

Ultraviolet Disinfection

Improved methods of UV processing for fruit juices

Larry J. Forney and John A. Pierson

The Center for Disease Control (CDC) estimates a mortality rate of 5,000 Americans per year among 76 million cases of foodborne illness. While a majority of foodborne illnesses are related to consumer handling, many originate with the food processor. Because of recent outbreaks across North America associated with the consumption of unpasteurized juices and cider, greater pressures are being placed upon the juice industry for cost-effective sanitation methods for juice production.

In response, the United States Food and Drug Administration (FDA) has published a rule designed to improve the safety of juice products. The final version of the rule (21 CFR 120) requires juice manufacturers to develop a Hazard Analysis and Critical Control Point (HACCP) plan for the production of juice products. Moreover, the juice manufacturers must achieve a five-log reduction in the numbers of the most resistant pathogen in the finished products.

The most common and accepted method of reducing pathogen levels in juices is a mild heat treatment called pasteurization which raises the fluid temperature to roughly 72°C (162°F) for 15 seconds. Pasteurization destroys the vegetative microorganisms (e.g., *E-coli*, lysteria, and salmonella) but not heat-resistant spores. The process reduces viable bacteria to very low levels and refrigeration reduces further growth. Unfortunately, pasteurization also reduces the nutritional value of juices by partially destroying essential vitamins such as C, B1, and B2, and natural enzymes. The most noticeable effect is the change in juice flavor.

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Fortunately, the FDA rejected mandatory pasteurization in the HACCP plan thus encouraging the development of other technologies. An attractive alternate technology is the use of UV irradiation which the FDA approved in a

subsequent ruling (21 CFR 179). The latter specified that units used for this purpose must carry a validation certificate to prove they are capable of achieving the necessary five-log reduction in target pathogens in the processed juice.

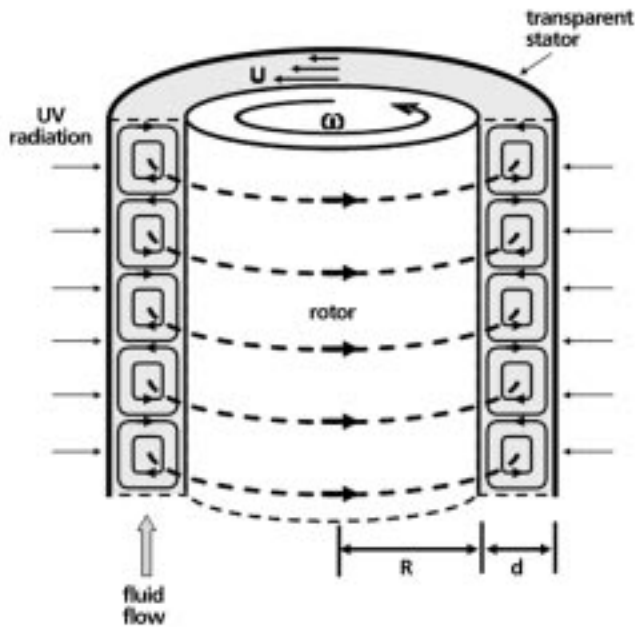
Although the use of UV irradiation to inactivate microorganisms in fruit juices is not new, the target organisms have typically been yeasts and bacteria that reduce the shelf life of the juice. In fact, the industrial use of UV has been limited because of the large absorbancy of the radiation in juices that contain suspended solids and pulp thus reducing the flow rates necessary to achieve sufficient exposure of contaminants to the UV.

Current UV reactors for juice processing use either very long tubes up to 91 meters (300 feet) with UV transparent walls or very thin films to ensure sufficient exposure to UV radiation. The reactor design with long tubes requires turbulent flow and over 38 liters (10 gallons) of juice exposed to a large number of UV lamps. In contrast, the design with thin films operates in laminar flow but is restricted to low viscosity juices with no pulp.

Recently, researchers at Georgia Tech have developed an attractive alternative to the commercial designs. The new UV reactor pumps fluid through the annular



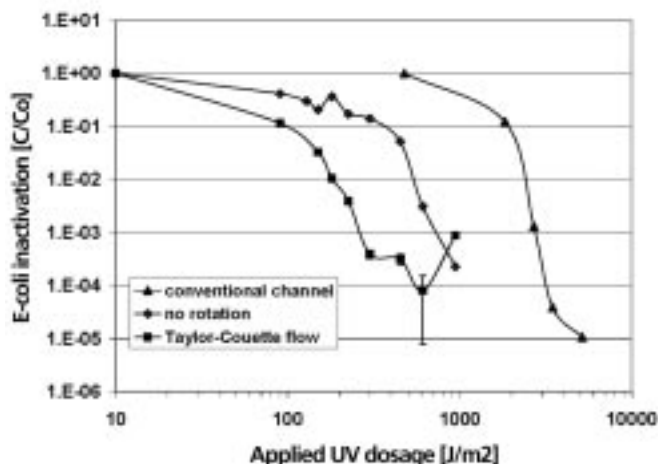
Shown above is a bench-scale UV reactor.



Schematic of the Taylor-Couette UV reactor, shown here, with rotating cylinder of radius R . Annular gap width is d .

gap between two concentric cylinders as depicted in the schematic. To provide sufficient exposure and to reduce the fluid boundary layer thickness next to the radiation source contained within the outer stationary cylinder, the smaller inner cylinder rotates at a low rpm. Rotation of the inner cylinder establishes a complex flow field called Taylor-Couette flow consisting of laminar vortices that both fill the annular gap of several millimeters and circumscribe the inner cylinder.

Pathogens that pass through the annular gap in the new design revolve around the axis of the reactor and are forced against a small number of stationary UV lamps. Each



Viable *E-coli* as a function of UV dosage: lower data is for Taylor-Couette flow; middle data is with rotation; upper data is a conventional channel.

pathogen thus makes multiple contacts with a single lamp and the distance separating the microorganism from each lamp is reduced to a millimeter or less because of the action of the laminar vortices. Preliminary tests with *E-coli* subjected to the same dosage indicate a substantial improvement in the inactivation levels compared to flow with no rotation or within a conventional channel as shown bottom left. Additional data also indicate that an optimum rpm exists for a given fluid and reactor size that optimizes the reactor performance. The latter data indicate that a maximum dosage occurs when the fluid boundary layer thickness is equal to the penetration depth of the UV radiation.

Numerical simulations of the flow field including pathogen trajectories, pathogen residence times, and dosage distributions are currently in progress. Preliminary experiments have been conducted with a bench-scale design as shown, but a larger pilot-scale with a maximum flow rate of several liters (gallons)/ per minute is under construction.

One concludes that the Taylor-Couette reactor is easy to scale-up. For a constant annular gap width, the only important parameters are the inner cylinder length, diameter, and rotation rate. Moreover, the character of the flow

Cost Comparison: Juice Processing Methods

Process	Cost (US cents/gal)
CO ₂	~ 5
High Pressure	~ 15
Pasteurization	~ 5
Conventional UV	~ 0.2

"Fresh Today, Safe Next Week," from *Food Engineering*, Feb. 2001

within the gap does not depend on the flow rate. The geometry also reduces the necessary lamp number and thus the power requirements.

To conclude, there are several non-thermal processes capable of providing the FDA requirement of a five-log reduction in viable pathogens. These technologies include: high pressure treatment, CO₂ pressure processing, and UV treatment. The table above gives a cost comparison of these different methods. As shown, the use of UV offers a cost effective method for meeting the new FDA requirements. R

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