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Benefits of Use of Microalgae in Spacecraft

Arnab Chattopadhyay[1,*], Suravi Pal[1]

Abstract

In this time of modern science and technology, we need sustainable development, so that we can meet the demand of future generations as well as the present generation. For this reason, scientists are trying to develop such products which have a considerable remark on every research. Consuming algae as a human food became popular over 70 years after it was discovered in 1942. This concept was first implemented in spacecraft when it was sent to space with human beings and scientists decided to cultivate and grow the algae in the space shuttle. Because there was not enough oxygen available for long-distance space travel, this technique was devised. To solve this problem, scientists have suggested that Chlorella vulgaris can be a blessing for the hybrid life support system (LSS), through physicochemical reaction, food production, and continuation of biological processes. The international space station has concluded that Chlorella can generate oxygen and water by consuming the carbon dioxide produced by the astronauts. It has a 10 times better effect in photosynthesis than any other complex plant. In space research, there is a main concern to managing the total weight of the spacecraft. From the research, scientists said that there is no effect on the algal population due to the weightlessness. Also, it is very tough to maintain a stable ratio between the consumption of oxygen and to exhalation of carbon dioxide. And for this again chlorella is the only solution. It is also seen that a green-algae is a very good source of vitamins, proteins, and other minerals. Chlorella can also survive in extreme conditions. So, it is suspected that, in upcoming space missions, microalgae is the only solution to resolve the scarcity of food and oxygen in spacecraft. Besides being used as a food supplement it will help to fill the nutrients, required for every human being in daily life. This paper focuses on the production and use of chlorella in space environment and its challenges.

Keywords: Life support system, microalgae, oxygen production, food supplementary, space research, *Chlorella*, algae

INTRODUCTION

Microalgae are single cells and photosynthetic microbes that can live in salty or freshwater environments, and scientists are putting them in space to provide a continuous life support system. Nowadays, various space research organizations are trying to develop such a technology that will allow astronauts, or any other living beings present in the spacecraft, to stay for a longer time in space without having any complex and heavy artificial setup. Using this methodology, 90% of the consumed water can be recycled, and 42% of the oxygen from the carbon dioxide exhaled by astronauts. This technique can also reduce the amount of food resources required from Earth, as microalgae are a rich source of proteins and vitamins. It can easily meet the demand for nutrition, which is required by astronauts when they are in space.

To fulfill all of the above-mentioned criteria, scientists are using *Chlorella vulgaris*. *Chlorella* is a unicellular eukaryotic microorganism that showed a remarkable effect in this study. *Chlorella* belongs to the Chlorellaceae family and is a blue-green alga.

***Author for Correspondence**
Arnab Chattopadhyay
E-mail: arnab.c3011@gmail.com

[1]Student, Department of Biotechnology, Haldia Institute of Technology, Haldia, West Bengal, India

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Microalgae require proper and well-designed equipment for controlled cultivation. A photobioreactor was used for this purpose. We also used PC technology for air management. The main objective of this technique is to manufacture a very lightweight spacecraft, which consumes fewer resources and has all the necessary resources, such as oxygen, food, and water.

HISTORY OF SPACE RESEARCH USING ALGAE

Spaceflight research was conducted on various plants between 1987 and 1992 [1]. The experiment was divided into three different domains: gravity sensing, transduction and response, development and reproduction, metabolism, photosynthesis, and transport.

This concept was first implemented on 19th August 19, 1960, when the "Vostok" rocket launched the spacecraft "Sputnik 2." The borders of the spacecraft were two dogs accomplished by 40 white mice, two rats, numerous flies, and cultures of *Chlorella pyrinoidosa* for a very short duration. This mutation was not observed in the algal culture.

A second attempt was made six years after the previous attempt. On February 22, 1966, another rocket was launched along with the Soviet spacecraft "Cosmos110", carrying two dogs and *Chlorella* culture. Two strains of *Chlorella* were used. One was LARG 2 and the other was LARG 3. They spent 22 days in space with this experimental setup, and this experiment indicated that algae possess the ability to survive for 22 days, even in space. Only the LARG 2 strain showed some mutation, but no such mutation was observed in the strain LARG 3 [2].

