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Microorganisms in marine biotechnology – the great powers of the smallest inhabitants of the seas and oceans

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Key words: ***marine microorganisms, marine biotechnology, microbial cultures, astrobiology, marine drugs, pigments, lipids, bioremediation***

Abstract

In this study, we present five infographics created by thirteen students of the Marine Biology and Biotechnology course at the Klaipeda University (Lithuania). The topics of the works are related to the potential applications of marine microorganisms in biotechnology. The paper also includes an introduction illustrating the overall aim of the classes and survey results summarizing the completed work.

Introduction

Biotechnology is a branch of applied science that uses biological systems or living organisms and their metabolites to develop various products and technologies. It is a broad field of science and therefore it is usually divided into different subfields (different colors represent different biotechnology branches). Of these, blue (or marine) biotechnology plays an important role and is characterized by its still undiscovered potential. Blue biotechnology, defined by the Organization for Economic Cooperation and Development (OECD), is the application of science and technology to living organisms from marine resources, as well as parts, products, or models for the production of knowledge, goods, and services.

It is observed that society, secondary school teachers, school children who are about to enter higher education institutions, as well as first-year students of natural/ environmental sciences, do not always know or are familiar with the potential of blue biotechnology, and, in fact, even with the term itself. Therefore, there is a need to intensify education, share knowledge, and inspire young people to study, conduct research, and plan their professional careers in this field.

In this work, we present infographics prepared by the second-year BSc Marine Biology and Biotechnology students at Klaipeda University (Lithuania). The task was a component of the overall grade from the course named Microorganisms in Marine Biotechnology (15 %). This new approach (group tutoring) to this part of the assessment was intended to replace the multimedia presentations prepared by students in previous years, which lecturers considered ineffective in terms of learning outcomes. The change was also intended to result in a more individual and partnered approach to the student, greater involvement, and broader competence development. At the beginning of the semester, students self-selected into groups and chose topics; lecturers provided some materials to get started. The blended learning approach included also e-mail and face-to-face consultations. One meeting was held mid-semester to discuss the progress of the work, licensing, and intellectual property issues. At the end of the semester, students presented their work to the whole group and the lecturers. Brainstorming during that meeting resulted in a final version of infographics.

The themes of the infographics cover a variety of angles of marine biotechnology. Infographic no. 1 presents state-of-the-art approaches that help to grow marine microorganisms that were previously unculturable, which is a huge challenge for marine microbial biotech. To date, more than 99% of marine microbes have never been cultured under laboratory conditions. Infographic no. 2 is about the possible use of eukaryotic microorganisms called thrausto-chytrids. These enigmatic microbes have enormous potential for application in the field of human health and green chemistry. Two further works (no. 3 and 4) deal with specific compounds, dolastatin and astaxanthin. These are metabolites of marine microorganisms that have already found their place on the market. The last infographic (no. 5) describes the potential use of marine microorganisms in the future colonization of space.

For the majority of Students (80%) this was a new challenge, since they had not done infographics before, and the vast majority (70%) were unwilling to return to the previous form of the task (multimedia presentation) (Fig. 1A, and B). The challenge of learning the new software and designing graphic concepts did not pose difficulties for the students; the most difficult challenge was the synthesis of the available materials, and the selection of the final content (Fig. 1C). It seems, therefore, that through this task the students had the chance to develop new competences, which are extremely important in a world overloaded with information. The overall perception of the task was very positive (Fig. 1D), and the opportunity to learn to work in a group was specifically noted. One voice only questioned the purpose of the task, which required more time in an already overloaded semester.

