BioNutrients: Microbial production of on-demand nutrients on the International Space Station

**Abstract**: Providing adequate nutrition to crew members is essential as deep-space missions cannot rely on consistent Earth-based resupply. The current NASA pre-packaged food system is designed for low-earth-orbit missions with a stated shelf-life of two years and notable vitamin degradation over time. One strategy to mitigate nutrient loss is to implement bioregenerative food sources to supplement the pre-packaged food system. The BioNutrients project is designed to provide targeted production of short shelf-life nutrients in a single-use production pack. BioNutrients-1 includes two strains of edible yeast that have been genetically engineered to produce carotenoids, β-carotene, and zeaxanthin. This five-year mission on the International Space Station (ISS), launched in 2019, tests the long-term storage and nutrient production of the microorganisms of interest. Additional microorganisms are also stored in stasis packs to determine the effects of long-duration storage on the ISS. These organisms may be useful for production of fermented foods, pharmaceuticals, or biomanufacturing processes. Improving on the BioNutrients-1 project, BioNutrients-2 has optimized the production pack hardware by reducing the overall mass and volume of the system. Furthermore, BioNutrients-2 has expanded the projects scope by investigating novel products and microbial food sources. BioNutrients-2 is a six-month mission, launched in 2022, which tests production of fresh foods such as yogurt and kefir. The BioNutrients missions seek to provide advances for in-space biomanufacturing by addressing safe and reliable production of high-value nutrients and on-demand foods for future exploration efforts.

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