Biological life support systems, including NASA, JEXA, and ESA, have been studied by several space agencies. The ESA performed a focused experiment under an international project called MELiSSA. The aim was to create a closed loop by using five compartments.

1. Waste qualification
2. Carbon transformation
3. Nitrification
4. Food, water and oxygen production.
5. Crew compartment

WHY ALGAE INSTEAD OF MULTICELLULAR PLANTS

The Reasons behind using algae instead of a complex plant are:

1. *Chlorella* is a unicellular eukaryotic organism.
2. It is a rich source of protein, iron, vitamin B complexes, and other necessary components.
3. Being an alga, it provides oxygen and consumes the carbon dioxide exhaled by humans. This reduces the requirement of carrying heavy oxygen tanks in space flights.
4. After much research, scientists found that the use of *Chlorella vulgaris* is much more beneficial as it recovers from any damage occurring within 5 days, and its oxygen production stability is much higher than that of higher species of plants. It has also been identified as a potential multifunctional component for the use of *Chlorella vulgaris* as part of the Bio Regenerative Life Support System (BLSS) [3].

Species Specification

In this study, the wild-type green algae *Chlorella vulgaris* strain SAG 211-12 was selected as it grows photo-autotrophically, may produce a large amount of biomass, and contributes to the flexibility of agriculture [4–9]. A specific cyclic bath cultivation process of SAG 211-12 can enhance biomass growth up to a maximum of 12.2 g. L^{-1} with a maximum global productivity of 13 g. $L^{-1}d^{-1}$ was reached in a closed-loop system. A global molar photosynthetic quotient of 0.31 is used to determine the photosynthetic capacity [9]. Normally, *Chlorella vulgaris* grows between 10° and 35°C and its optimum temperature range is 29°–31°C [10].

Mechanism

Algae are normally cultured in open sources, such as ponds, or closed vessels, such as the Photo bioreactor. The most important equipment for this research was a photo-bioreactor, which is an alga-powered bioreactor. This plays a very important role in the creation of a closed-loop life support system. This system can last for one day without cargo resupply missions. This will be beneficial for future long-duration missions and will reduce the weight of space crafts. The photo-bioreactor acts as an artificial light source for continuing photosynthesis in *Chlorella* and maintains the specific wavelength at which the rate of photosynthesis is optimal. It not only helps in photosynthesis but also helps in the production of algal protein for future purposes and removes carbon dioxide to balance the ecological conditions inside the spacecraft. The density of algae in the photo-bioreactor increased from 0.174 g (dry weight) L^{-1} to 4.064 g (dry weight) L^{-1} after seven days of growth.

The process of providing Carbon dioxide to the photo-bioreactor for algae and removing oxygen from the medium is suitable for space conditions [4]. It is also important to observe the effects of micronutrients on the growth medium. This will help in the metabolic processes during the growth of algae. Effect of macronutrients such as nitrogen (N), phosphorus (P), and carbon(C) on *Chlorella vulgaris* using synthetic wastewater [8].

Analysis

In space research to understand the nature of the production of oxygen and other substances in spacecraft, some experiments have been conducted using different sample concentrations. From the current experience, the growth rate of *Chlorella vulgaris* in a photo-bioreactor (PBR) can be expected between 2 and 4 g/L/d, the system with only PC technologies would require around 0.64 kg/d of food supply per day for each astronaut.

An LSS with a PBR requires a PBR system mass, volume, power, and nutrient supply. From the two graphs, we can see the ESM calculation results, as shown in the poster. Considering a 10% food supply, the break event point lies between 4.8 and 7.3 years, depending on the assumed growth rate Figure 1 When comparing PC and Hybrid LSS systems supplemented with microalgae at 10% food supply, a growth rate ranging from 2 to 4 g/l/d is deemed realistic, supporting mission durations spanning 4.8 to 7.3 years, in accordance with prevailing experimental findings. Figure 2 shows that utilizing microalgae for 30% of food supply in PC and Hybrid LSS indicates a growth rate between 2 and 4 g/l/d, favoring mission durations of 4.0–6.5 years based on published and laboratory data. Based on these results, we can say that a PBR system is more advantageous for long-duration missions. The research was conducted in the IRS laboratory. It focuses on both the biological and technological aspects of microalgae cultivation [5].

