Overview of Protected Agriculture and Controlled Environment Agriculture

Elena Rogers, Area Specialized Agent,
Food Safety – Fresh Produce

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University of Florida

Defining Protected Agriculture

Modifying natural environment of vegetable and fruit crops in order to extend their growing season and produce higher yields. Includes structures such as greenhouses, high tunnels, low tunnels, shade structures and indoor agriculture systems.


Tunnel


Fan and pad greenhouse


Shade structure


Passively ventilated greenhouse

The Indoor Farming Industry
(Dr. Celina Gomez, Purdue University)

- Indoor farm
  - Vertical
  - Non-vertical
- Container farm


Urban Ag News


CNN


MMJdaily

Controlled environment agriculture (CEA)

CEA is an advanced and intensive form of hydroponically- based agriculture where plants grow within a controlled environment to optimize horticultural practices.

Need a sound knowledge of chemistry, horticulture, engineering, plant physiology, plant pathology, IT systems and entomology at a minimum.

Dr. Neil Mattson

Cornell University CEA

Hydroponic systems

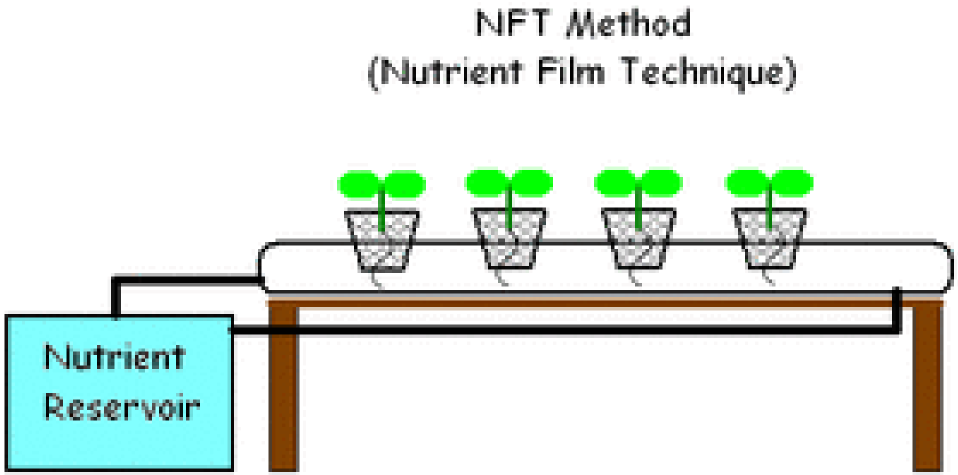
Solution- only based

- Nutrient film technique
- Floating systems
- Vertical NFT type towers
- Aeroponics
- Ebb and flow

Soilless media based

- Vertical pots
- Lay flat bags or slabs
- Upright bags
- Open troughs
- Container (nursery pots)
- Bato bucket, Dutch bucket
- Earth boxes
- Microgreen mats (Sure to Grow, burlap)

Nutrient Film Technique



Vertical NFT type towers

Microgreens- NFT

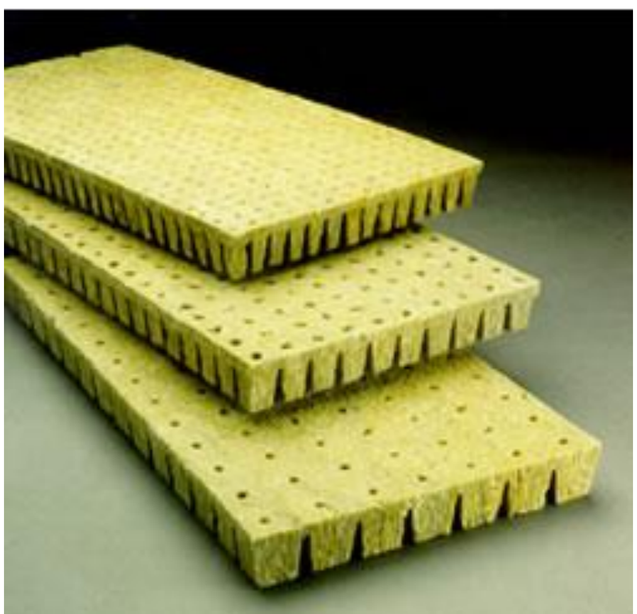
Floating Systems: Solution Culture

Floating lettuce beds- Solution only

Soilless Media Choices

- Sand
- Gravel, pea gravel, etc
- Sawdust
- Crop waste products: rice hulls, peanut hulls, cotton gin wastes, etc.
- Peat moss, peat-lite mixes
- Styrofoam beads (no longer used)
- Perlite
- Vermiculite
- Pine Bark
- Oasis foam cubes (granulate or phenolic resin)
- Rockwool
- Clay beads
- Wood byproducts

