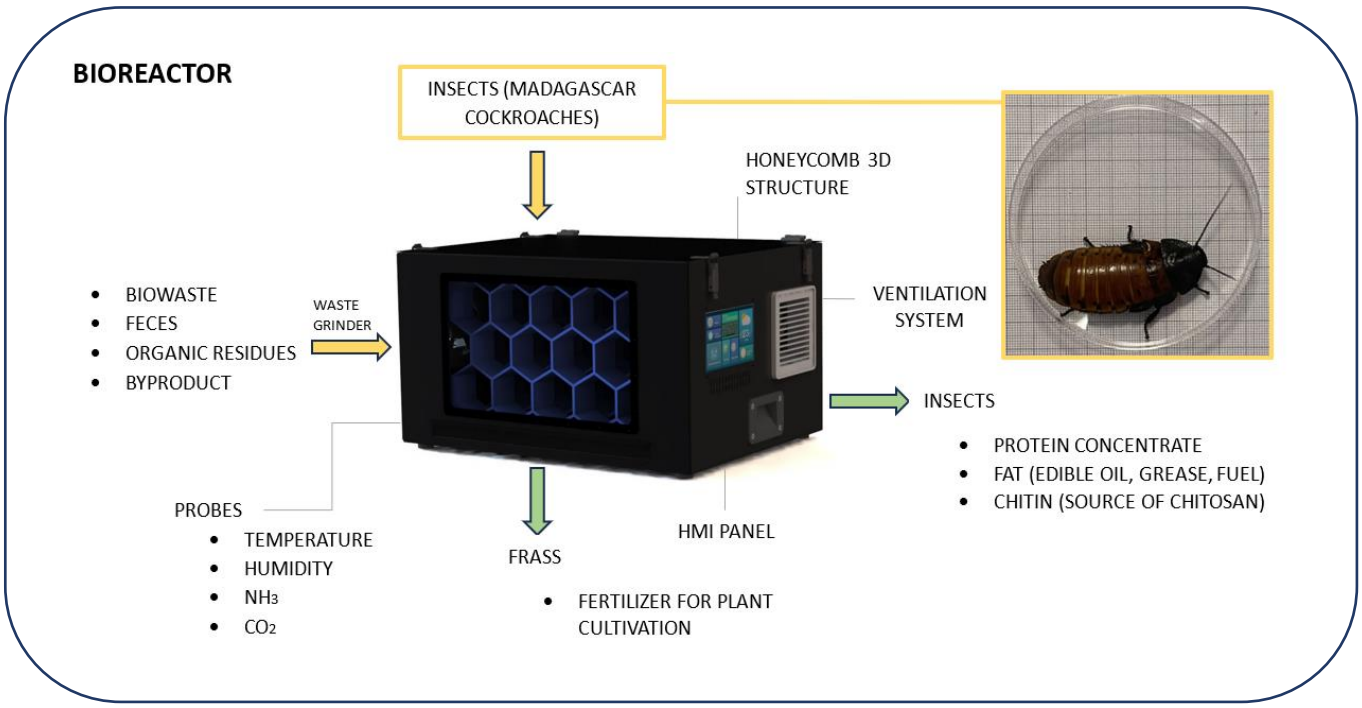

An insect bioreactor for increased circularization of ECLSS economy (ECLSS Insect Bioreactor)

Executive summary

Early technology development

Affiliation(s): Astronika, Nomi Biotech Corporation

Activity summary:
The experiment aimed to confirm the potential of insects, specifically Madagascar cockroaches (Gromphadorhina portentosa), to process waste biomass, including faeces, in controlled environments. These cockroaches were selected for the experiment due to their unique features, trophic preferences, behavior and the specificity of the development cycle. The study demonstrated that cockroaches could thrive on a mono-diet of animal faeces, complete their development cycle, and reproduce without adverse effects. Key parameters such as feed conversion rate, optimal environmental conditions, and nutritional values of cockroach biomass were determined. The success of this study supports further research into bioconversion of waste generated during space missions.

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Implemented as ESA Initial Support for Innovation

Introduction:

In response to the critical challenges posed by waste management and biomass production in long-duration space missions, such as those on the International Space Station (ISS) and future lunar bases or Gateway missions, this project proposed the development and demonstration of an innovative closed-loop bioreactor system utilizing insects. Traditional waste disposal methods in space, which often involve storage or return to Earth, contribute to orbital debris and increased logistical demands. By leveraging insect farming within a bioreactor, this project aimed to facilitate the enhancement of sustainability and reduction of operational costs associated with waste management and life support technologies in space environments.

Scope of Work:

The scope of this project encompassed the following key activities:

1. **Biological Path**: Study and optimize farming methods for selected species of roaches known for their resilience and adaptability to diverse environmental conditions, aiming to establish robust insect populations capable of sustained growth solely on mission waste or supplemented feedstock.
2. **Non-biological Path**: [TRL3] Design a bioreactor system to support insect life and process waste efficiently, maintaining optimal environmental conditions.
3. **Integration and Demonstration**: [TRL4] Integrate the biological and non-biological pathways to populate the bioreactor with insects and demonstrate a closed-loop life cycle.