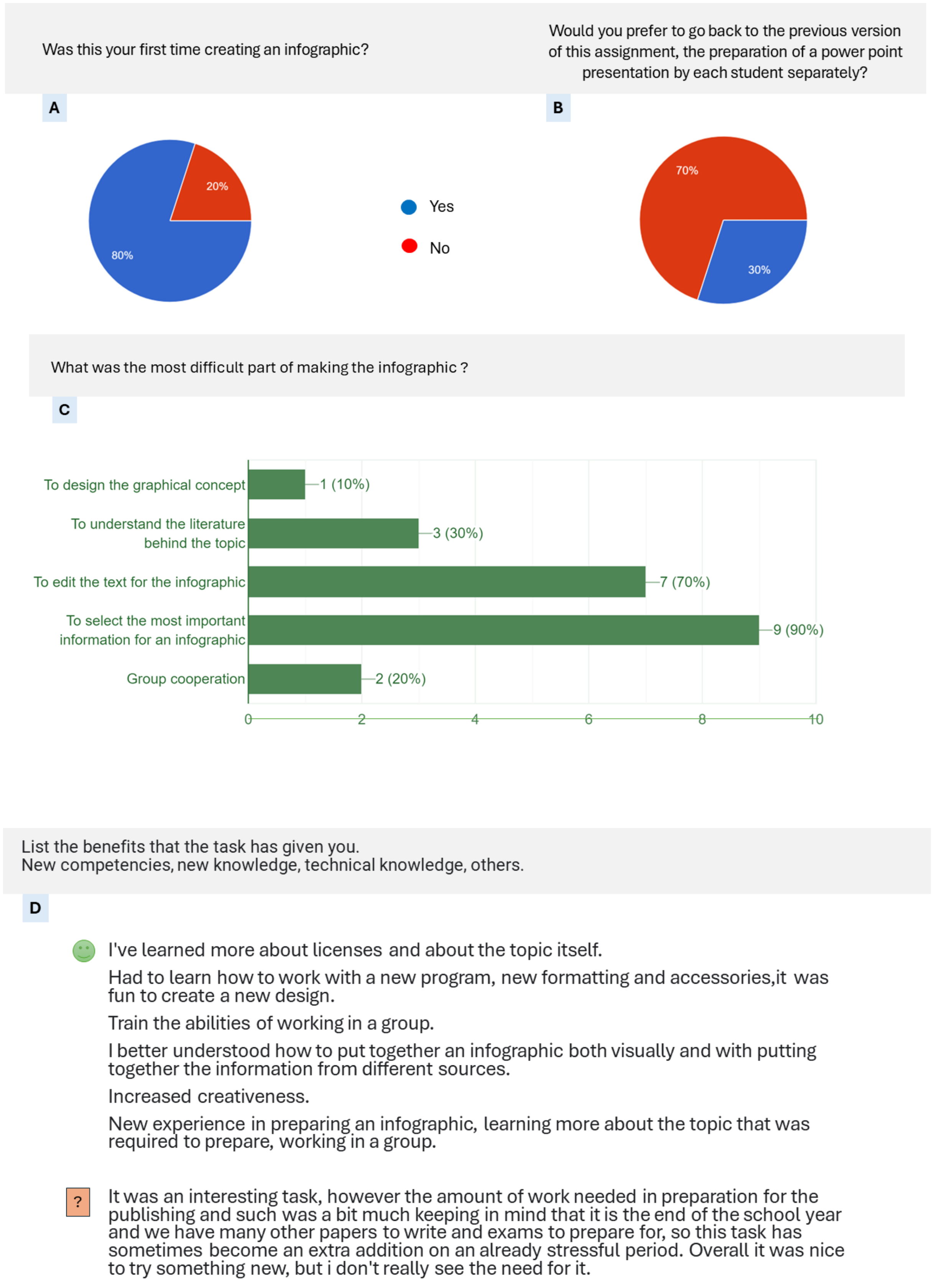

Fig.1. Results of the anonymous post-class survey

INFOGRAPHIC no. 1

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NOVEL STRATEGIES TO CULTIVATE UNCULTURED MARINE MICROORGANISMS

Pareigytė Martyna and Dukanauskaitė Karolina

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Owning to the extensive metagenomics studies, that are based on the analyses of the environmental DNA, we know that marine microbial diversity is huge.

It is estimated that uncultivable genera constitute 81% of the Earth's microbiome (Liu et al., 2022). In this work, we present some new ideas that are likely to increase the number of cultured marine bacteria.

1. Enrichment culturing

Involves usage of non-standard media components (e.g. extract from marine sediment, or from marine macroorganisms) to provide unknown to science components, essential for bacterial growth (Cardoso et al., 2023).

Enrichment culture techniques are mainly used to increase a small number of the desired microorganisms to detectable levels (Madhuri et al., 2019).

2. Co-culturing

Involves growing two or more microorganisms together in the same culture medium to create a relationship beneficial for their growth (Kapoore et al., 2021). Bacteria in the marine environment are never alone, they are found in numerous habitats, not only in water sediments, but also in association with algae and other macro-organisms.

For many years, microbiologists have instead focused on pure cultures. The co-culturing approach thus creates conditions closer to the natural environment (Caudal et al., 2022).

4. Metagenomics

These days, we are 'flooded' with a plethora of metagenomic data. Can they also help to increase the success rate in marine bacterial cultivation?

Yes! Metagenomic data can provide information on primary metabolism, which further can help to adjust media for selected microbes. Shotgun sequencing may also reveal rare taxa, on which further cultivation could be focused (Liu et al., 2022).

5. High-throughput culturing

This involves culturing microorganisms in high-throughput format, using miniaturized culture conditions and automated systems that allow to grow many microorganisms at the same time.

This facilitates the screening of large numbers of microorganisms and the identification of optimal culture conditions for each one.

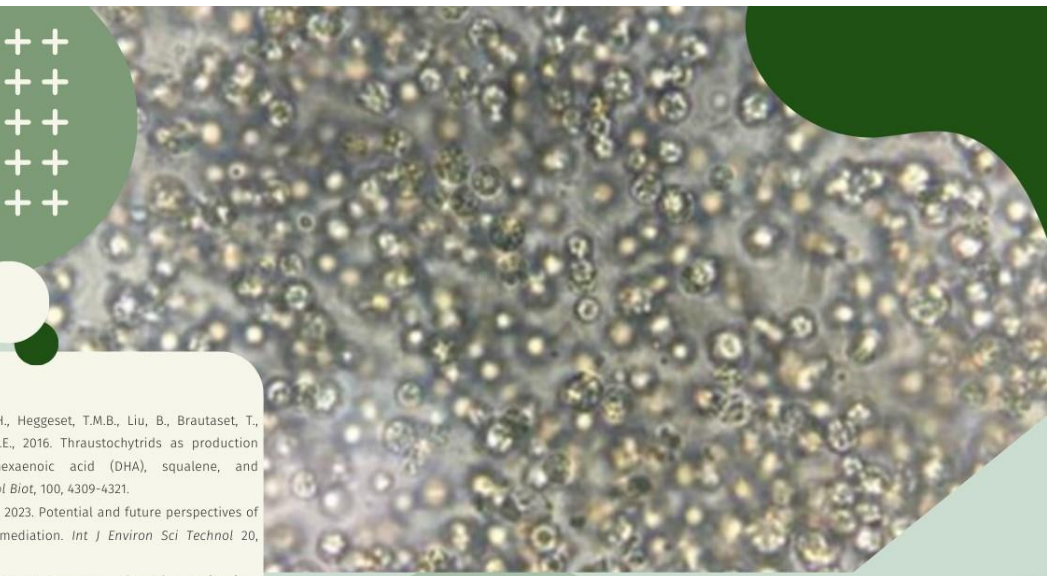
System works when you dipping a plate with multiple through-holes mixed environmental cells leads to capturing a single cell. It has a membrane that covers arrays of through hole from each side and there are screws that provide sufficient pressure (Nichols et al., 2010).

