

Space Life Sciences Research Highlights

Genetic Research Produces a More Nutritious Sweet Potato

Dr. Marceline Egnin and her colleagues at Tuskegee University have developed a protein-enriched sweet potato by incorporating a synthetic storage protein gene into it. This new sweet potato has the potential to provide enhanced nutrition in space and on Earth.

On future long-duration space missions on the lunar surface or to Mars, limited space onboard spacecraft will not allow astronauts to bring enough food, water, and oxygen to sustain their survival. They will depend on bioregenerative life support systems to produce food and recycle water, air, and waste.

NASA's Advanced Life Support (ALS) Program is responsible for the development of such systems. Crop plants are an essential component of ALS: they are a primary food source and they contribute to water purification, oxygen regeneration, and waste materials processing. The Center for Food and Environmental Systems for Human Exploration of Space (CFESH) at Tuskegee University—funded by the Minority University Research and Education Division of NASA—is an ALS center dedicated to working with sweet potato and peanut crops for potential use in bioregenerative life support.

The sweet potato, the sixth largest food crop on Earth, is a good candidate for space travel because it has high levels of carbohydrates and minerals and therefore is a good source of energy. Also, the leaves are edible, producing more food products and less waste. Onboard the spacecraft there is limited space available for growing plants, and the sweet potato can produce a high yield in a confined space. The plant is also efficient in converting carbon dioxide to oxygen, which is an essential function in closed ecological systems. However, until recently, the sweet potato had a drawback: it did not contain

sufficient protein and amino acids to provide astronauts with their complete nutritional requirements. NASA is looking for such nutritionally rich crops because animal products will not be available on space missions.

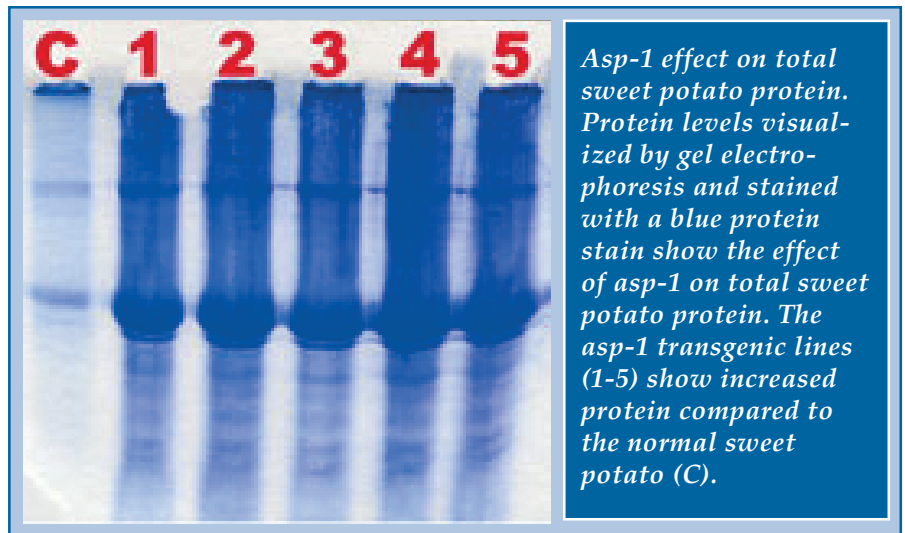


*Sweet potato is a candidate crop for NASA's bioregenerative life support systems. (Left) Transgenic sweet potatoes growing in field show that yield is comparable to that of control sweet potatoes. (Right) Incorporation of the *asp-1* gene increases protein in the sweet potato by 300 to 500 percent.*

Synthetic Gene Enhances Nutrition

Part of NASA's mandate to CFESH, explains the center's coordinator Dr. Desmond Mortley, is to increase the sweet potato's nutrition. This goal is the responsibility of the Germplasm Development and Improvement team of CFESH. With the aid of biotechnology, Dr. Marceline Egnin has developed a transgenic sweet potato that has dramatically enhanced levels of protein and essential amino acids. Egnin's team achieved this higher protein level by incorporating a synthetic storage protein gene into the sweet potato. With the gene, called *asp-1*, the protein levels increased three-to-five fold. This increase in protein level is important to NASA because it reduces the amount of sweet potato astronauts would need to consume in order to receive a sufficient amount of protein, which in turn reduces the number of plants required in the limited growing space.

