

Evaluation of Responses to a Plant-Based Diet in an Analog Setting

Aedanaya N. R. Diamond

American Public University System

ABSTRACT

Long-duration spaceflight requires food systems that are nutritionally adequate, logistically efficient, and psychologically sustainable. Animal-based food production is not feasible in space, making plant-based diets a necessity for missions beyond low Earth orbit and during the establishment of off-world outposts. This study examined analog astronauts' lived experiences with a fully plant-based diet during two confined 10-day missions at the SAM analog habitat.

Using the Health Belief Model as a framework, qualitative data were collected through pre-mission surveys and food logs, daily logs, mid- and post-mission surveys, and post-mission interviews. Participants reported higher-than-expected satisfaction, with benefits including taste, satiety, and team cohesion, while barriers such as food monotony and ingredient limitations were present but often mitigated by creativity and shared meal preparation. Several participants described post-mission shifts in their attitudes toward plant-based diets, indicating greater openness and confidence in plant-based cooking. The findings suggest that plant-based systems, when thoughtfully designed, can meet both nutritional and psychosocial needs in confined environments and should serve as the foundation for future space food system design.

Keywords: Space food systems, Space nutrition, Closed-loop life support systems, Space analog research, Human factors in space-flight

Evaluación de las respuestas a una dieta basada en plantas en un entorno analógico

RESUMEN

Los vuelos espaciales de larga duración requieren sistemas alimentarios nutricionalmente adecuados, logísticamente eficientes y psi-

cológicamente sostenibles. La producción de alimentos de origen animal no es viable en el espacio, lo que hace que las dietas basadas en plantas sean necesarias para las misiones más allá de la órbita baja terrestre y durante el establecimiento de puestos de avanzada en el espacio. Este estudio examinó las experiencias vividas por astronautas análogos con una dieta completamente basada en plantas durante dos misiones confinadas de 10 días en el hábitat análogo SAM.

Utilizando el Modelo de Creencias de Salud como marco, se recopilaban datos cualitativos mediante encuestas y registros de alimentos previos a la misión, registros diarios, encuestas a mitad y después de la misión, y entrevistas posteriores a la misión. Los participantes reportaron una satisfacción mayor de la esperada, con beneficios como el sabor, la saciedad y la cohesión del equipo. Si bien existían barreras como la monotonía alimentaria y las limitaciones de ingredientes, estas a menudo se mitigaron mediante la creatividad y la preparación compartida de las comidas. Varios participantes describieron cambios en su actitud hacia las dietas basadas en plantas después de la misión, lo que indica una mayor apertura y confianza en la cocina vegetal. Los hallazgos sugieren que los sistemas basados en plantas, cuando se diseñan cuidadosamente, pueden satisfacer las necesidades nutricionales y psicosociales en entornos confinados y deberían servir como base para el diseño futuro de sistemas alimentarios espaciales.

Palabras clave: Sistemas alimentarios espaciales, Nutrición espacial, Sistemas de soporte vital de circuito cerrado, Investigación análoga espacial, Factores humanos en los vuelos espaciales

在模拟环境下评估对植物性饮食的反应

摘要

长期太空飞行需要营养充足、后勤高效且心理上可持续的食物系统。在太空中，以动物性食物为主的生产方式不可行，因此，对于远超近地轨道的任务以及建立地外前哨站而言，以植物性食物为主的饮食必不可少。本研究考察了模拟宇航员在SAM模拟栖息地执行两次为期10天的封闭任务期间，对完全以植物性食物为主的饮食的体验。本研究以健康信念模型为框架，通过以下方式收集定性数据：任务前调查问卷和食物记录、每日记录、任务中期和任务后调查问卷以及任务后访谈。参与者报告的满意度高于预期，其益处包括口味、饱腹感和团队凝聚力。虽然食物单调和食材限制等障碍仍然

存在，但通常能通过创造力和共同准备膳食来缓解。一些参与者描述了任务后他们对植物性饮食态度的转变，表明他们对植物性烹饪更加开放和自信。研究结果表明，精心设计的植物性系统能够满足密闭环境下的营养和心理社会需求，并应成为未来太空食品系统设计的基础。

关键词：太空食品系统，太空营养，闭环生命维持系统，太空模拟研究，太空飞行中的人为因素

Introduction

Food systems in space must address more than energy balance and nutrient sufficiency; they must also support the psychological well-being and social cohesion of crews living in isolated, confined, and extreme environments. For long-duration missions and early off-world settlements, reliance on plant-based diets is not optional. The mass, volume, and resource demands of animal husbandry preclude its feasibility in spaceflight contexts.

Plant-based systems offer logistical and environmental advantages including greater shelf stability, lower water and energy requirements, and alignment with closed-loop life support. However, their success depends not only on nutritional adequacy but also on human acceptance under conditions where choice is limited and food plays a central role in morale and daily structure.

This study examined analog astronauts' experiences with a plant-based food system during confined missions, focusing on the psychological, behavioral, and social responses that inform the future design of space food systems.

Methods

Two analog crews participated in 10-day missions at the SAM facility, which maintains a fully plant-based operational food system. The study employed a qualitative, exploratory design using the Health Belief Model as a framework, with particular emphasis on perceived benefits and perceived barriers.

