Sowing the Seeds of Innovation

NASA is working with Tupperware to grow vegetables in space

By Robert Grace

Most consumers know Tupperware Brands Corp. as the maker of high-quality, plastic containers in which to store their food. The National Aeronautics and Space Administration, however, views the Orlando-based company as a strategic partner that is helping the U.S. space agency to keep its astronauts healthy.

"We've had quite a long relationship with NASA," David Kusuma said in a recent interview.

Kusuma: Helping take Tupperware to new heights

Kusuma, Tupperware's vice president of research and product innovation, said the two organizations first began interacting shortly after he joined the firm in 2001. Back then, the agency asked Tupperware to design a storage system for the Orion capsule. While that project never came to fruition, the seeds of a working relationship had been planted.

In about 2009, Tupperware collaborated with retired International Space Hall of Fame astronaut Story Musgrave to develop a water filtration system. Until then, Kusuma recalls, the company had only dealt with water in products such as pitchers used in refrigerators or in sports bottles, but it wanted to get into more significant, higher-technology water-related products, especially for developing countries where water quality is lacking.

Building on original NASA technology, Tupperware went on to develop what it now calls its Nano Nature Water Filtration System, a household device that retails for close to $1,000 but which is one of the company's top sellers worldwide.

Aiding NASA's Green Thumb

In the past few years Tupperware's partnership with NASA has expanded, and it is now working closely both with NASA scientists and Techshot Inc. engineers to develop and refine a method for delivering nutrients to plants. Greenville, Ind.-based Techshot builds hardware for NASA and is one of the agency's implementation partners.

The system they've jointly developed—dubbed PONDS for Passive Orbital Nutrient Delivery System—has already been to the International Space Station (ISS), after riding aboard the SpaceX Dragon cargo spacecraft on a Falcon 9 rocket in April 2018, as part of the 14th mission to resupply the ISS.

One of that mission's scientific research tasks was to learn about growing vegetables in space. All of the astronauts' food is freeze-dried, noted Kusuma, which is why NASA says it is important to create a viable system to allow them to grow fresh plants and "salad-type crops to provide the crew with a palatable, nutritious, and safe source of fresh food, and a tool to support relaxation and recreation."

A key goal of the effort, NASA notes, is to increase the ability to provide astronauts nutrients on long-duration missions as the agency plans to sustainably return to the Moon and move forward to Mars.

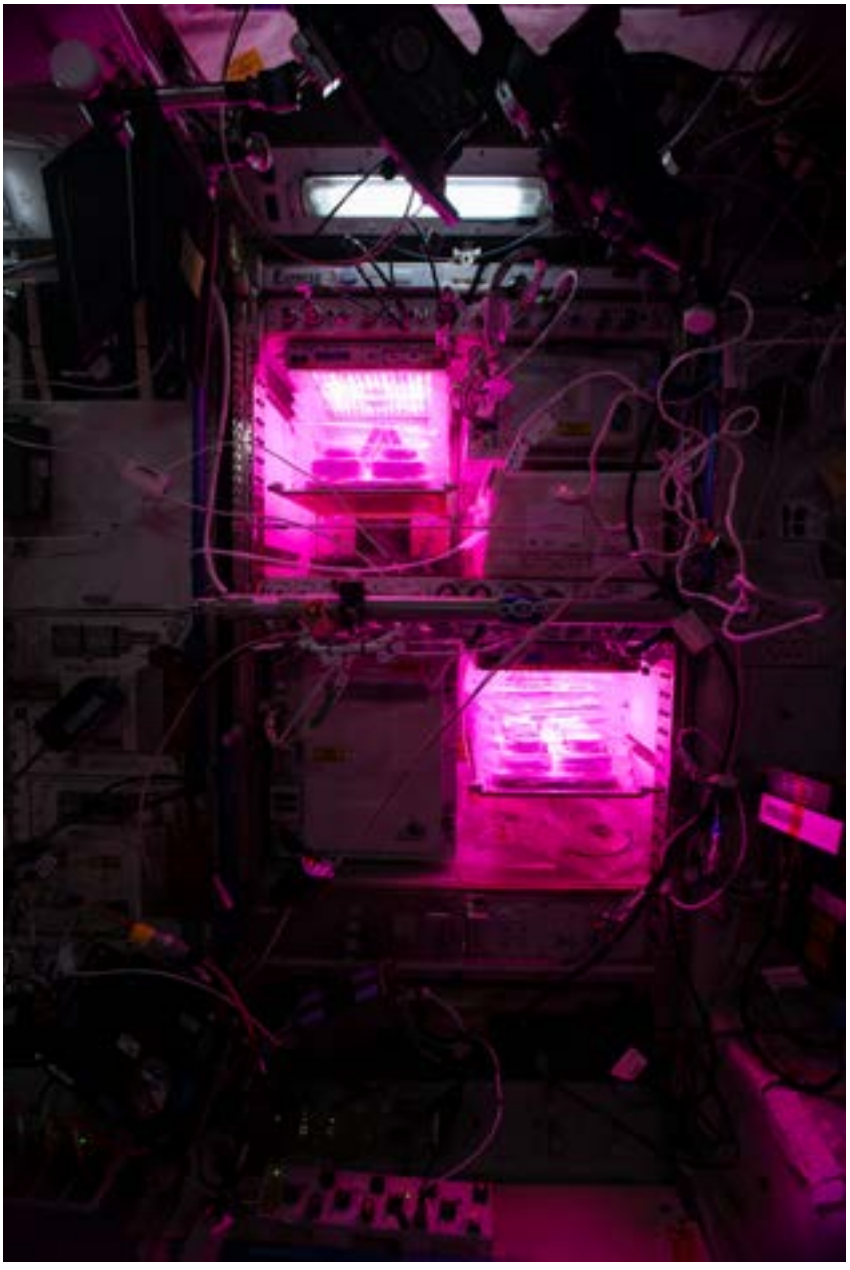
Since 2015, astronauts have grown crops in space using what is called the Vegetable Production System (or Veggie), a plant growth unit deployed on board that grows vegetables such as lettuce and tomatoes. To grow plants in space, they used seed bags, referred to as pillows, into which astronauts inject water with a syringe. But this method makes it difficult to grow certain types of "pick and eat" crops beyond lettuce varieties. Crops such as tomatoes use a large amount of water, and pillows don't have enough holding capacity to support them.

