How does water delivery system design impact the microbial load of salad crops?

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Abstract

In a microgravity setting, such as the environment aboard the International Space Station (ISS), an ideal plant water delivery system is one that can grow edible crops with minimal resource consumption and minimal risk to crew members. There are also concerns associated with the ability to control fluid escape and biofilm formation resulting in potential dangers to systems, crops, or crew members. To identify an appropriate system, candidate systems were assembled and operated under simulated ISS environmental conditions (T, CO_2, and RH) with red romaine lettuce (*Lactuca sativa* cultivar 'Outredgeous') as a model crop. Fluid reservoirs and randomly selected planting sites were sampled every seven days until maturity at which point edible plant biomass and root samples were also taken. Heterotrophic bacteria and fungi growth patterns throughout each planting cycle were determined by plate counts on appropriate agar media. The candidate systems were compared to a classic hydroponics system as a control and harvested crops were compared to controls as well as Veggie-grown and market produce. Plants harvested from candidate systems yielded lower average heterotrophic bacteria and fungi per gram of plant mass levels when compared to market and Veggie samples as well as those from the control system. Additional studies to evaluate the system sanitation regimen as well as testing additional crops should be considered to aid in the selection of an ideal system.

Introduction and Goals

- Determining the microbial load of produce grown in spaceflight is essential for maintaining crew health by identifying and avoiding potential foodborne illness.
- Fluid behavior in a microgravity setting necessitates control and containment.
- A primary goal for this work is determining if and how nutrient delivery system design impacts the microbial load of the generated produce.
- While crew health is the primary concern, ease of system cleaning and maintenance is also a consideration.

Figure 1. Mature 'Outredgeous' lettuce grown on an active PTNDS system.

Water Delivery Experiments

- Candidate systems included an active Porous Tube Nutrient Delivery System (PTNDS), a passive PTNDS, and an On-Demand Nutrient Delivery System (Fig. 4).
- All growth tests were compared to a Nutrient Film Technique (NFT) hydroponic growth system as a control. Additionally, several growth tests included a ground analog system of the current state of the art spaceflight system: the Advanced Plant Habitat (APH) science carrier.
- Systems were sampled weekly providing a direct comparison between reservoirs and planting sites across systems.
- All system reservoirs and components were manually cleaned using 3% H_2O_2 before each growth test.
- Tested crop: Red leaf lettuce (*Lactuca sativa* cultivar 'Outredgeous') (Fig. 1).

Risk Assessment

- Samples from Water Delivery experiments were compared to market and Veggie-grown crops (Fig. 2).
- Water delivery candidate system counts are significantly lower than unclean market produce and samples from Veggie experiment: VEG-03D.
- NFT control system noted to be similar to the cleaned market produce aerobic plate counts as well as cleaned market produce and VEG-03D yeast and mold counts.
- Average microbial counts for all systems were below NASA standards for non-thermostabilized foods

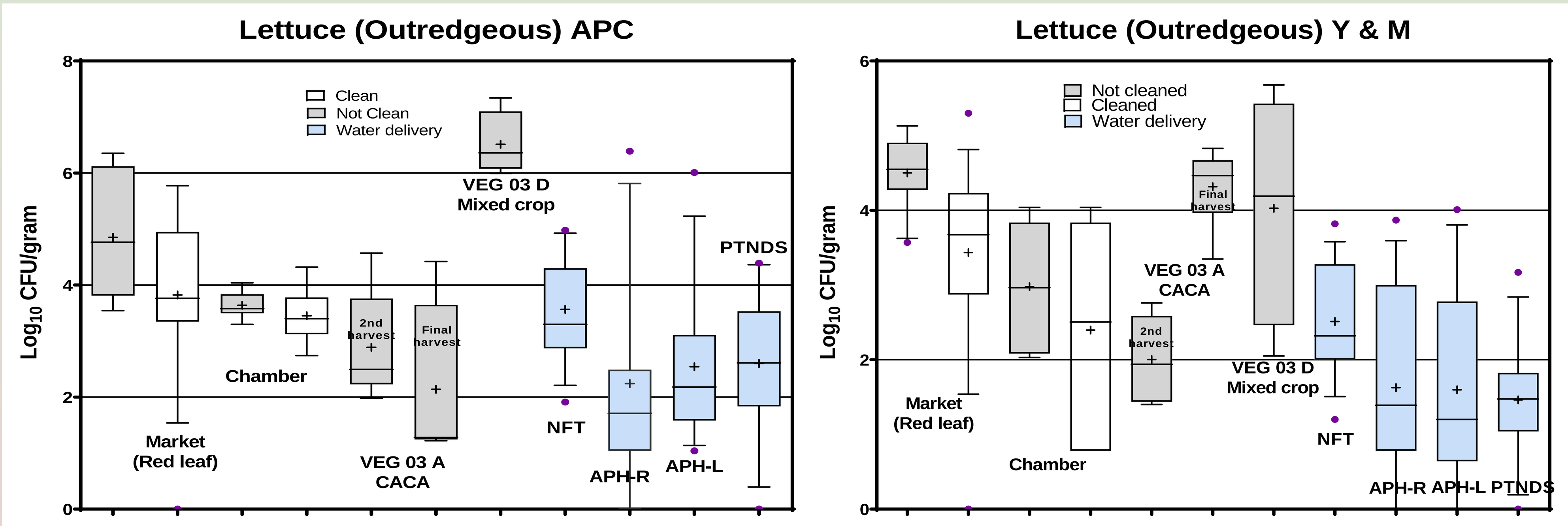

Figure 2. Box and whiskers (10-90 percentile) plots for aerobic plate counts and yeast and mold counts on 'Outredgeous' lettuce grown under a variety of conditions. Purple circles indicate outliers. Chamber samples grown in growth medium with timed release fertilizer/sub irrigation, ISS conditions. VEG 03 A and D grown in veggie pillows on ISS. Water delivery system counts are significantly lower than the unclean market produce and Veg 03 D with the exception of NFT APC and market produce and NFT Y & M and Veg 03D.

Results

- All system surfaces were measured to be within one log in both aerobic and yeast and mold plate counts.
- Reservoir measurements were heavily influenced by dilution events as plants took up more water later in their growth cycle (Fig. 2).
- The proposed cleaning method was effective in reducing the overall microbial load to acceptable levels (Fig. 3).
- The microbial load of harvested edible biomass does not appear to be fully dependent on surface or reservoir measurements (Figs. 2 & 3).

Figure 3. Average APC and Y & M plate counts over time for system reservoirs and planting surfaces.

Discussion

The microbial data collected from these experiments is a factor that will aid in the selection of an optimal system for providing crew nutrient supplementation while also minimizing the risk to crew health. The candidate systems show promise when compared to current spaceflight hardware by exhibiting lower plate counts. Testing with other crops will help differentiate systems further.

Figure 4. NFT (bottom left), Passive PTNDS (Top left), Active PTNDS (Top right), and On-Demand (bottom right)

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