ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 18, Issue, 06, pp.37556-37558, June, 2026
DOI: https://doi.org/10.24941/ijcr.50675.06.2026

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

THE USE OF *PHYSCOMITRIUM PATENS* AS SPACE FOOD —NUTRITIONAL ANALYSIS RESULTS OF *PHYSCOMITRIUM PATENS* AS A FOOD SOURCE

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ARTICLE INFO

Article History:
Received 27th March, 2026
Received in revised form
24th April, 2026
Accepted 25th May, 2026
Published online 30th June, 2026

Keywords:

Space Food, Physcomitrium Patens, Nutrition

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ABSTRACT

Bryophytes are attracting attention as a plant resource capable of surviving even in extreme environments such as outer space. This is due to their high environmental tolerance, thanks to their spores, which have been reported to exhibit high survival rates even under strong ultraviolet radiation, extremely low temperatures, and even in vacuum environments. Because of these characteristics, they are expected to be used as a food production resource in the future space environment.

Until now, moss has been considered for use as feed for other organisms for protein production. However, this study aimed to evaluate the nutritional value of moss as a food resource that humans can directly consume. The sample used was *Physcomitrium patens*, which has a proven track record in space experiments. A 40g sample obtained after culturing for approximately 5 months was sent to the Nagoya branch of the Japan Food Research Laboratories for analysis, and the moisture, protein, lipids, ash, carbohydrates, energy, sodium, and salt equivalent per 100g were measured. The analysis results showed a moisture content of 96.9g/100g, an energy content of 14kcal/100g, and a protein content of 0.5g/100g. It became clear that *Physcomitrium patens* has a very high moisture content and low nutrient density, making it difficult to use *Physcomitrium patens* alone as space food at present. However, its potential for use in combination with other foods in menus, or as feed for animals and insects, could indirectly contribute to protein production. This study provides fundamental knowledge for examining the potential of mosses as space food resources, and further developments in mass cultivation techniques and research into improving nutritional value are expected.

Citation: **Naomi Katayama, Akitaka Kojima, Sakimi Mito, Hiroyuki Kamachi, Tomomichi Fujita and Atsushi Kume, *2026.*** "The use of *physcomitrium patens* as space food —nutritional analysis results of *physcomitrium patens* as a food source". ***International Journal of Current Research, 18, (06), 37556-37558.***

INTRODUCTION

Long-term stays in space require the use of a variety of food sources. Humans need five major nutrients(carbohydrates, proteins, lipids, vitamins, and minerals) to sustain life. Many researchers involved in space agriculture have published numerous reports on four of these major nutrients (carbohydrates, lipids, vitamins, and minerals). However, there are still few reports on protein. Currently, there is growing interest in using plants cultivated in space agriculture as feed to raise fish, insects, amoebas, bacteria, etc., and ultimately utilize them as proteins. Moss, a plant resource with remarkable vitality that allows it to survive in various environments, boasts a high survival rate even under ultraviolet light, extremely low temperatures, and vacuum conditions thanks to its spores (Maeng et al. 2025), making it highly promising as a food-producing material in space. Therefore, this study focuses on the nutritional analysis of moss as a food source, considering its direct use by humans, rather than as food for other organisms that utilize it to produce proteins. Based on these results, we aimed to take the first step towards considering the use of moss as space food in combination with other foods.

MATERIALS AND METHODS

Moss *Physcomitrium patens*cultibation The cultivation of *Physcomitrium patens* was conducted at the Kamachi Laboratory at Toyama University, following the cultivation method described in the paper (A hypergravity environment increases chloroplast size, photosynthesis, and plant growth in the moss *Physcomitrium patens*: J Plant Res (2017) 130: 181-192). Large-scale culture of *Physcomitrium patens* stems and leaves. The stems and leaves of *Physcomitrium patens* were cultured in the Kamachi Laboratory aToyamaUniversity. Sixteen plant culture containers (Bio Medical Science Inc., Tokyo, Japan) were used for cultivation. 8 mL of BCD liquid medium was added to each plant box, and three cell strainers (Falcon®, 100 μm) were installed. Ten stems and leaves were aseptically planted in each cell strainer. The culture medium was changed every two weeks during the cultivation period, and the plants were cultured for approximately 5 months under continuous white light conditions at 24°C with a photosynthetically active photosynthetic photon flux density (PPFD) of 30 μmol m^2 s^{-1}. After cultivation (Figure 1), the obtained stems and leaves were collected and used as samples for nutritional analysis.