The increased nutritional value of the sweet potato also has the potential to make a tremendous impact on human health on Earth, since it is a major crop in many developing countries in Africa and South Asia. In these regions, many people, especially children, suffer from malnutrition. Explains Dr. Egnin: "A child would have to consume about 4 kilograms of sweet potatoes to meet his or her daily nutritional requirement. But with this new essential amino acid and high protein sweet potato, a child would have to consume only about 300 grams." For people becoming more health conscious and eliminating meat from their diet, the transgenic sweet potato provides an alternative that can provide the required protein.



Incorporation of the Gene

The *asp-1* gene is an artificial storage protein gene invented in the late 1980s by Dr. Jesse Jaynes of Demeter Biotechnologies Inc. When the Tuskegee team began the project, they entered a research agreement with Jaynes for use of the *asp-1* gene.

Egnin's team incorporated the *asp-1* gene by a method called agrobacterium-mediated transformation. *Agrobacterium tumefaciens* is a soil-borne bacterium, which has a circular piece of DNA called a plasmid. With this method, the *asp-1* gene is inserted into the plasmid. In turn, the bacteria infect the sweet potato leaves and the plasmid naturally incorporates the gene into the plant chromosomes and the *asp-1* becomes part of its genome. "It's a natural, beautiful system which has been going on for millions of years," says Egnin. This gene transfer system is a more efficient and accurate alternative to particle bombardment, which is a system that uses a gene gun to shoot the gene straight into the plant cell. Recent improvements in the agrobacterium-mediated transformation technique have enabled its application to a wide range of plants.

The Future of the Transgenic Sweet Potato

With the gene successfully inserted into the plant DNA, the next stage for the researchers was to grow the crops. CFESH has succeeded in growing the plants in the lab, in greenhouses, and in the field. Field trials have revealed that the yield of the transgenic sweet potato is comparable to that of the normal sweet potato, so yield is not being compromised for increased nutrition.

Egnin's team has conducted an animal nutritional evaluation of the new sweet potato. In this test, hamsters were fed six different diets, including one with

transgenic sweet potato. The results of the 28-day test showed that the growth of the hamsters on the transgenic sweet potato diet was similar to the growth of hamsters with a soy diet, which is very rich in protein. Future testing includes a 90-day animal trial and a human trial.

Egnin says the *asp-1* transgenic sweet potato is about four years from being ready for introduction into the commercial market. Before the transgenic sweet potato goes up in space, the other CFESH teams will work together to integrate the plant into an advanced life support system for use on long-duration missions. The Crop Production and Environmental Systems team will work to improve its growing ability in hydroponics. The CFESH Food Technology and Utilization team will use the transgenic sweet potato to develop new food products for astronauts such as breakfast cereal, ice cream, sports drinks, and lasagna. Finally, the Waste Management and Recycling team will take the end products from the biomass production and foods area and find a way to recycle them.

The sweet potato is a versatile plant that can make a significant contribution to NASA's advanced life support goals. With the increased protein, the plant will help provide astronauts with the nutrition they need to remain healthy and perform well in space. On Earth, the plant can provide countless people with additional protein necessary to help prevent malnutrition.

Reference

1. Egnin M; Daniels CL; Prakash CS; Urban L; Zimmerman T; Crossman S; Jaynes J. Field performance of transgenic 'high protein' sweetpotatoes (*Ipomoea batatas* L., PI 318846-3) show no yield or phenotypic cost of an extra gene. *In Vitro Cellular & Developmental Biology* 37(3, Pt 2):37A, 2001.