Participants and Protocol

All crew members were required to follow the same shelf-stable plant-based diet. No outside food was permitted. Participants voluntarily provided informed consent and completed multiple forms of data collection.

Data Collection

- Pre-mission surveys and food logs captured baseline habits and expectations.
- Daily food logs recorded consumption, preparation, satisfaction, and emotional reactions.
- Mid- and post-mission surveys provided reflections on adaptation and perceptions.

- Post-mission interviews explored participants' holistic evaluations of the food system.

Analysis

Data were analyzed thematically, with coding categories informed by the Health Belief Model. Themes were compared across time points and between crews to identify recurring patterns and variations.

Results

Satisfaction and Benefits

Participants reported higher-than-expected satisfaction with meals, frequently noting that food was flavorful and sufficient despite its shelf-stable form. Shared meals were described as positive, unifying experiences that reinforced team cohesion. Several participants described feelings of health, comfort, and psychological support from the food system.

Barriers

Perceived barriers included limited ingredient variety, food fatigue, and preparation effort. The absence of fresh produce was frequently cited. However, these barriers were mitigated by creativity in preparation and the social context of meals.

Social Dynamics

Meal preparation and consumption served as focal points for social interaction. Food was valued not only as sustenance but also as an activity that built routine, identity, and cohesion within the crew.

Post-Mission Shifts

Several participants reported changes in attitude toward plant-based eating. Some expressed greater confidence in cooking without meat, while others described increased openness to incorporating plant-based meals in their daily lives.

Future Technologies

When asked about the inclusion of cultured or 3D-printed meat, participants generally emphasized that nutrition was already sufficient. They valued food systems primarily for their sensory and psychological qualities rather than animal content, suggesting that plant-based systems may suffice if designed for variety and enjoyment.

Discussion

This study demonstrates that plant-based food systems, though constrained by shelf-stable formats, can meet both nutritional and psychosocial needs in confined mission settings.

Participants' experiences align with the Health Belief Model's constructs of perceived benefits and barriers, showing that barriers such as monotony and preparation effort were outweighed by perceived benefits including satisfaction, health, and team cohesion.

Importantly, food was not merely functional. It served as a cultural and psychological anchor, reinforcing routine, identity, and social bonds. These findings underscore the need to design

future space food systems around human factors as much as logistical constraints.

The results also highlight that acceptance of plant-based diets is not only possible but may improve over time as crews adapt, build new habits, and find meaning in shared food experiences.

Conclusion

Plant-based food systems are not an option but a necessity for spaceflight. This study provides evidence that such systems can be acceptable, adaptable, and even positively transformative for crews, provided they incorporate creativity, variety, and opportunities for shared engagement. For mission planners, the challenge is not whether plant-based diets can work, but how to design them to sustain both the body and the lived experience of the crew in space.

Acknowledgements

The author would like to acknowledge the APUS Analog Research Group and SAM at Biosphere 2 for their support and collaboration in integrating this research into their analog missions. The research described in this paper was supported through grants awarded by the APUS Graduate Research Office.

References

- Appleby, P. N., & Key, T. J. (2016). The long-term health of vegetarians and vegans. *Proceedings of the Nutrition Society*, 75(3), 287–293. <https://doi.org/10.1017/S0029665115004334>
- Belwal, T., Cravotto, C., Prieto, M. A., Venskutonis, P. R., Daglia, M., Devkota, H. P., Baldi, A., Ezzat, S. M., Gómez-Gómez, L., Salama, M. M., Campone, L., Rastrelli, L., Echave, J., Jafari, S. M., & Cravotto, G. (2022). Effects of different drying techniques on the quality and bioactive compounds of plant-based products: A critical review on current trends. *Drying Technology*, 40(8), 1539–1561. <https://doi.org/10.1080/07373937.2022.2068028>
- Carpenter, C. J. (2010). A meta-analysis of the effectiveness of Health Belief Model variables in predicting behavior. *Health Communication*, 25(8), 661–669. <https://doi.org/10.1080/10410236.2010.521906>

Graça, J., Calheiros, M. M., & Oliveira, A. (2015). Attached to meat? (Un)will-
ingness and intentions to adopt a more plant-based diet. *Appetite*, 95, 113–125.
<https://doi.org/10.1016/j.appet.2015.06.024>

Kim, H., Caulfield, L. E., Garcia-Larsen, V., Steffen, L. M., Coresh, J., & Rebholz,
C. M. (2019). Plant-based diets are associated with a lower risk of incident cardio-
vascular disease, cardiovascular disease mortality, and all-cause mortality. *Jour-
nal of the American Heart Association*, 8(16), e012865. [https://doi.org/10.1161/
JAHA.119.012865](https://doi.org/10.1161/JAHA.119.012865)

McClements, D. J., & Grossmann, L. (2021). A brief review of the science behind
the design of healthy and sustainable plant-based foods. *NPJ Science of Food*, 5(1),
17. <https://doi.org/10.1038/s41538-021-00099-y>

Sabaté, J., & Soret, S. (2014). *Sustainability of plant-based diets: Back to the fu-
ture*. The American journal of clinical nutrition. [https://pubmed.ncbi.nlm.nih.
gov/24898222/](https://pubmed.ncbi.nlm.nih.gov/24898222/)