Media: Rockwool



Media: Perlite

Vermiculite

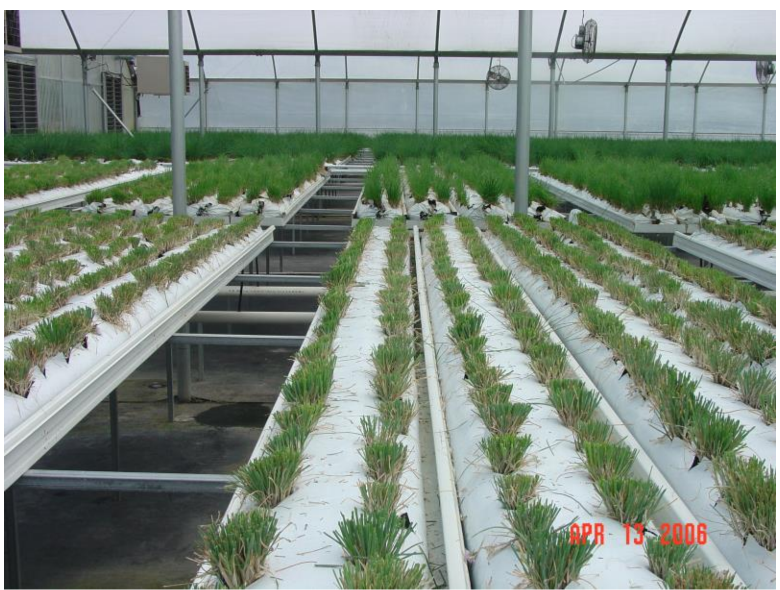
Media: Pine Bark

Media: Coconut Coir or Fiber

Media: Sphagnum Peat

Kale and tomatoes growing in composted pine bark

Chives growing in perlite bags



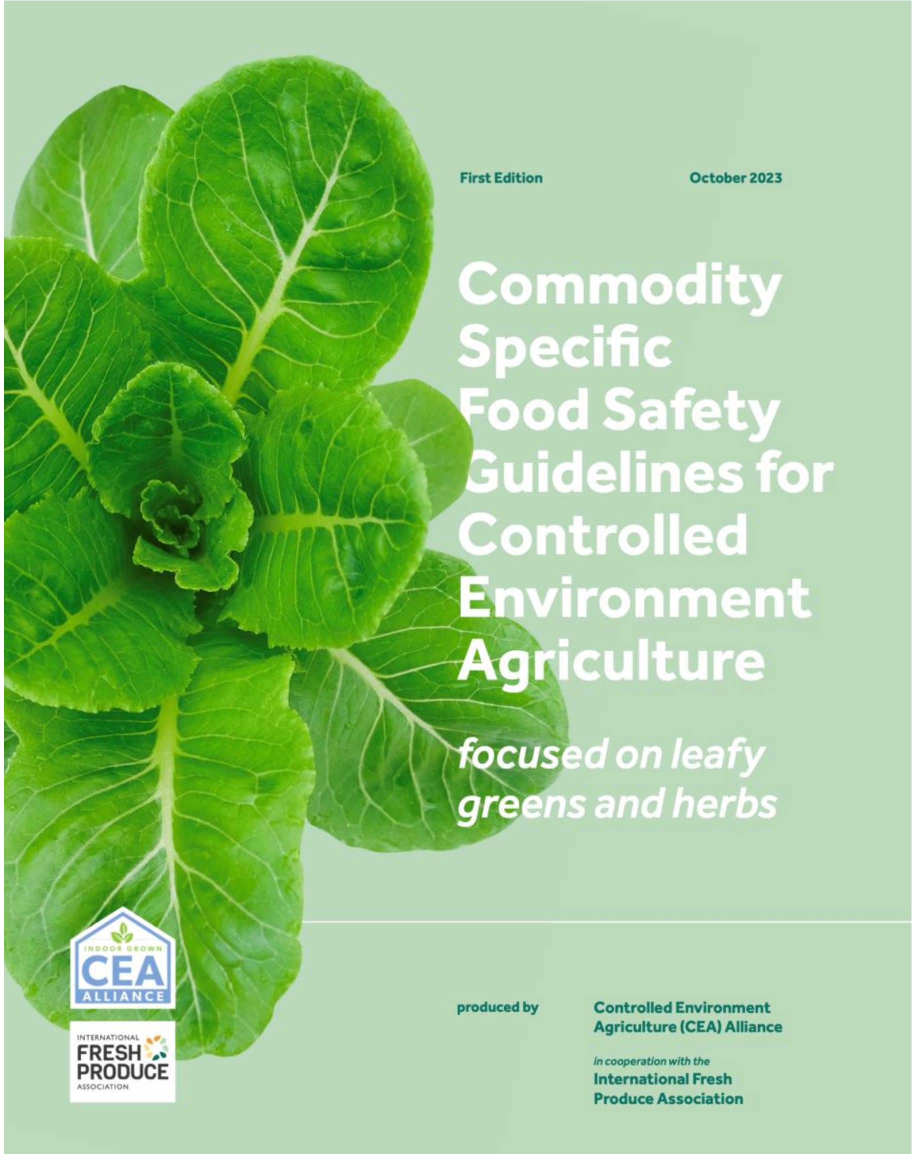
Tomatoes, peppers and eggplant growing on lay flat coconut coir bags

