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Benefits of Use of Microalgae in Spacecraft

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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. By consuming algae as a human food, becoming popular over 70 years since it was discovered in 1942. This concept was first implemented in spacecraft, when it was sent to space with human being 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 process. International space station has concluded that Chlorella can generate oxygen and water by consuming the carbon dioxide produced by the astronauts. It has 10 times better effect in photosynthesis than any other complex plant. In space research there is a main concern to manage total weight of the spacecraft. From the research, scientists said that there is no effect in the algal population due to the weightlessness. Also, it is very tough to maintain a stable ratio between the consumption of oxygen to exhale 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 mission, the microalgae is the only solution to resolve the scarcity of food and oxygen in spacecraft. Besides being use as a food supplement it will help to fill the nutrients, required for every human being in daily life. This paper focuses 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 is a single cell and photosynthetic microbe that can live in salty or freshwater environments, and scientists are putting them in spaces to provide a continuous life support system. Nowadays, the various space research organisations are trying to develop such a technology that will allow the astronauts, or any other living beings present in the space craft can stay a longer time in space without having any complex and heavy artificial set up. By this methodology it can recycle 90% of the consumed water and recover 42% of the oxygen from the carbon dioxide exhaled by the astronauts. This technique can also reduce the amount of the requirement of food resources from the Earth, as microalgae is a very rich source of proteins and vitamins. It can easily meet the demand of nutrition which is required for the astronauts when they are in the space.

To fulfil all the above-mentioned criteria, scientists are using *Chlorella vulgaris*. *Chlorella* is a unicellular eukaryotic microorganism which shows a very remarkable effect in this study. *Chlorella* belongs to the family Chlorellaceae is a blue-green algae.

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The microalgae need a proper and well-designed equipment for a controlled cultivation. A photo-bioreactor is used for this purpose. Now we also use PC technology for air management. The main moto of this technique is to manufacture such a spacecraft which is very light weight, consume less resources and have all the necessary resources such as oxygen, food, and water.

HISTORY OF SPACE RESEARCH USING ALGAE

The spaceflight research was conducted with various plants in-between 1987 and 1992 [1]. The experiment was divided into three different domains like gravity sensing, transduction, and response, development and reproduction, and metabolism, photosynthesis, and transport.

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

A second attempt was made after 6 years of the previous one. On 22nd February 1966, another rocket launched along with the soviet spacecraft **"Cosmos110"**, carrying two dogs and *Chlorella* culture. Here two strains of *Chlorella* were used. One was **LARG 2** and another one was **LARG 3**. They spent 22 days in space with this experimental set up and this experiment gave an estimation that algae possess the ability to survive for 22 days even in space. Only LARG 2 strain showed some mutation but there was not such a mutation, observed in the strain LARG 3 [2].

These biological life support systems have been studied by several space agencies in the last few decades including NASA, JEXA, and ESA. ESA performed a focused experiment under an international project named MELiSSA. The aim was to create a closed loop using 5 compartments namely-

1. Waste equification
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 complex and other necessary components.
3. Being an algae 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 occurred within 5 days and its oxygen production stability is much higher as compared to higher species of plants. It has also been identified as potential multifunctional components for the use of *Chlorella vulgaris* as part of such a Bio regenerative Life support System (BLSS) [3].

Species Specification

In this research work basically the wild type green algae *Chlorella vulgaris* strain SAG 211-12 is selected as it grows photoautotrophically, may produce a large amount of biomass, and contributes to the flexibility of agriculture. On the basis of a specific cyclic bath cultivation process of SAG 211-12, able to enhance biomass growth up to a maximum 12.2 g. L^{-1} with a maximum global productivity of 13 g .$L^{-1}d^{-1}$ has reached in a closed loop system. The global molar photosynthetic quotient 0.31 is used to determine the photosynthetic capacity [9]. Normally *Chlorella vulgaris* grows between 10^0 and 35^0C and its optimum temperature range is 29^0 to 31^0C [10].

Mechanism

Algae are normally cultured in open source like pond or closed vessel like Photo- bioreactor. The most important equipment for this research is a Photo-bioreactor, an algae- powered bioreactor. It plays a very important role to create a closed-loop life support system. This system can last for a day without cargo resupply missions from earth. This will be beneficial for future long duration missions, and this reduces the weight of the space crafts. Photo-bioreactor acts as an artificial light source for continuing the photosynthesis of *Chlorella* and maintains the specific wavelength at which the rate of photosynthesis will be best. Not only help in photosynthesis it also helps in the production of algal protein for future purposes and remove carbon dioxide for balancing the ecological condition inside the spacecraft. It is observed that the density of algae in photo-bioreactor is increased 0.174 g (dry weight) L^{-1} to 4.064 g (dry weight) L^{-1} after 7 days growth.