References

- Cardoso, F.A., Souza, da Silva S do R., Oliveira, Prado, G.I., Bitencourt, P.A.J., Gastauer, M, 2023. Microorganisms, 11(2), 1-13.
- Caudal, F., Tapissier-Bontemps, N., Edrada-Ebel, R. A., 2022. Impact of Co-Culture on the Metabolism of Marine Microorganisms. Mar Drugs, 20(2), 153.
- Kapoore, V.R., Padmaperuma, G., Maneein, S., Vaidyanathan, S., 2021. Co-culturing microbial consortia: approaches for applications in biomanufacturing and bioprocessing, Critical Reviews in Biotechnology, 42(1), 46-72.
- Liu, S., Moon, C.D., Zheng, N., Huws, S., Zhao, S., 2022. Opportunities and challenges of using metagenomic data to bring uncultured microbes into cultivation, Microbiome, 10, 76.
- Madhuri, J.R., Saraswathi, M., Gowthami, K., Bhargavi, M., Divya, Y., Deepika, V., 2019. Recent Approaches in the Production of Novel Enzymes From Environmental Samples by Enrichment Culture and Metagenomic Approach of theRecent Developments in Applied Microbiology and Biochemistry, 251-262.
- Nichols, D., Cahoon, N., Trakhtenberg, M. E., Pham, L., Mehta, A., Belanger A., Kanigan, T., Lewis, K., Epstein, S.S., 2010. Use of Ichip for High-Throughput In Situ Cultivation of “Uncultivable” Microbial Species. Appl Environ Microbiol, 76(8), 2445-50.

INFOGRAPHIC no. 2

Thraustochytrids can biodegrade and detoxify organic pollutants like PAHs (Polycyclic Aromatic Hydrocarbons), DDT (Dichlorodiphenyltrichloroethane), and PCBs (Polychlorinated Biphenyls), making them potential candidates for bioremediation. They can use these pollutants as a carbon source and break them down into less toxic compounds. Using these protists for bioremediation could be a cost-effective and environmentally friendly way to clean up marine environments (Contreras and Oviedo, 2023).



Sources:

1. Aasen, I.M., Ertesvåg, H., Heggeset, T.M.B., Liu, B., Brautaset, T., Vadstein, O., Ellingsen, T.E., 2016. Thraustochytrids as production organisms for docosahexaenoic acid (DHA), squalene, and carotenoids. *Appl Microbiol Biot*, 100, 4309-4321.
2. Contreras, P., Oviedo, C., 2023. Potential and future perspectives of thraustochytrids in bioremediation. *Int J Environ Sci Technol* 20, 4483–4498.
3. Kalidasan, K., Vinithkumar, N.V., Peter, D.M., Dharani, G., Dufossé, L., 2021. Thraustochytrids of mangrove habitats from Andaman Islands: Species diversity, PUFA profiles and biotechnological potential. *Mar Drugs*, 19(10), 571.
4. Lewis, T.E., Nichols, P.D., McMeekin, T.A., 1999. The biotechnological potential of thraustochytrids. *Mar Biotechnology*, 1, 580-587.
5. Lyu, L., Wang, Q., Wang, G., 2021. Cultivation and diversity analysis of novel marine thraustochytrids. *Marine Life Science & Technology*, 3, 263-275.
6. Marchan, L.F., Lee, Chang, K.J., Nichols, P.D., Polglase, J.L., Mitchell, W.J., Gutierrez, T., 2017. Screening of new British thraustochytrids isolates for docosahexaenoic acid (DHA) production. *J Appl Phycol*, 29, 2831-2843.
7. Morabito, C., Bournaud, C., Maës, C., Schuler, M., Cigliano, R.A., Dellero, Y., Maréchal, E., Amato, A., Rébeillé, F., 2019. The lipid metabolism in thraustochytrids. *Prog in Lipid Res*, 76, 101007.
8. Patel, A., Mu, L., Shi, Y., Rova, U., Christakopoulos, P., & Matsakas, L. 2020. Novel biorefinery approach aimed at vegetarians reduces the dependency on marine fish stocks for obtaining squalene and docosahexaenoic acid. ACS Sustain Chem Eng, 8(23), 8803-8813.

THRAUSTOCHYTRIDS

MARINE PROTISTS WITH BIOTECHNOLOGICAL POTENTIAL

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Meet the thraustochytrids:

Thraustochytrids are common in marine and estuarine environments, including sediment, water, algae, and mangroves. They are unicellular and heterotrophic protists that aid in decomposing leaf litter in mangrove ecosystems, which helps with nutrient enrichment and food web enhancement (Kalidasan et al., 2021).

