply water is regularly inspected, maintained, and replaced when needed.

❑ Records are kept to document performance of processes.

Production Stage

❑ Characteristics of the crops being grown have been researched to identify potential risks.

❑ The hydroponic system(s) I am using is/are (check all that apply):

- □ NFT channels
- □ NFT microgreen trays with burlap
- □ DWC rafts
- □ Media plastic containers
- □ Media Dutch buckets
- □ Media bags
- □ Media microgreen trays
- □ Other system

❑ Hydroponic system(s) have been evaluated to identify and document food safety concerns:

- □ Growing channels, containers, and trays are cleaned and sanitized between crop rotations, and then stored in such a way as to minimize contamination.
- □ Growing rafts are inspected after each use, cleaned and sanitized, and are discarded when they become worn and damaged.
- □ Sanitizer is labeled for use with produce and food contact surfaces, and labeled rates are being used.
- □ Growing bags are new and are not re-used.
- □ The water delivery system has been thoroughly mapped.
- □ Each water source is sampled and tested to determine water quality.
- □ If water is reused or recycled, water is treated and tested to ensure the water meets post-harvest microbial standards (zero detectable generic *E. coli*). Test results are kept on file.
- □ Corrective actions are taken when water does not meet *E.coli* water quality standards.
- □ If the corrective action is treatment, the water source is re-tested to verify the treatment is effective.
- □ Any bulk fertilizers, acids, and other agricultural chemicals are stored and labeled to prevent accidents and contamination.

❑ Production areas are monitored for evidence of rodents and other pests, and control measures have been put into place.

❑ Pets are not allowed in production, packing, and headhouse area.

❑ Outdoor and indoor spaces are kept clean to reduce rodent habitat and refugia.

❑ Preventive steps have been taken to avoid overhead light breakage, such as installing sleeves or protective covers to light fixtures.

Harvest Stage

❑ A pre-harvest assessment is conducted before any harvest event. Any produce showing signs of visible contamination is removed and discarded, and corrective actions are taken to resolve the source of contamination.

❑ Harvesting tools, carts, bins, and totes are cleaned and sanitized prior to use, and are properly stored to minimize cross-contamination.

❑ Sanitizer is labeled for use with produce and food contact surfaces, and labeled rates are being used.

❑ Harvest machinery is inspected regularly and in good repair to avoid cross contamination.

❑ All packaging materials are new and stored to protect them from contamination.

❑ When harvested crop is packed directly into containers and boxes in the production area, a traceability code is used for each unit of product.

- ❑ When harvested crop is re-packed in a separate area from the production area, the growing location of the crop in the greenhouse is documented as part of the traceability code.
- ❑ A procedure has been developed to address culls, "spent" growing substrate, and other waste generated.

Post-Harvest Handling Stage

- ❑ Non-baited, live rodent traps are used and regularly monitored to track pest pressures.
- ❑ Light fixtures are protected to prevent glass from shattering over product.
- ❑ Food contact surfaces are made of materials that can be cleaned and sanitized prior to use.
- ❑ Sanitizer is labeled for use with produce and food contact surfaces, and labeled rates are being used.
- ❑ Water used for post-harvest activities is tested at least annually or as dictated by industry guidelines to ensure it meets the standard of zero detectable generic *E. coli* per 100ml water. Water test results are kept on file.
- ❑ If a sanitizer is added to wash water, it is monitored to ensure efficacy.
- ❑ Boxes and containers used for re-packing are stored to prevent cross-contamination from pests and other hazards.
- ❑ Cardboard boxes are new, or if re-used, are always lined with new plastic.
- ❑ A traceability program is in place.
- ❑ Packaged product has identifiable traceback codes to provide a traceability system.
- ❑ Storage coolers are kept clean, maintained, identified with proper signage, and do not contain both produce and non-produce items (such as meat) or allergen-containing products.
- ❑ Produce in coolers is kept at appropriate holding temperatures, which are monitored to ensure consistency.
- ❑ Transport vehicles are clean, well maintained, and maintain the cold chain to the marketplace.

General Practices (applicable to all stages)

- ❑ All workers, including family members, have been trained in proper health, hygiene, and produce handling practices and policies for any of the stages they are involved in.
- ❑ Visitors are instructed in policies of the farm or operation, especially in terms of access to any production and packing areas.
- ❑ Appropriate signage is posted to remind workers and visitors of food safety practices and policies.
- ❑ Restrooms are readily available and well stocked.
- ❑ All workers and visitors wash hands after using the restroom and at other specified times as stated in training/policy.
- ❑ Eating is only permitted in designated eating or break areas.
- ❑ Smoking, if permitted, is never allowed in production and handling areas.
- ❑ Anyone who is exhibiting signs of an infection, sickness, or has an accident knows to report to the supervisor and not work around produce until authorized to do so.
- ❑ A first aid kit and emergency contact numbers are readily available.
- ❑ The food safety manual, SDS, and other related documents (e.g., agricultural product labels) are readily accessible.

_____
Name

_____
Signature

_____
Date

Additional Comments

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