The process of providing Carbon dioxide to the photo-bioreactor for the algae and removing oxygen from the medium is suitable for the demand of space condition [4]. It is also important to observe the effect of macronutrients in the medium. It will help for the metabolic processes, going during the growth of the algae. The effect of macronutrients like Nitrogen (N), Phosphorus(P) and carbon(C) on *Chlorella vulgaris* using synthetic wastewater [8].

Analysis

In space research for understanding the nature of production of oxygen and other substances in the spacecraft some experiment has done by taking different sample concentration. 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.

The LSS with a PBR will require a PBR system mass, volume, power, and a nutrient supply. From the two graphs, as shown in the poster, we can understand the ESM calculation results. 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. And Figure 2 depicts that utilizing microalgae for 30% food supply in PC and Hybrid LSS indicates a growth rate between 2 and 4 g/l/d, favoring mission durations of 4.0 to 6.5 years based on respective published and laboratory data. By these results, we can say that a PBR system will be more advantageous for long-duration missions. The research was carried out in at IRS lab. It focused both the biological and technological aspect in microalgae cultivation [5].

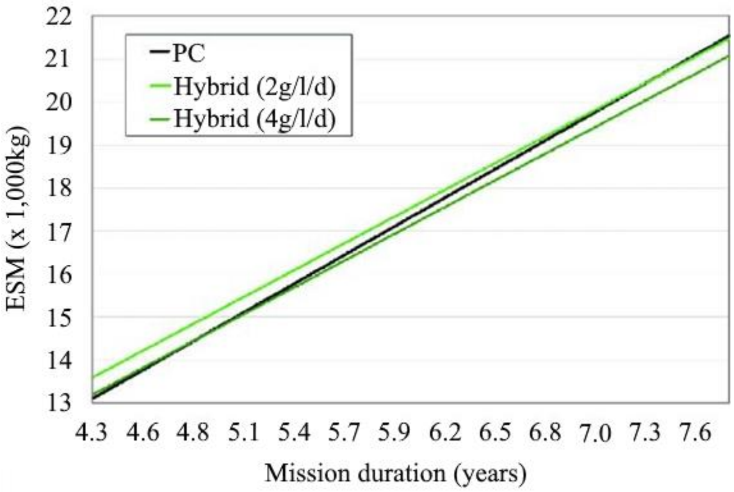

Figure 1. ESM comparing PC and Hybrid LSS with microalgae 10% food supply [5].

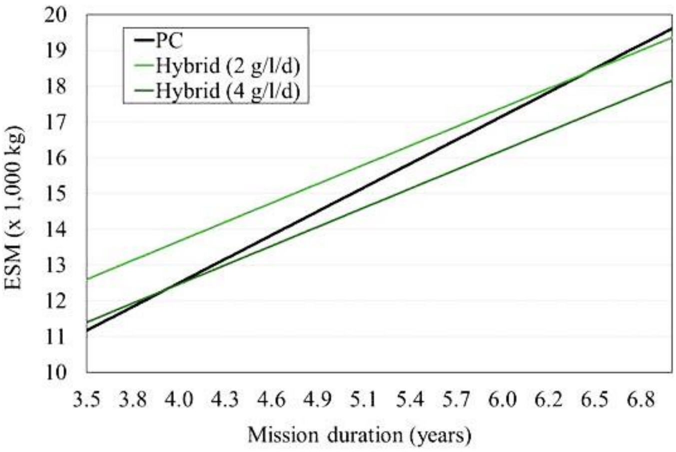

Figure 2. ESM comparing PC and Hybrid LSS with microalgae 30% food supply [5].

Challenges

This experiment is a good initiative towards developing a superior system for space exploration but it has some challenges that are needed to be dealt with:

1. Firstly, there can be a scarcity of light when the spacecraft will be in a straight line with the moon [5].
2. Secondly, the thick cell wall of *Chlorella* does not allow the human body to assimilate the nutrients inside the cell as it will require a cell wall break down process before human consumption.
3. Thirdly, space radiation like UV ray can cause mutation in the algae [7].

Few of those effects are observed only in the cell at the beginning g G1 stage which precedes the DNA synthesis [6].

CONCLUSION

Chlorella vulgaris is very important for the space research now a days, and scientists are trying to develop such an advance technology, so that it can be a good alternative method for the oxygen production in spacecraft. By using photo-bioreactor for production of algae it can be easier to cultivate *Chlorella* and produce a huge amount of oxygen for the astronauts so that they can survive for a long time in space without any problem. *Chlorella* is also a very good source of food and gives appropriate nutrition which are important for the survival of human being. In space it is really problematic to carry food and heavy oxygen cylinders for the astronauts in a very compact air craft. This process will also end the limitation of the time in the space research. But there are some challenges also, but scientists are trying to overcome this by introducing artificial set up for the huge production of *Chlorella*. So this unicellular algae can be a great answer for the scarcity of oxygen in a small spacecraft.

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