Bioreactor – proof of concept development

The bioreactor was designed to fit the European Drawer Rack on the ISS, with features like 3D honeycomb structures to facilitate insect movement in low gravity environment, a waste grinder to process the waste more efficiently by the insects and various sensors for environmental monitoring. It included air ventilation with carbon filters and HMI panel for monitoring and controlling the environmental parameters.

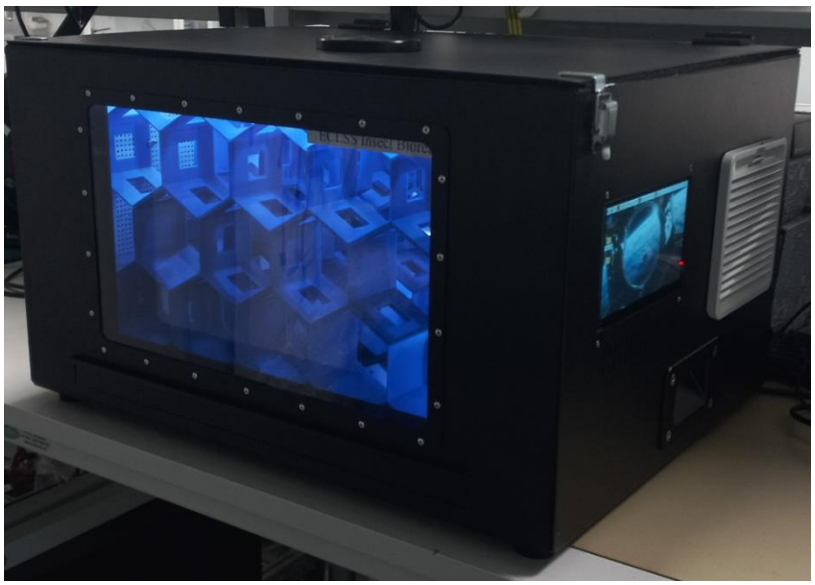

Figure 1 Bioreactor

Figure 2 Insects moved to Bioreactor

Conclusions

The experiments have confirmed that:

- cockroaches can use a mono-diet based on animal feces (a generic diet based on horse manure was used in the experiments),
- cockroaches can be bred in a closed system,
- cockroaches fed a mono-diet can complete the development cycle and produce offspring,
- mono diet does not cause adverse effects such as dwarfism, developmental anomalies, deformations and does not significantly affect fertility and reproductive abilities,
- a system of 3D inserts based on a honeycomb structure allows for even and effective use of 3D space within the breeding container,
- with minor improvements needed (sealing of the ventilation, improved air flow, upgraded grinder and canteen, improved lightning, zonal heating) bioreactor fully matches its expected functionality,
- current size of the bioreactor can steadily maintain the population of **4-6 kg** of the roaches, being able to convert between **2,5 and 3,6 kg** of the waste containing ca 50% of the dry matter per week,
- with the full capacity of the bioreactor between **1,2 and 2 liters** of the water can be recycled from the waste (per week) depending on the vapor condensation efficiency,
- depending on the population capacity and with ambient temperature between 20 and 24 deg. C total energy consumption can be estimated at **0,5-1,0 kWh at 0,7A** per day,
- productivity of the bioreactor **500-700 g** of insect biomass per week which is equal to **100 - 140 g** of crude protein.

Additionally, the following parameters were designated:

- FCR (feed conversion rate) for a mono-diet,
- optimal environmental parameters (humidity, temperature, air exchange),
- length of the development cycle,
- population growth rate,
- basic nutritional values of cockroach biomass,
- basic parameters of frass (feces) as fertilizer.

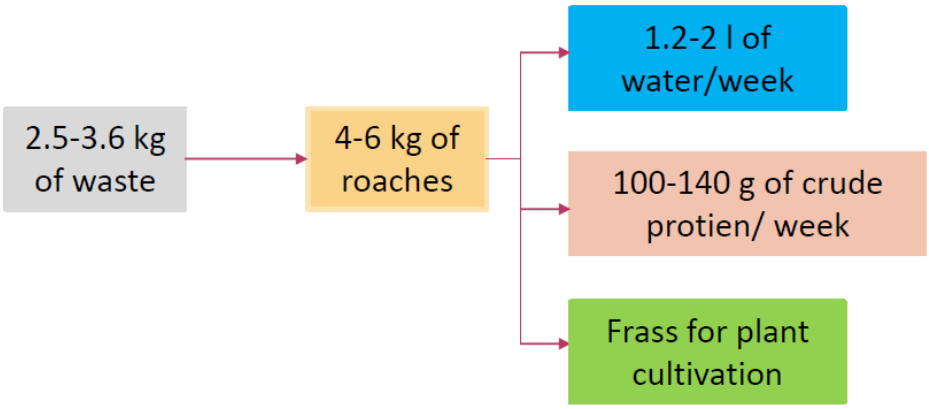

Figure 3 Insert feed and receive water output and biomass protein - approximation based on the experiment