Discovered 80 years ago, thraustochytrids have recently gained considerable attention due to their biotechnological potential, fast growth, specific lipid metabolism, and their potential applications in various fields such as human health and green chemistry (Morabito et al., 2019).

Thraustochytrids' rapid growth and ability to grow on various carbon sources such as molasses make them economically interesting for lipid production. Their high biomass can be collected in a few days, and using low-cost carbon sources from agro-industrial waste can reduce the cost of lipid production. (Morabito et al., 2019)

FUN FACT: Some species of Thraustochytrids are bioluminescent, meaning they can produce light.

Thraustochytrids' life stages heavily rely on nutrition. They can accumulate high amounts of lipids and biomass when grown in artificial media with yeast extract or peptone, making them ideal for biotechnological applications. *Aurantiochytrium* and *Schizochytrium* thraustochytrids can accumulate lipids up to 30-50% of their dry weight, with DHA (docosahexaenoic acid) accounting for about half of the total fatty acids (Morabito et al., 2019 and Marchan et al., 2017).

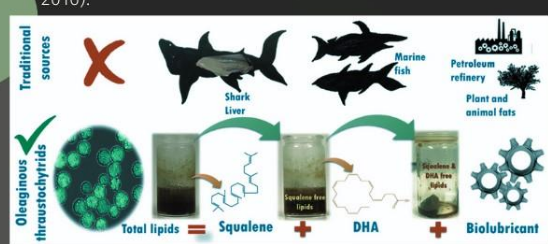
Bioactive metabolite production in thraustochytrids depends on the strain and growth substrate. Strains with extensive substrate preference and high utilization efficiency for cheap and widely available substrates are desirable for biotechnological and industrial applications (Lyu et al., 2020).

GROWS ON CHEAP AND WIDELY AVAILABLE SUBSTRATE !

Why did the Thraustochytrid go to the comedy club? To tell jokes about its cheap carbon sources and how it's always trying to find ways to pinch a penny, but nobody laughed because they were all too busy being impressed by how much lipids it could produce!

Products, that can be produced by thraustochytrids:

- *PUFAs* (Polyunsaturated Fatty Acids) are essential components of cell membranes and deficiencies can lead to cellular function defects. Thraustochytrids are a promising option for cheaper PUFA production as compared to fish oils (Lewis et al., 1999). PUFAs have potential applications in human health, aquaculture, and nutraceutical sectors (Kalidasan et al., 2021). Efforts are being made to improve and engineer the lipid production of thraustochytrids, including mutagenesis and metabolic engineering approaches (Morabito et al., 2019).
- *Squalene* is a primary metabolite used in the production of steroids, bile acids, hormones, and vitamin D. The main source is deep sea shark liver, but due to declining populations, a sustainable alternative is needed. Thraustochytrids are a potential source of squalene (Aasen et al., 2016 and Morabito et al., 2019).
- *Carotenoids*, divided into xanthophylls and carotenes, are used as colorants in food and feed, and as supplements due to their antioxidant and anti-free radical activities. Thraustochytrids can produce carotenoids like astaxanthin, phoenicoxantin, canthaxanthin, echienone, and β-carotene. The amount of each carotenoid varies with growth period and strain, and the efficiency of β-carotene conversion to xanthophylls varies between strains (Aasen et al., 2016).

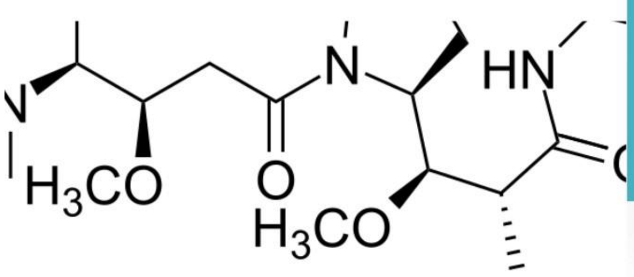


USE OF THRAUSTOCHYTRIDS FOR SUPPLEMENTS
(Patel et al., 2020)

INFOGRAPHIC no. 3

Dolastatin 10 - what is it?

Dolastatin 10 is bioactive, cyclic peptide, and cytotoxin. It disrupts cell function, leading to death in tumors. Currently, its analogs are used as a treatment for cancers. This bioactive marine metabolite was first extracted from the sea hare *Dolabella auricularia* (1972) which lives in the Indian Ocean. Years later, it turned out that the real producers are symbiotic cyanobacteria (Singh, 2022).



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DOLASTATIN 10

SUCCESSFULLY MARKETED NATURAL MARINE PRODUCT IN PHARMACEUTICAL INDUSTRY

From discovery to innovation

1972 – DOLASTATIN-10 WAS DISCOVERED AND EXTRACTED FROM SEA HARE

1987 – 29 MG OF DOLASTATIN 10 WAS EXTRACTED FROM 1 TONE OF MOLLUSK DOLABELLA AURICULARIA

1989 – THE FIRST TOTAL SYNTHESIS OF DOLASTATIN 10, THE PROCESS DID NOT DEPEND ON THE NATURAL SOURCE

2008 – TWO DERIVATIVES (TASIDOTIN, SOBLIDOTIN) HAD BEEN ADVANCED IN II CLINICAL TRIALS

2011 – BRENTUXIMAB (ANTIBODY-DRUG CONJUGATES) IS BEING APPROVED FOR TREATMENT OF HODGKIN'S LYMPHOMA

NOW – FROM BIOACTIVE CYANOBACTERIUM INTO THE DRUG, TO THE LAB AN TOTAL SYNTHESIS

Singh, 2022

TESTED ON 7 TYPES OF CANCER

Dolastatin 10 can successfully induce apoptosis in various tumor cells, such as leukemia, small-cell lung cancer, prostate cancer, and lymphoma (Gao et al., 2021).

