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WIRELESS AND AUTONOMOUS MODULAR AGRICULTURAL SYSTEM FOR MICROGREENS IN EXTREME ENVIRONMENTS: ADVANCING LIFE SUPPORT FOR SPACE EXPLORATION

Abstract

In long-duration space missions, ensuring a reliable and sustainable source of fresh food is a major challenge. Growing essential crops in harsh environments requires innovative farming solutions. Building upon our product designed for Siberia's extreme climate, we propose a scalable, fully autonomous farming system for extreme weather conditions - from analog sites to real space. Optimized for the efficient growth of microgreens, this system offers a constant supply of nutrient-dense fresh produce for astronauts that could play a pivotal role in future space habitats.

The system is a compact, modular, and insulated enclosure designed for controlled environment agriculture (CEA), tailored for the cultivation of microgreens. Microgreens are ideal for space farming due to their rapid growth cycle, small space requirements, and high nutritional value, offering essential vitamins, minerals, and antioxidants. The system features an Arduino-based control system for regulating key environmental factors such as temperature (15-20C), pH levels, and lighting (200-400 mol/m/s PAR). Utilizing LED lighting and a nutrient reservoir with integrated sensors, the system ensures that microgreens grow optimally without natural sunlight.

Key components of the system include a Sensor Tower for real-time monitoring, a wireless communications system for remote control via LoRaWAN, and efficient power management (25-30W for 15-20 crops). This ensures minimal energy usage, a critical factor for space missions where power resources are limited. The system is designed to be scalable, adaptable to both small habitats and larger commercial-scale agricultural setups, providing astronauts with a reliable and energy-efficient food source in isolated environments.

Microgreens are particularly advantageous for space farming due to their short growth cycle (7-14 days), low water and space requirements, and high concentrations of vitamins A, C, K, and various antioxidants. Their cultivation provides not only a fresh food source but also a psychological benefit to astronauts, contributing to overall well-being during long-duration missions. The autonomous nature of the system ensures that astronauts can focus on mission objectives without worrying about the day-to-day maintenance of the crops.

In conclusion, our modular and autonomous agricultural system offers a practical solution for growing microgreens in extreme environments, making it ideal for long-duration space missions. By addressing critical factors such as environmental regulation, energy efficiency, and scalability, this system represents a key advancement in life support technology. Its ability to cultivate high-nutrient crops like microgreens ensures sustainable food production for astronauts on missions to the Moon, Mars, or beyond, redefining the future of human space exploration.