The Veggie also serves a scientific purpose, helping the agency to determine how plants sense, develop, and respond to gravity. And the taxpayer-supported agency is always looking for ways to transfer and apply the technology they develop in space to more terrestrial applications. To that end, NASA scientists say growing plants in space can help them understand how to improve plant production on Earth.

A New Plant-Growth System

In 2017, Howard Levine, chief scientist of NASA's Utilization and Life Sciences Office at the agency's Kennedy Space Center (KSC) in Florida, designed and created a prototype of the new PONDS plant-growing system. "There comes a point," Levine has said, "where you have longer and longer duration missions, and you reach a cost benefit point where it makes sense to grow your own food."

NASA then asked Techshot and Tupperware to work together to further develop Levine's prototype for use on the ISS.



Via the recently developed Passive Orbital Nutrient Delivery System (PONDS), Tupperware and Techshot are helping NASA to upgrade its Veggie plant-growth system in space, shown here. Courtesy of NASA

NASA's reason for approaching Tupperware, Kusuma says, is that "we have decades of experience in food conservation, and also in food-grade materials. And the whole purpose of this product was to create something that the astronauts could grow, germinate and harvest," with the goal of eventually consuming the vegetables and fruits they grow--not only on the ISS, but possibly in deep space, as well.

The system strives to address one of the main challenges of growing plants on orbit, which is to deliver the right amount of water and nutrients efficiently in a microgravity environment. PONDS units have features designed not only to mitigate microgravity effects on water distribution, but also to increase oxygen exchange and provide sufficient room for root zone growth.

"It's been a great relationship," Kusuma says of the three-way partnership. "We have been very close to the Techshot people ... and also had far more access to NASA resources than I had anticipated." Early in the project, Tupperware and Techshot got together at least weekly, he said—either at Tupperware headquarters in Orlando or at NASA's KSC in Cape Canaveral on central Florida's Atlantic coast. As the launch approached, the partners often met daily.

Kusuma and his team also visited Johnson Space Center in Houston, the site of NASA's space kitchen, where all the astronauts' food is prepared, and worked with the

agency's Cleveland-based Glenn Research Center, which has expertise in fluid dynamics in zero gravity. "We worked with [Glenn] primarily on the final product, with regard to materials, and shape and form," he said.

The partners also developed some of the key elements of PONDS with Dr. Mark Weislogel, a former NASA scientist and a preeminent expert in fluid dynamics who teaches at Portland State University in Oregon.

The Key is Controlling Water

The project involved some serious engineering challenges, Kusuma explained. Typically, if one pours water into a plant pot, the water goes down through the soil, and the roots follow that same path, while the plant grows upwards.

"But in space," he notes, "that's not how it works. Basically, water wants to go everywhere. So, the challenge is, how do you control the water so that it's only at the location where you need it, so the plant can continue to draw water from the reservoir by itself."

Working with Dr. Weislogel and the Glenn Research Center, the partners solved the problem by using three basic engineering principles:

- Specialized geometry, using generous radiuses to facilitate the channeling of the water;
- Surface energy, which can be manipulated to allow surfaces to attract or repel water; and
- Capillary forces, to draw liquids into areas through which they normally wouldn't want to flow. The team used special capillary mats to help draw the water at certain rates.

There were other challenges along the way, in terms of matching the expectations of Tupperware with those of NASA, according to Kusuma. NASA wanted the PONDS plastic base containers to be opaque, and they specified black as the color.

The issue is one of mold. If light can shine on a container with water, then algae and mold can grow. And mold—a sporadic, airborne activity—aboard the ISS would be a bad thing.

"For us at Tupperware," Kusuma explained, "being 'opaque' just means you can't see through it. But that's not NASA's definition. For them, being opaque means zero percent light transmission. So, we had to add more pigment. That was extremely important to them, in terms of the makeup of the material."

