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Food Safety and *E. coli* in Aquaponic and Hydroponic Systems

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The following document is The Aquaponic Association's response to a recent publication on *E. coli* in Aquaponic and Hydroponic systems.

1. Overview of the Study

On 6 April 2020, Purdue Agriculture News published a story about a study related to the contamination risk of Shiga toxin-producing *E. coli* (STEC) in aquaponics and hydroponics production. The full study was published in the MDPI Journal *Horticulturae*, January 2020, by Hye-Ji Kim, an assistant professor of horticulture, Yi-Jung Wang, a graduate student in Kim's lab, an d Amanda Deering, a Purdue clinical assistant professor of food science.

Researchers conducted the study from December 2017 through February 2018. It consisted of side-by-side aquaponic and hydroponic systems in a controlled lab environment growing lettuce, basil, an d tomatoes with tilapia. The purpose of the study was to identify the food safety risks associated with soilless systems. The study indicated that both the aquaponic and hydroponic systems contained Shiga toxin-producing *E. coli* (STEC) at the time of sampling. It did not find the presence of *Listeria* spp., or *Salmonella* spp.

The authors contend that the aquaponic system and specifically the fish feces were likely the sources of *E. coli*. However, we believe that there is no evidence to prove that this was the actual source of contamination because the authors admit traceback was not performed, an d there were several other possible introductions.

The pathogen was present in the water and on the root system of the plants. The researchers did not detect it in the edible portion of the plants. However, if the water is positive for a contaminant, and it accidentally splashes onto the edible portion of the crop throughout its life, or during harvest, this could still result in a food safety concern.

2. History of *E. coli* in Soilless Growing Systems

Up to this point, researchers have only discovered environmental *E. coli* in soilless growing systems. It is essential to note that there are hundreds of types of non-fecal coliform bacteria in the air, water, an d soil, as well as the fecal coliform bacteria represented mostly by *E. coli* in the waste of all mammals, humans, an d some birds. The vast majority of these coliforms are perfectly harmless.

The *E. coli* found in this study were Shiga toxin-producing O157:H7, an d historically have been associated with warm-blooded mammals, more specifically bovine fed with corn in feedlots [1], as well as swine and turkeys. Further research must be performed to prove that cold-blooded, non-mammal aquatic species such as tilapia can harbor pathogenic *E. coli*; this is currently refuted by a wide group of studies, university professors and industry professionals. The lack of evidence detailing the ability of aquatic animals to harbor *E. coli* makes the fish being contaminated with this particular strain of bacteria very rare and suspect.

Many foodborne illnesses have been identified in fresh produce such as romaine lettuces, green onions, herbs, an d sprouts, an d historically the source of contamination is the soil, the irrigation water used in these crops [2], the seed stock, or poor sanitation in the handling facilities.

There are a wide variety of community and commercial aquaponic and hydroponic growing facilities that routinely perform pathogen testing and have not identified this pathogen being present. If it was, traceback procedures would be followed to identify and remove the source, as well as any necessary food safety precautions and recalls performed.

3. Our Position

The Aquaponic Association and its members agree that food safety and proper handling practices are critical to commercializing our industry and the safety of our customers. One thing that the study points out is that a contaminant can occur in a soilless system, which creates a potential food safety concern. We agree on this; however, we have numerous concerns with the procedures and statements made in the publication.

We have reached out to the professional investigator on this study Hye-Ji Kim to receive answers to essential questions that the study publication does not adequately address. There are significant gaps and questions with the study.

4. Concerns about the Study Findings and Publication

4.1. Lack of Traceability

The study group is unsure how the pathogen was introduced into the two systems. They admit that no traceback was performed to identify the source of contamination. They speculate both in the study and in their email response that this pathogen was:

(1) Accidentally introduced,
(2) That it is from the fish feces in the aquaponics system that splashed into the hydroponic system through the open top of the fish tank during feeding,
(3) That it was from contaminated fish stock (which were provided by the Purdue Animal Sciences Research and Education Center),
(4) That it was human contamination from visitors or operator handling issues.

A traceback was not conducted because it was not within the scope of the study (Kim personal communications). We disagree; the discovery of O157:H7 strain in the university greenhouse with the suspicion of fish being contaminated should have resulted in immediate action in order to track down the source of contamination and prevent infection of the university students and staff. Outside of a university setting, traceback would have been essential in a commercial facility; therefore, we do not recognize the response that "it was out of the scope of the study" to be acceptable.

4.2. Questioning Fish Feces as the Source of Contamination

Blaming fish feces as the contaminating source seems incredibly misleading when so many other options exist, an d no traceback proved that as the source. The contents of the fish intestines were tested for the presence of *E. coli*, and none was found (Kim personal communications). It, therefore, seems logical, that if the fish do not have STEC *E. coli* inside of their guts, then it seems more likely that the fish feces being positive would be related to the contaminated water in which the feces was floating.

In wild fish species, levels of *E. coli* in the fish appear to follow trends similar to ambient water and sediment concentrations; as concentrations in their environments rise so do concentrations within the fish [3].