Microgreens on cloth/fiber media

Systems: Reservoir Containers

CEA Alliance

The best practices described in this document represent a current understanding of food safety risks and mitigations available to the fresh produce industry for controlled environment agriculture (CEA) production, with a focus on leafy green and herb production.



Assessing risks in hydroponic systems

High → Medium → Low

Risk level

Overhead irrigation in any system

Nutrient film technique and deep water culture

Drip irrigation in bato bucket systems or channels

Ilic, S. & Ivey, M. Hydroponic GAPs – Good agricultural practices for food safety hydroponic crops

Resources

Join Robert Hadad + Angela Shaw's monthly calls. Next call:

March 28- 3 pm

What CEA Food Safety Research Are You Currently Conducting?

Robert Hadad's email: rgh26@cornell.edu

A comprehensive examination of **microbial** hazards and risks during indoor soilless leafy green production

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Review

A comprehensive examination of microbial hazards and risks during indoor soilless leafy green production

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ABSTRACT

Produce grown under controlled environment agriculture (CEA) is often assumed to have a reduced risk of pathogen contamination due to the low chance of exposure to outdoor contaminant factors. However, the 2021 outbreak and numerous recalls of CEA-grown lettuce and microgreens demonstrate the possibility of pathogen introduction during indoor production when there is a failure in the implementation of food safety management systems. Indoor production of commercial leafy greens, such as lettuce and microgreens, is performed across a range of protective structures from primitive household setups to advanced and partially automatized growing systems. Indoor production systems include hydroponic, aquaponic, and aeroponic configurations. Hydroponic systems such as deep water culture and nutrient film technique comprised of various engineering designs represent the main system types used by growers. Depending on the type of leafy green, the soilless substrate, and system selection, risk of microbial contamination will vary during indoor production. In this literature review, science-based pathogen contamination risks and mitigation strategies for indoor production of microgreens and more mature leafy greens are discussed during both pre-harvest and post-harvest stages of production.

1. Introduction

Food crop production in controlled environments is an increasingly important sector of the U.S. and global agricultural systems. According to the United States Department of Agriculture (USDA) 2019 Census of Horticultural Specialties, sales from "food crops grown under protection" were roughly $700 million in the U.S. (United States Department of Agriculture - National Agricultural Statistics Service (USDA-NASS), 2021). These crops primarily include tomatoes, lettuce, cucumbers, peppers, berries, and herbs and account for 54 % of the total production (cwt) of these crops in the U.S. (United States Department of Agriculture - National Agricultural Statistics Service (USDA-NASS), 2021). Globally, countries such as the Netherlands, Canada, Spain, China, South Korea, and United Arab Emirates (UAE) cultivate a significant volume of produce within controlled environment agriculture (CEA) systems contributing to the USD $37.7 billion market value for these crops (Research and Markets, 2022). In the Netherlands, nearly 24,000 acres (~9,700 ha) of crops, including leaf lettuces, are grown in greenhouses (Reiley, 2022). Meanwhile, Spain has 75,000 ha of greenhouse production space dedicated mainly to tomatoes, peppers, and cucumbers (Di Pastena, 2023). Moreover, UAE is hosts the world's largest vertical farm (Emirates Crop One or ECO 1) which spans a production area of approximately 30,700 m^2 and can produce >1 million kilograms of leafy greens annually (Tesorero, 2023).

Controlled environment agriculture takes advantage of technologies and automation to modify production climates, shield crops from biotic and abiotic stresses, and optimize environmental factors that maximize plant yield and quality. Greenhouses and indoor warehouses or shipping containers are common CEA structures, and hydroponics, soilless substrate culture, and vertical farming systems are common CEA growing techniques. Common terms used when discussing CEA along with their definitions are provided in Table 1. While CEA can offer many advantages over traditional farming, such as increased yields, year-round production regardless of external weather conditions, reduced water use, and protection from pests, it also presents unique challenges related to food safety.

