Post-harvest fresh produce wash water disinfection by submerged cold plasma non-chemical continuous treatment system

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Summary

Cold plasma water treatment is a possible solution for non-thermal disinfection washing of minimally processed fresh-cut produce. The reverse vortex gliding arc plasma systems created by scientists of Nyheim Plasma Institute (NPI), Drexel University, can be used to disinfect delicate fresh produce with no adverse quality effects, low cost operation, and no added chemicals. For this project, Drexel University scientists started collaborative activities with Dole Food Company analyzing the possibility of using plasma-activated water (PAW) and plasma-activated mist (PAM) for their industrial washing process. We will optimize the existing reverse vortex gliding arc plasmatron for the specifics of the food processing plant, validate this new system in the lab, and finalize this project by a full validation of the created prototype at an industrial-scale testing facility.

Benefits to the Industry

By developing a working method for a non-thermal disinfection of minimally processed fresh-cut produce, disinfection of fresh produce can be done in an effective, less expensive, and less harmful manner. This method would be able to be used for large-scale disinfection of produce due to its lack of adverse quality effects, low cost operations, and elimination of chemicals that are typically used to disinfect fresh produce.

Objectives

1. Construct and install a 100-gallon flow-through water tub for lab-scale testing.
2. Modify the reverse vortex gliding arc plasmatron electrode to fit the 100-gallon tub.
3. Optimize the existing 3-kW power supply for the newly constructed electrode.
4. Using the microbial "cocktail" (*E. coli* strains ATCC 2592, 35218, 11229, and 8739), validate the disinfection efficiency and generate the operating parameter space for the plasma system.
5. Using an increasing amount of organic load, validate the plasma disinfection efficiency.
6. Optimize the plasma system for industry-level testing and perform testing at SmartWash Solutions facility in Salinas, CA.
7. Generate the intellectual property, such as patent applications, schematics, etc. for the commercial prototype system.

Methods

Experiments were performed with plasma-treated water and E. coli O157:H7 (ATCC 700728) to validate disinfection efficiency. Plasma-treated water was produced by the gliding arc plasmatron (**Figure 1**): water flow at 60 mL/min, plasma air flow at 50 standard liters/min (SLPM), wall protection air at 45 SLPM, and water atomization air at 22 SLPM.

- For experiments performed with 975 W plasma power, *E. coli* was inoculated on spinach, kale and lettuce (105–106 CFU/g). After 2 days storage at 4°C, produce was separated into bags and washed for 1 min in plasma-treated water cooled to 3–5°C (10 g leaves: 200 mL water). Sucrose was added to plasma-treated water to increase organic load to 2000 mg/L. Produce was dewatered and then stomached in 10 mL sterile PBS to extract *E. coli*. *E. coli* was quantified by plating on tryptic soy agar overnight at 37°C.

Results to Date

After plasma-treated water was generated for each experiment, pH, temperature, conductivity, and the amount of NO3- and H2O2 were measured (**Table 1**). Log reduction of *E. coli* on each produce type washed in plasma-treated water and tap water was determined (**Table 2**). *E. coli* remaining in wash water (plasma treated and tap) was also quantified (**Table 3**). *E. coli* remained in washed tap water at higher level than in plasma-treated water, which means plasma-treated water is able to reduce cross contamination between batches of produce wash in the same tank of water.

Based on preliminary lab-scale experiments with disinfection and activation of water we have designed a scaled-up integrated 3-tank plasma washing system (total volume ~100 gallons) to be tested in industrial conditions. This integrated system (**Figure 2**) includes a gliding arc based subsystem for disinfection and activation of washed water (plasma power 1.3-1.6 kW; air flow rate 80-100 SLPM; water flow rate 30-60 ml/min).

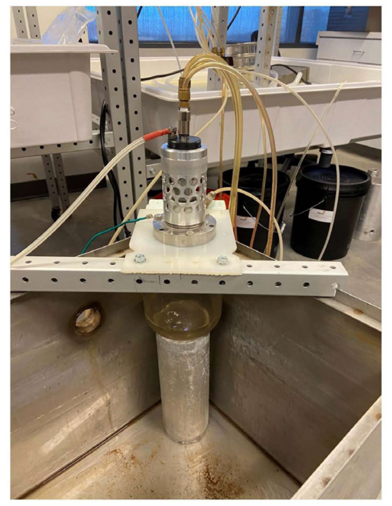

Figure 1 Water Collection from the Gliding Arc Plasmatron

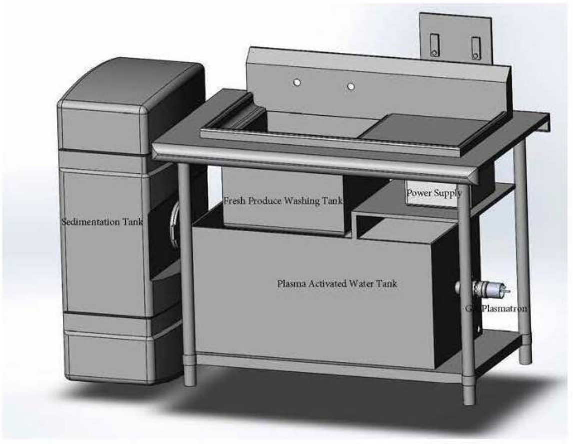

Fig.2 Integrated Fresh Produce Plasma Washing System

Table 1 Plasma-treated Water Parameters

	right after collection	1 hour after collection in room temp	1 hour after collection in chiller	tap water
pH	3	3	3	7.3
EC mS/cm	1	1	1	0.36
Temperature °C	28.7	23.6	4.6	4.9
Peroxide ppm	50	25	50	0
NO3- mg/L	250	250	250	0
NO2- mg/L	0	0	0	0

Table 2 E.coli Log Reduction on Produce Washed in Plasma Water and Tap Water without and with additional organic

	plasma water COD 0/2000	tap water COD 0/2000
spinach	2.70±1.09/2.36±0.49	1.90±0.79/2.09±0.28
kale	1.92±0.51/2.17±0.59	1.26±0.45
lettuce	1.21±0.43/0.73±0.2	0.63±0.27/0.80±0.21

Table 3 E.coli Remained in Wash Water without and with additional organic

			plasma water COD 0/2000 CFU/mL	tap water COD 0/2000 CFU/mL
spinach			25±26%/168±44%	79±7%/63272±15%
kale			1997±22%/1336±51%	175200±18%
lettuce			150800±13%/2300±9%	150000±10%/13680±4%