Furthermore, it seems very suspect that a two-month-old system in a controlled lab environment could have been so quickly contaminated. It is well-known that *E. coli* cannot survive in a biologically-active environment, such as anaerobic digester or aquaponics [4]. *E. coli* are outcompeted by other microorganisms, which have adapted to survive in the environment outside animal guts much better than *E. coli*. Thus, *E. coli* O157:H7, which is specially adapted to live in cattle guts, will inevitably be replaced by other microorganisms.

As for the hydroponic system showing positive results, this also seems suspect if the nutrients were synthetic, because there would be very little chance for the *E. coli* to survive without a biological host or continuous contamination source being present. An accidental exposure in the hydroponics system would have become diluted over time, or the pathogen died off to the point that they would have been undetectable. The fact is that organic matter in hydroponics is virtually absent and, therefore, provides a poor environment for *E. coli* growth and propagation [5]. Therefore, one would need a continuous source, not an accidental one (such as splashing), in order to maintain the *E. coli* population in hydroponic systems.

Both systems were contaminated, therefore we suggest that there was a more likely common pathogen source that the researchers did not correctly identify and remove. The source of contamination could be from source water, filtering systems, repurposed equipment, airborne in the greenhouse or HVAC system, a human vector, lab equipment, the seed stock, nutrients, or other inputs.

The Purdue Animal Research and Education Center, where the researchers sourced the fish, is an operation that also has swine, cattle, an d poultry production. Research suggests that pathogenic *E. coli* can travel ~180 m through airborne exposure [6]. Airborne exposure poses a more significant risk to controlled environments because pathogens can persist in the HVAC system [7]. STEC has the potential to live in dust particles for up to 42 weeks, which can act as a possible vector of contamination if there is a continuous source. Therefore, even a slight possibility of the pathogenic Shiga-producing O157:H7 strain of *E. coli* transfer from the Animal Research and Education Center resulting in the uncontrolled cross-contamination of other research labs and facilities certified below Biosafety level 2 not designed to work with the pathogenic bacteria would raise a serious concern about the existing safety practices [8].

4.3. Lack of Third Party or Peer University Test Verification

It has also been recognized that there are a high frequency of false-positive signals in a real-time PCR-based "Plus/Minus" assay [9]. Hence, the possibility that the PCR verification method may have resulted in inaccurate results. The pathogen was not verified by a third party lab to be actual STEC *E. coli* O157:H7. Only positive or negative results were obtained for this study.

We recommend that several other universities and third-party labs run samples and validate the results. However, no samples have been provided, which may be impossible to obtain based on the study being conducted in early 2018. Without this verification, there are questions about the possibility of false-positives due to the presence of environmental *E. coli*, fecal coliforms, or a wide variety of other bacteria commonly found in nutrient-rich environments [10].

4.4. Impact of Sterilization

The study conclusion suggests that sterilization efforts are critical. "Our results indicated that contamination with bacterial pathogens could likely be reduced in aquaponic and hydroponic systems if the entire systems were thoroughly sanitized before each use and pathogen-free fish were used for the operation." This statement is inaccurate and could be detrimental to proper food safety practices. As the microflora of the system develops, it creates an environment that can suppress phytopathogens [11] and other zoonotic pathogens as a result of antibiotic compounds released by beneficial bacteria [12]. In recirculating aquaculture (RAS), some microbial communities take over 15 years to develop [13], resulting in greater stability over time.

Many papers support this hypothesis with regards to probiotics in wastewater treatment, aquaculture, and hydroponics. Microbial community analysis also depicts a greater microbial diversity in aquaponics over decoupled or aquaculture systems [14], indicating a more significant potential for the suppression of pathogens in coupled aquaponic systems over RAS or decoupled aquaponic system. No pathogens were discovered in a mature coupled aquaponics system during 18 years of continuous research in Canada since 2002 (Savidov, personal communications).

These findings support the argument that more biologically mature systems are less likely to develop pathogens and that periodic sanitation should not be done outside of initial start-up unless a zoonotic pathogen [15], is detected. If a pathogen is found, producers should follow proper sanitation and recall procedures.

5. Final Words

Overall, this and other research into food safety are ongoing, an d new information becomes available continuously to help shape the best practices for proper greenhouse management. As the Aquaponic Association, we hope to provide the most accurate and reliable resources for this purpose. At the same time, we hope to reduce the possibility of studies such as this creating unnecessary fear, or unsubstantiated claims that could harm the growth of the aquaponic (and hydroponic) industry.When a document such as this is published, it will be quoted by the media, an d referenced in other studies as if it is an absolute. Other research must be performed to validate or negate this study's outcomes.

Our findings conclude that although there is a low chance of the persistence of a pathogen in properly designed aquaponic and hydroponic systems, there is still a potential concern. No agricultural system is immune to this. Compared to soil production, soilless crops grown in a controlled environment are far less likely to become infected with pathogens from mammals, birds, an d other creatures, which are difficult to prevent in field crop production. Human contamination or poor handling practices are of significant concern [16]. The best way to avoid risk is to adhere to food safety guidelines set forth by the USDA, GlobalGAPs, the Aquaponic Association, an d other accredited organizations.