HOW IT WORKS IN CELL

Dolastatin 10 treats tumors by inducing cell death (apoptosis). It interferes with tubulin balance and microtubule assembly, which arrests the cell cycle and causes apoptosis (Gao et al., 2021 and Singh, 2022).

CLINICAL TRIALS

Dolastatin 10 entered the I and II clinical trials, but due to strong side effects was dropped out from the clinical trials. However, in 2011 the analog of Dolastatin 10 conjugated with specific antibodies and approved for marketing (Gao et al., 2021).

MIRACLE MOLECULE

New analogs have been developed based on dolastatin, conjugates of these analogs with antibodies can be found in 4 approved drugs, and more than 20 products that are in phase 1-3 clinical trials.


REFERENCES
1. Gao, G., Wang, Y., Hua, H., Li, D., Tang C., 2021. Marine Antitumor Peptide Dolastatin 10: Biological Activity, Structural Modification and Synthetic Chemistry. Mar Drugs, 19 (7), 363.
2. Singh, S.B., 2022. Discovery and Development of Dolastatin 10-Derived Antibody Drug Conjugate Anticancer Drugs. J Nat Prod, 85 (3), 666-687.
Chemical structure of Dolastatin 10 is quite simple, therefore, the development of the Dolastatin 10 luckily did not depend on the natural source. Can you imagine that to extract such a small amount of active compund you would need every time 1 t of mollusks. The alternative is chemical synthesis.
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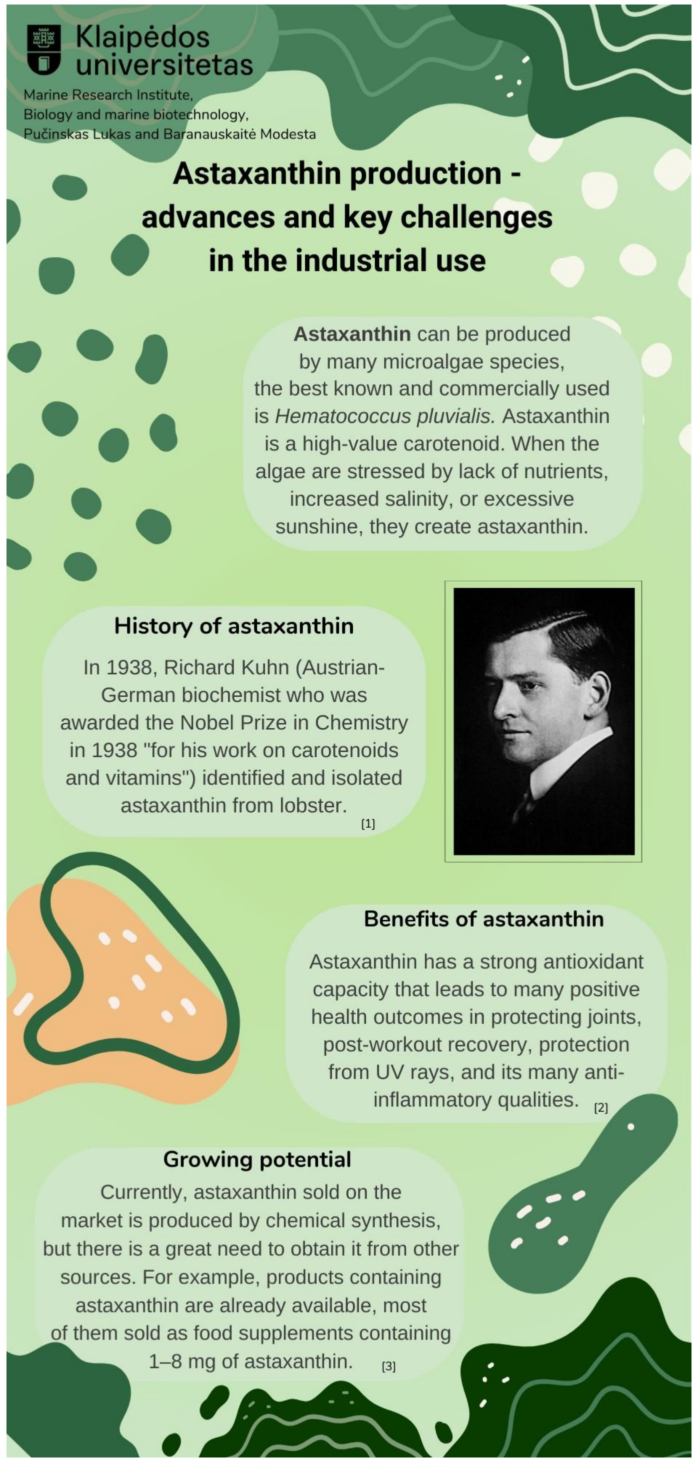
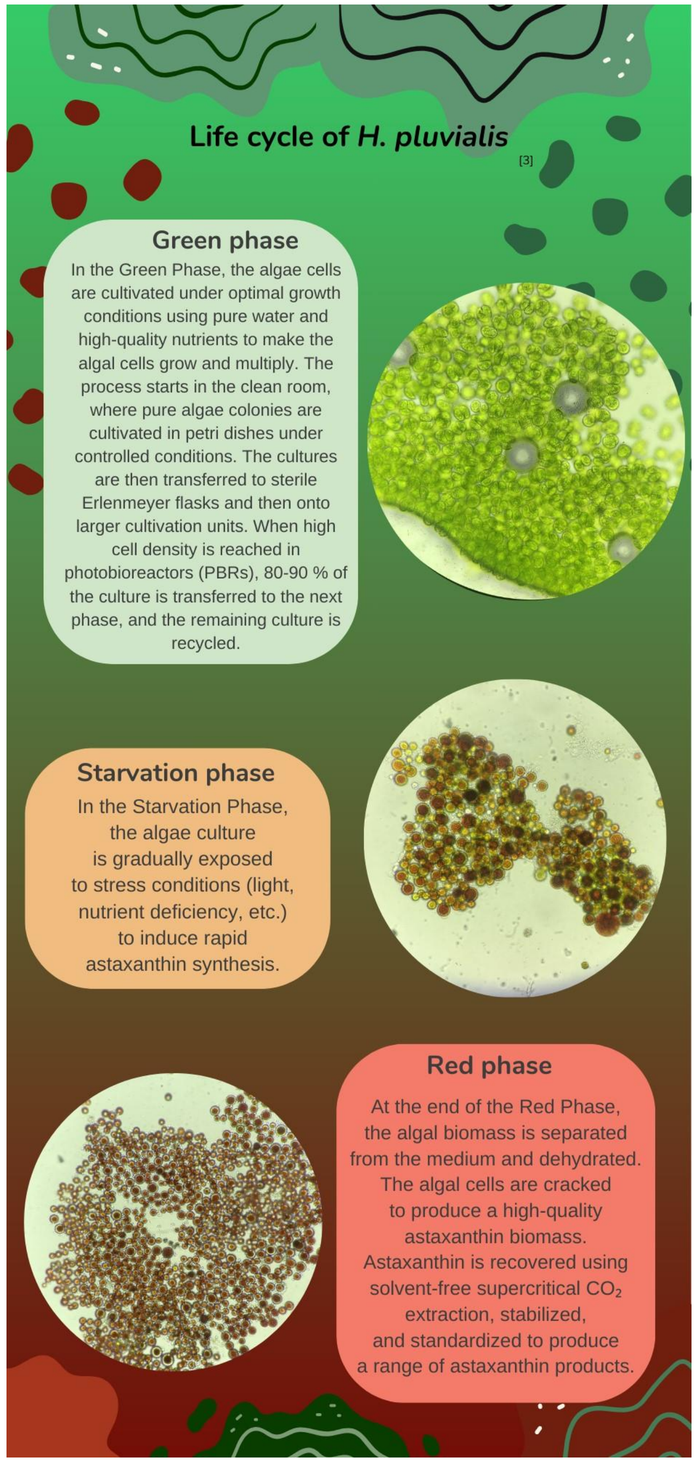
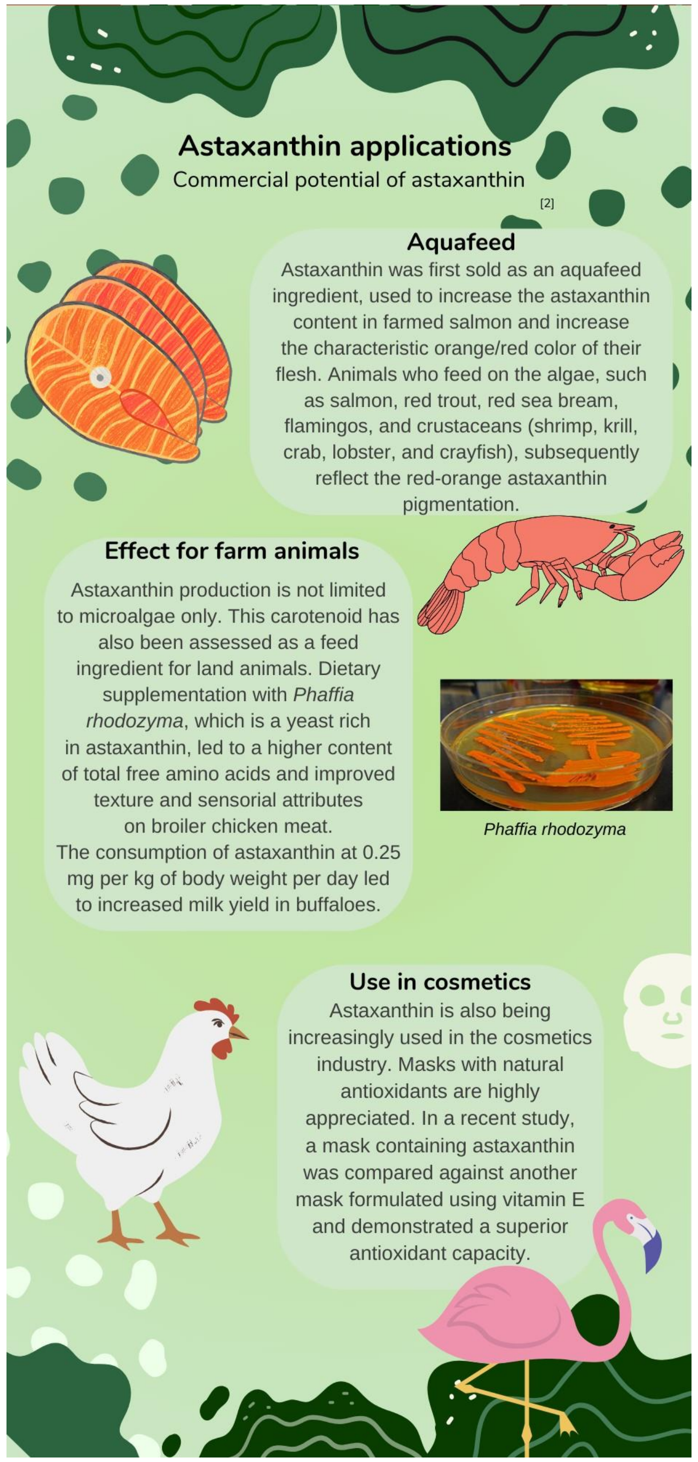
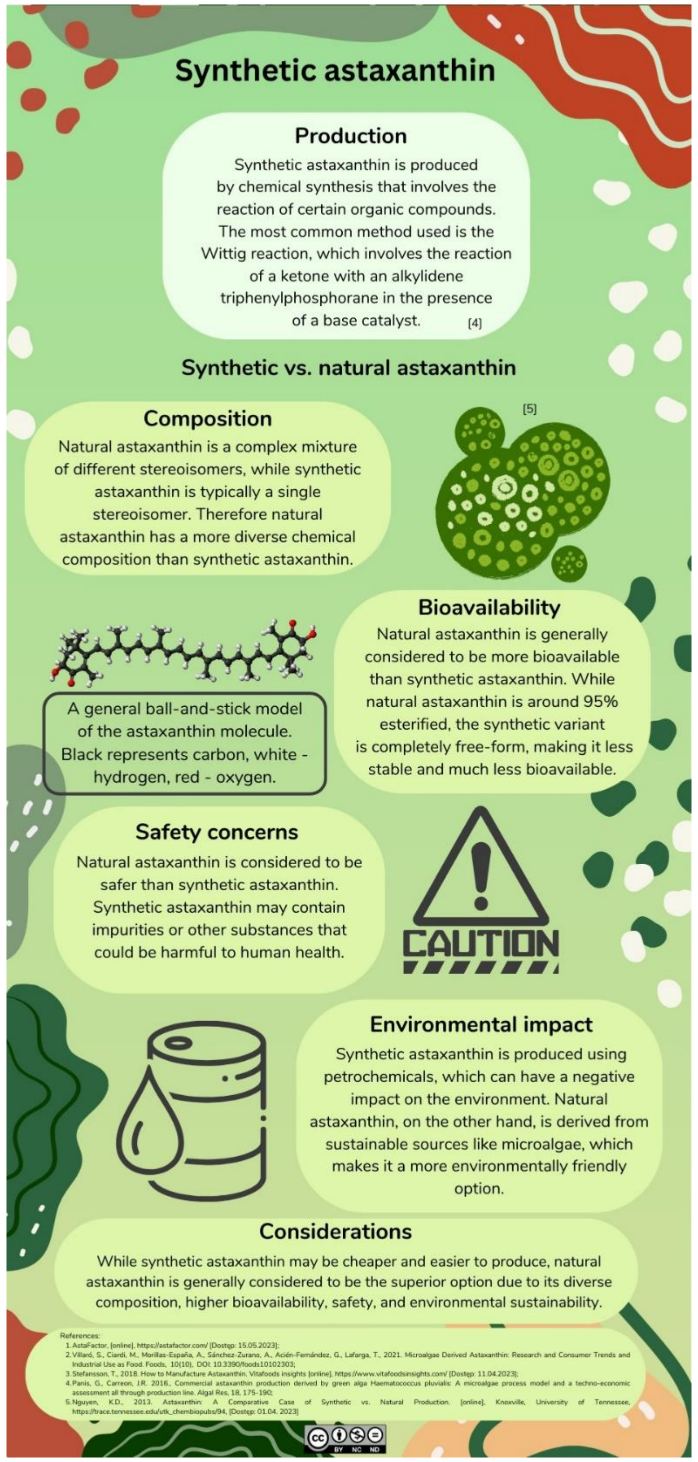
INFOGRAPHIC no. 4