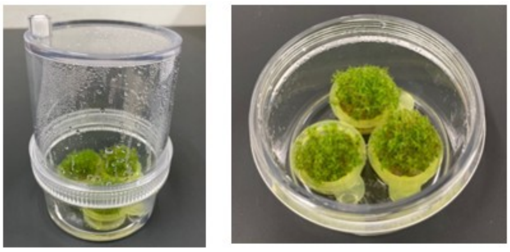

Photo 1. Moss after 5 months of cultivation

Nutrient analysis of Moss.: 40g of *Physcomitrium patens* cultured in the Kamachi Laboratory at Toyama University as described above was sent to the Nagoya branch of the Japan Food Analysis Centerfor analysis of moisture content, protein content, lipid content, ash content, carbohydrate content, energy content, sodium content, and salt equivalent. Moisture content was analyzed by vacuum heating and drying method, protein content by combustion method, lipid content by acid decomposition method, ash content by direct ashing method, and sodium content by atomic spectrophotometry. The nitrogen-to-protein conversion factor was 6.25, carbohydrate content was calculated using the formula: 100 - (moisture + protein + lipid + ash), energy absorption content was calculated using conversion factors: protein, 4; lipid, 9; carbohydrate, 4, and salt equivalent was calculated using the formula: sodium × 2.54

RESULTS

The nutritional analysis results for *Physcomitrium patens* are shown in Table 1. The water content is 96%, and therefore the nutrient content per 100g of P*hyscomitrium patens* immediately after harvest is low. However, it was shown that the carbohydrate content is higher than the protein and fat content. When comparing the energy and protein content of *Physcomitrium patens* (a type of moss) with other plants, particularly alfalfa and seaweed that can be grown hydroponically (see Table 2), it was found that immediately after harvest, *Physcomitrium patens* (a type of moss) contained less of both nutrients compared to other plants.

Table 1. Nutrient analysis results of *Physcomitrium patens*

Nutrient	Unit /100g	Physcomitrella patens
Water	g/100g	96.0
Protein	g/100g	0.5
Fat	g/100g	0.2
Ash	g/100g	0.7
Carbohydrates	g/100g	2.6
Energy	kcal/100g	14.0
Sodium	mg/100g	8.4
Solt equivalent	g/100g	0.021

Table 2. Comparison of nutrients (energy and protein content) with other plants

Nutrient	Unit /100g	Physcomitrella patens	Azolla	soybean sprout *Glycine max*	Alfalfa sprout *Medicago sativa*	Marine macro-aga *Porhyra* sp.	Marine macro-alga *Ulva* sp.
Energy	kcal	14	29	155	50	23	22
Protein	g	0.5	1.2	3.7	1.6	1.3	0.9

DISCUSSION

Bryophytes are considered to be among the earliest groups of land plants to expand their habitat from aquatic to terrestrial environments during plant evolution (Rubinstein et al., 2010). Among them, *Physcomitrium patens* (composed of cells less than 100 μm in diameter) forms a relatively simple plant body with a stem, single-layered leaves, and rhizoids. Furthermore, its genome sequence has been deciphered, and it is widely used as a model organism for bryophytes (Rensing et al., 2008). In this study, a nutritional value analysis was conducted on *Physcomitrium patens* to evaluate its potential as a food resource.

The sample used was provided by the Kamachi Laboratory at Toyama University, and the nutritional value analysis was commissioned to the Japan Food Research Laboratories. The results showed that immediately after harvesting, *Physcomitriuma patens* is 96% water, resulting in a low nutrient content. Therefore, it is suggested that drying and preserving the dried product after harvesting, and using it like seaweed such as nori, might be beneficial.

We believe that *Physcomitrium patens* can be used as food for other microorganisms, insects, and fish, and that these microorganisms, insects, and fish can then be used as food by humans, thus providing a source of the five major nutrients: protein, lipids, carbohydrates, vitamins, and minerals. Since efficient use of available resources is crucial for food production in enclosed spaces like space, the use of *Physcomitrium patens* is highly valuable as a food production material in space because it is a plant resource with remarkable vitality that can survive even under harsh conditions such as ultraviolet light, extremely low temperatures, and vacuum. In the future, research into the optimal cultivation conditions (temperature, humidity, nutrients, light, etc.) and preservation methods (freezing, drying, room temperature, processing) for*Physcomitrium patens* will enable mass production, which is expected to stabilize food production in space.

CONCLUSIONS

Considering its use as space food, the moss *Physcomitrium patens*, which boasts a high survival rate even under ultraviolet light, extremely low temperatures, and vacuum, is being considered as a plant resource with the vitality to survive in harsh environments like space, and its nutritional components are being studied. Analysis revealed that when fresh, it is 98% water and contains 14 kcal/100g of energy. It may be better to dry it for storage and use. Furthermore, instead of using *Physcomitrium patens* directly as food, it might be more effective to utilize it as a food source for other organisms, thus integrating it into a food production cycle.

ACKNOWLEDGMENTS

We express our deepest gratitude to everyone at the Kamachi Laboratory at Toyama University for cultivating the moss *Physcomitrium patens*.

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