References

1. Lim, J.Y.; Li, J.; Sheng, H.; Besser, T.E.; Potter, K.; Hovde, C.J. Escherichia coli O157:H7 colonization at the rectoanal junction of long-duration culture-positive cattle. *Appl. Environ. Microbiol.* **2007**, *73*, 1380–1382. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1828644/ (accessed on 28 July 2020). [CrossRef] [PubMed]
2. Solomon, E.B.; Potenski, C.J.; Matthews, K.R. Effect of Irrigation Method on Transmission to and Persistence of Escherichia coli O157:H7 on Lettuce. *J. Food Prot.* **2002**, *65*, 673–676. Available online: https://www.ncbi.nlm.nih.gov/pubmed/11952218 (accessed on 28 July 2020). [CrossRef] [PubMed]
3. Guillen, G.; Wrast, J.; Environmental Institute of Houston. Fishes as Sources of E. coli Bacteria in Warm Water Streams. 2010. Available online: https://www.uhcl.edu/environmental-institute/research/publications/documents/10-015guillenetalfishreport.pdf (accessed on 28 July 2020).
4. Gao, T.; Haine, T.; Chen, A.; Tong, Y.; Li, X. 7 logs of toxic strain of E. coli were removed by mesophilic AD process while ~5 logs increase of the strain were seen in water control with the same condition for 7 days. 2011.
5. Dankwa, A.S. Safety Assessment of Hydroponic Closed System 127. 2019. Available online: https://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?article=4052&context=etd (accessed on 28 July 2020).
6. Berry, E.D.; Wells, J.E.; Bono, J.L.; Woodbury, B.L.; Kalchayanand, N.; Norman, K.N.; Suslow, T.V.; López-Velasco, G.; Millner, P.D. Effect of Proximity to a Cattle Feedlot on Escherichia coli O157:H7 Contamination of Leafy Greens and Evaluation of the Potential for Airborne Transmission. *Appl. Environ. Microbiol.* **2015**, *81*, 1101–1110. [CrossRef] [PubMed]
7. Riggio, G.; Jones, S.; Gibson, K. Risk of Human Pathogen Internalization in Leafy Vegetables During Lab-Scale Hydroponic Cultivation. *Horticulturae* **2019**, *5*, 25. [CrossRef]
8. Boston University Agent Sheet E. coli EHEC or STEC. Available online: https://www.bu.edu/researchsupport/safety/rohp/agent-information-sheets/e-coli-0157h7-agent-information-sheet/ (accessed on 28 July 2020).
9. Nowrouzian, F.L.; Adlerberth, I.; Wold, A.E. High Frequency of False-Positive Signals in a Real-Time PCR-Based "Plus/Minus" Assay. 2009. Available online: https://www.ncbi.nlm.nih.gov/pubmed/19161539 (accessed on 28 July 2020).

10. Konstantinidis, K.T.; Luo, C.; Georgia Tech Institute. Environmental E. coli: New way to classify *E. coli* Bacteria and Test for Fecal Contamination. 2011. Available online: https://www.sciencedaily.com/releases/2011/04/110411152527.htm (accessed on 28 July 2020).
11. Bartelme, R.P.; Oyserman, B.O.; Blom, J.E.; Sepulveda-Villet, O.J.; Newton, R.J. Stripping Away the Soil: Plant Growth Promoting Microbiology Opportunities in Aquaponics. *Front. Microbiol.* **2018**, *9*, 8. [CrossRef]
12. Compant, S.; Duffy, B.; Nowak, J.; Clément, C.; Barka, E.A. Use of Plant Growth-Promoting Bacteria for Biocontrol of Plant Diseases: Principles, Mechanisms of Action, an d Future Prospects. *Appl. Environ. Microbiol.* **2005**, *71*, 4951–4959. [CrossRef]
13. Bartelme, R.P.; McLellan, S.L.; Newton, R.J. Freshwater Recirculating Aquaculture System Operations Drive Biofilter Bacterial Community Shifts around a Stable Nitrifying Consortium of Ammonia-Oxidizing Archaea and Comammox Nitrospira. *Front. Microbiol.* **2017**, *8*, 101. [CrossRef] [PubMed]
14. Eck, M.; Sare, A.; Massart, S.; Schmautz, Z.; Junge, R.; Smits, T.; Jijakli, M. Exploring Bacterial Communities in Aquaponic Systems. *Water* **2019**, *11*, 260. [CrossRef]
15. Henderson, H. Direct and indirect zoonotic transmission of Shiga toxin–producing Escherichia coli. *J. Am. Vet. Med. Assoc.* **2008**, *232*, 848–859. [CrossRef] [PubMed]
16. Pattillo, D.A.; Shaw, A.M.; Currey, C.J.; Xie, K.; Rosentrater, K.A. Aquaponics Food Safety and Human Health. 2015. Available online: https://southcenters.osu.edu/sites/southc/files/site-library/site-documents/abc/aquaponics_workshop/AquaponicsFoodSafetyandHumanHealthAllenPatillo.pdf (accessed on 28 July 2020).