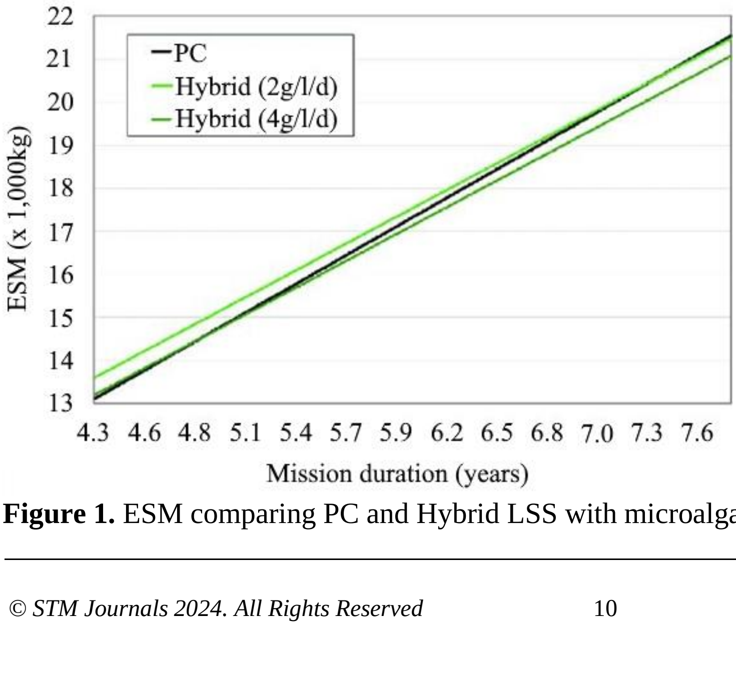

Figure 1. ESM comparing PC and Hybrid LSS with microalgae 10% food supply [5].

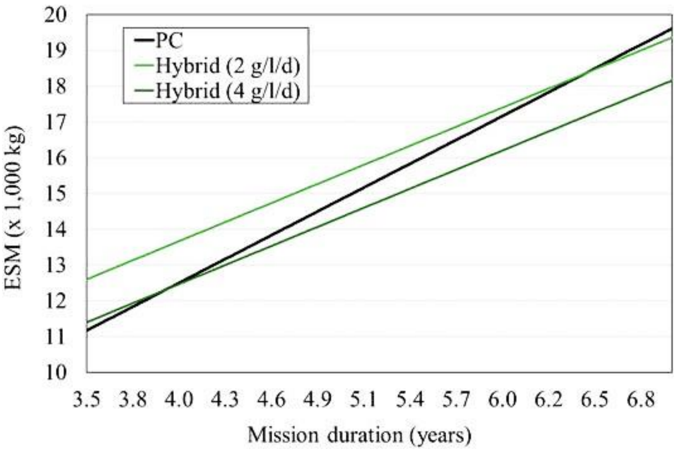

Figure 2. ESM comparing PC and Hybrid LSS with microalgae 30% food supply [5].

Challenges

This experiment is a good initiative toward developing a superior system for space exploration, but it has some challenges that need to be addressed.

1. First, there may be a scarcity of light when the spacecraft is in a straight line with the moon [5].
2. Second, the thick cell wall of *Chlorella* does not allow the human body to assimilate nutrients inside the cell, as it requires a cell wall breakdown process before human consumption.
3. Third, space radiation, such as UV rays, can cause mutations in algae [7].

Few of these effects are observed only in the cell at the beginning of the G1 phase, which precedes DNA synthesis [6].

CONCLUSION

Chlorella vulgaris is very important for space research today, and scientists are trying to develop such advanced technology so that it can be a good alternative method for oxygen production in spacecraft. Using a photo-bioreactor for algae production, it is easier to cultivate *Chlorella* and produce a large amount of oxygen for astronauts so that they can survive for a long time in space without any problems. *Chlorella* is also a very good source of food and provides appropriate nutrition, which is important for human survival. In space, it is problematic for astronauts to carry food and heavy oxygen cylinders in a very compact aircraft. This process will also overcome the limitations of time in space research. However, there are some challenges, and scientists are trying to overcome these challenges by introducing artificial setups for the huge production of *Chlorella*. Therefore, these unicellular algae can be a great answer to the scarcity of oxygen in a small spacecraft.

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