Canadian Space Agency astronaut David Saint-Jacques performs a reservoir fill on the Veggie PONDS facility in the Columbus module of the International Space Station. Courtesy of NASA

Developing PONDS 2.0

After a very successful ground test, in which the samples scored 100 percent germination, NASA decided to send samples to the ISS in spring of 2018. They learned from that test that the capillary action and the other principles applied to the samples were "too efficient," meaning the plants drew more water than had been expected. That led NASA to ask Techshot and Tupperware to work on version 2.0 of PONDS, to create some restrictions on the water flow.

NASA did not want to alter any of the plastic components, which fit well and already had been qualified. (Kusuma declined to identify the resin used in the components, other than to say it was not polyethylene.) Techshot worked closely with Tupperware's material scientists and mechanical engineers to design and injection mold components for what they called Veg-PONDS-02. They designed six PONDS containers to fit exactly into one of the Veggie's existing apparatuses.

This past April 19, a Northrup Grumman Cygnus spacecraft containing 12 new PONDS units in three new design configurations arrived at the orbiting laboratory. Six of those units had a clear design to allow researchers viewing real-time video to observe the performance of water in the units during the experiment. All the units contained red romaine lettuce seeds and were placed in

NASA astronaut Christina Koch works on space botany research using the Veggie PONDS gear to cultivate and harvest lettuce and mizuna greens for consumption on the International Space Station and analysis on Earth. Courtesy of NASA

the Veggie to test growth performance.

NASA astronaut Christina Koch initiated the experiment by filling the upper reservoir on April 25. Canadian Space Agency astronaut David Saint-Jacques filled the PONDS unit lower reservoir on May 2 and documented how water behaved in the system.

On May 16, the final day of the experiment, the plants were harvested. Six of the PONDS 2.0 units on June 3 returned to Earth on SpaceX's 17th commercial resupply services mission for further analysis.

Fine-Tuning the Next Design

Kusuma said they learned on the latest mission that they had over-restricted the water flow, which means more tinkering with the design. The partners plan to take the successful components and combine them into one final PONDS design, which will pave the way for the agency to truly begin testing the growth capability of crop varieties beyond leafy greens.

"PONDS was an opportunity to do something that no one else has done before," Dave Reed, Techshot's Florida operations director, has said. "People have been growing plants in space since the Apollo era but not like this."

NASA is now waiting for Tupperware and Techshot to deliver PONDS 3.0, with the redesigned units likely to go back to the ISS early next year for further testing, Kusuma said.

It has already been proven that the PONDS growth units are less expensive to produce than previous versions, have more water-holding capacity, provide a greater space for root growth, and are a completely passive system—meaning PONDS can provide air and water to crops without extra power.

And again, both Tupperware and NASA see promise for adapting the lessons learned in space with PONDS to Earth-based applications. So-called "green kitchens" are growing in popularity, involving the use of plant-growing systems for inside the home.

Highly Efficient Water Filtration

Which brings us back to the Nano Nature Water Filtration System, another product finding its place on

Tupperware has taken NASA technology and adapted it to produce this Nano Nature Water Filtration System for households. It filters out 99.99 percent of unwanted contaminants and has become one of Tupperware's biggest-selling products worldwide. Courtesy of Tupperware Brands Corp.

the countertops of many consumers. Using technology originally developed by NASA but later adapted and applied by Tupperware, this product is bringing clear, clean water to many who need it.

The unit attaches to a faucet and has a diverter valve to enable one to use the existing water—or to run it through the device's high-tech filter—to remove 99.99 percent of all bacteria, viruses, and cysts. The filter is wrapped in ceramic media and filters pathogens mechanically, meaning that no chemicals are needed or used.

The device also filters out all of the water's minerals and nutrients, which can be desirable to retain. So Tupperware added an enhancement tank, featuring a mineral rock found only in Japan that releases those desirable minerals back into the water before it is dispensed for drinking.

The outer case is molded from ABS, a resin that Tupperware seldom uses since it tends not to withstand dishwasher heat well. But this unit is not subjected to that type of high heat. Some of the interior parts are made from polyolefins, Kusuma said, and fluoropolymers are used at some of the connection points.

"It's probably the only Tupperware product that is assembled out of more than 100 parts," he notes. The Nano Nature is expensive, he acknowledges, but its high-end technology and performance make it worth the price.

And so, space-age technology continues to evolve and make the move from rocket ships to kitchen counters. Kusuma says Tupperware leverages its "super-strong relationship" with NASA and particularly with its Life Sciences group at the Kennedy Space Center, to discuss other potential areas of cooperation.

ABOUT THE AUTHOR

Robert Grace is a writer, editor and marketing communications professional who has been active in B2B journalism since 1980. He was founding editor of and worked for 25 years at *Plastics News*, serving as editorial director, associate publisher and conference director. He was managing editor of *Plastics Engineering* from July 2016 through October 2017, and is now both editor of SPE's *Journal of Blow Molding* and directing content strategy for SPE. He runs his own firm, RC Grace LLC, in Daytona Beach, FL., and can be contacted at bob@rcgrace.com.