Foodborne pathogens can enter and spread through CEA similar to field-grown crops via: (i) contaminated water or nutrient solution, (ii) unsanitary equipment, (iii) contaminated incoming materials such as seeds or plant materials, (iv) employees and staff, and (v) insects and

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Cultivating Food Safety Together: Insights About the Future of Produce Safety in the U.S. Controlled Environment Agriculture Sector

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Research Paper

Cultivating Food Safety Together: Insights About the Future of Produce Safety in the U.S. Controlled Environment Agriculture Sector

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A R T I C L E I N F O

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Extension needs
Produce Safety
Research needs

A B S T R A C T

Controlled environment agriculture (CEA) is a rapidly growing sector that presents unique challenges and opportunities in ensuring food safety. This manuscript highlights critical gaps and needs to promote food safety in CEA systems as identified by stakeholders (n=47) at the Strategizing to Advance Future Extension and Research (S.A.F.E.R.) CEA conference held in April 2023 at The Ohio State University's Ohio CEA Research Center. Feedback collected at the conference was analyzed using an emergent thematic analysis approach to determine key areas of focus. Research-based guidance is specific to the type of commodity, production system type, and size. Themes include the need for improved supply chain control, cleaning, and sanitization practices, pathogen preventive controls and mitigation methods and training and education. Discussions surrounding supply chain control underscored the significance of the need for approaches to mitigate foodborne pathogen contamination. Effective cleaning and sanitization practices are vital to maintaining a safe production environment, with considerations such as establishing standard operating procedures, accounting for hygienic equipment design, and managing the microbial communities within the system. Data analysis further highlights the need for risk assessments, validated pathogen detection methods, and evidence-based guidance in microbial reduction. In addition, training and education were identified as crucial in promoting a culture of food safety within CEA. The development of partnerships between industry, regulatory, and research institutions are needed to advance data-driven guidance and practices across the diverse range of CEA operations and deemed essential for addressing challenges and advancing food safety practices in CEA. Considering these factors, the CEA industry can enhance food safety practices, foster consumer trust, and support its long-term sustainability.

Controlled Environment Agriculture (CEA) represents a transformative paradigm in agricultural practices, often harnessing advanced technologies and scientific principles to cultivate crops within controlled indoor environments. This approach encompasses various system types, including traditional soil-based cultivation as well as hydroponics, aeroponics, aquaponics, and vertical farming, which are all designed to optimize plant growth conditions and resource utilization. In contrast to traditional open-field production, CEA operations combine production, harvesting, and packaging within one indoor facility. As concerns over food security, resource scarcity, and environmental sustainability intensify, CEA has garnered significant attention from researchers, policymakers, and industry stakeholders as a potentially viable solution to food insecurity (Benke & Tomkins, 2017; Broad et al., 2022; Engler & Krarti, 2021). Furthermore, CEA systems' scalability and economic viability require careful consideration to support their accessibility and economic sustainability for farmers at various scales (Despommier, 2010, Benke and Tomkins, 2017). Srivani et al (2019) highlights that there are economic challenges for CEA operations to scale up due to the infrastructure and equipment cost and for larger CEA operations financial sustainability, production

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We asked USDA AMS if NFT channels are considered food contact surfaces under the GAP Harmonized audit..

- Answer: The channels would be considered a food contact surface, as the leaves are touching the channel.
- For cleaning and sanitation, the operation would need to set up a cleaning program that would include specifying a frequency, the methods and chemicals that they would use to clean those areas. This would fall under requirement F-8.2 and F-8.2.c (harmonized + only).

USDA GAP Harmonized audit

F-8.2	Equipment, vehicles, tools and utensils used in farming operations which come into contact with product are in good repair, and are not a source of contamination of produce.	**WP, R**		The Operation shall develop, implement, and schedule repair, cleaning, sanitizing, storage and handling procedures of all food contact surfaces to reduce and control the potential for contamination. Records must include the date and method of cleaning and sanitizing equipment. As necessary for food safety, vehicles and equipment shall be properly calibrated, operated, maintained, and used as intended. Equipment traffic flow is prevented from traveling through an untreated manure area into the harvesting field. These procedures shall be documented. Product contact tools, utensils and equipment shall be made of materials that can be cleaned and sanitized. Procedures include equipment and vehicles that are in the field infrequently.	Auditor observes production and harvest vehicles, equipment, tools and utensils which may come into contact with produce for evidence of food safety risks. Auditor reviews maintenance, cleaning and sanitation records that demonstrate compliance with procedures.	Operation develops maintenance, cleaning and sanitation procedures for equipment, vehicles, tools and utensils that may pose a risk for produce contamination. Affected product is evaluated for potential contamination and disposition.

Let’s compile the questions we have for FDA…

*** Understanding the systems and its components to work efficiently with these operations is critical to address risks**

*** Training that focuses on growing conditions in protected agriculture and CEA operations is needed**

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