INFOGRAPHIC no. 5

MICROALGAE IN THE CONTEXT OF ASTROBIOLOGY

BIOS-3

BIOS-3 - experimental closed ecosystem that has been explored for potential use of microalgae, specifically *Chlorella vulgaris*, to support life on lunar bases.

1972

1. *CHLORELLA* CONTAINS ALL THE ESSENTIAL AMINO ACIDS, SUFFICIENT LIPIDS, AND NEARLY ALL THE ESSENTIAL VITAMINS (SALISBURY ET AL., 1997).
2. A REACTOR SIZE OF 100 L PER PERSON IS ESTIMATED TO FULFILL 30% OF DAILY FOOD REQUIREMENTS (DETRELL G., 2021).
3. ALGAE CULTIVATION IS RELATIVELY SIMPLE AND HIGHLY RELIABLE. IN ONE EXPERIMENT, THE INITIAL GROWTH RATE WAS SUPPRESSED BY 70% WITH ULTRAVIOLET RADIATION, BUT THE CULTURE RECOVERED ITS GROWTH RATE IN 24 HOURS (SALISBURY ET AL., 1997).

70%

THE CULTURE OF *CHLORELLA VULGARIS* RECOVERED ITS GROWTH RATE IN 24 HOURS

ATTEMPTS TO PURIFY THE AIR AND GROW FOOD FOR SPACE EXPLORATION IN A SEALED ENVIRONMENT BEGAN IN 1972. A SMALL, CLOSED EXPERIMENTAL ECOSYSTEM CALLED BIOS-3 WAS CREATED IN THE SIBERIAN CITY OF KRASNOYARSK.
THE FACILITY WAS COMPLETELY UNDERGROUND. IT WAS POWERED BY A HYDROELECTRIC PLANT 30 KM AWAY. THE TOTAL GROWING AREA WAS 63 SQUARE METERS, WHICH PROVIDED AMPLE AIR-REGENERATION CAPACITY (SALISBURY ET AL., 1997).

IN THIS SYSTEM, PLANTS WERE GROWN IN A HYDROPONIC SOLUTION. STARCH-PRODUCING PLANTS AND OIL CROPS WERE GROWN AS WELL TO PROVIDE ENOUGH ENERGY (SALISBURY ET AL., 1997).

THE ABILITY TO RECYCLE WASTE, REMOVE CARBON DIOXIDE, AND PROVIDE OXYGEN, AS WELL AS THEIR NUTRIENT-RICH CONTENT, MAKES MICROALGAE REALLY USEFUL.

Challenges

ALGAE CONTAIN VIRTUALLY NO CARBOHYDRATES

FURTHER RESEARCH IS NECESSARY

SYSTEM AUTOMATION, MODULARITY, AND CONTINUOUS MONITORING WILL BE CRUCIAL DURING THE TECHNOLOGY DESIGN PROCESS.

RADIATION EFFECTS, OPERATION UNDER PARTIAL GRAVITY, HARDWARE SELECTION, SYSTEM AUTOMATION, AND LONG-TERM PERFORMANCE AND STABILITY NEED TO BE CONSIDERED (DETRELL, 2021).

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MICROALGAE IN THE CONTEXT OF ASTROBIOLOGY

MELiSSA

1. A MICRO-ECOLOGICAL LIFE-SUPPORTING SYSTEM (MELISSA) WAS CREATED TO AID HUMANS IN LONG-TERM SPACE EXPEDITIONS. THIS PROJECT WAS SUPPOSED TO BE USED AS A TOOL THAT WILL HELP US UNDERSTAND CLOSED LIFE-SUPPORT SYSTEMS AND WILL EVENTUALLY LEAD TO REGENERATIVE LIFE-SUPPORT SYSTEMS FOR LONG-TERM MANNED MISSIONS (LASSEUR, 2008.)!
2. IT IS INSPIRED BY AN AQUATIC SYSTEM AND IT CONSISTS OF FIVE MAIN COMPARTMENTS: FROM ANOXYGENIC THERMOPHILIC UP TO THE PHOTO-AUTOTROPHIC. THE DRIVING ELEMENTS ARE THE PRODUCTION OF FOOD, WATER, AND OXYGEN FROM THE ORGANIC WASTES GENERATED IN THE MISSION, LIKE URINE OR CO2.
THE WASTEWATER COMPARTMENT USES *FIBROBACTER SUCCINOGENES* TO GET RID OF FIBROUS MATERIAL.
THE FOOD PRODUCTION COMPARTMENT IS RESPONSIBLE FOR FIXATING CO2 AND MAKING OXYGEN AND, OF COURSE, PRODUCING FOOD (LASSEUR, 2008.).
3. THIS PROJECT IS MANAGED BY THE EUROPEAN SPACE AGENCY AND IT INVOLVES AROUND 30 ORGANIZATIONS FROM EUROPE AND CANADA. THE PROJECT IS ORGANIZED IN 5 PHASES: RESEARCH AND DEVELOPMENT, PRELIMINARY FLIGHT EXPERIMENTS, GROUND AND SPACE DEMONSTRATION, TECHNOLOGY TRANSFER, AND COMMUNICATION AND EDUCATION. (LASSEUR, 2008.)

ABOUT US

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References

DETRELL, G., 2021. CHLORELLA VULGARIS PHOTOBIOREACTOR FOR OXYGEN AND FOOD PRODUCTION ON A MOON BASE-POTENTIAL AND CHALLENGES. *FRONT ASTRON SPACE SCI*, 8, 700579, DOI: 10.3389/FSPAS.2021.700579.

LASSEUR, C., 2008. MELISSA: THE EUROPEAN PROJECT OF A CLOSED LIFE SUPPORT SYSTEM. *GRAVITONAL AND SPACE BIOLOGY*, 23(2), 3-12.

SALISBURY, F.B., GITELSON, J.I., LISOVSKY, G.M., 1997. BIOS-3: SIBERIAN EXPERIMENTS IN BIOREGENERATIVE LIFE SUPPORT. *BIOSCIENCE*, 47 (9), 575-85.

Klaipėdos universitetas

References:

INFOGRAPHIC no. 1

Cardoso, F.A., Souza, da Silva S do R., Oliveira, Prado, G.I., Bitencourt, P.A.J., Gastauer, M, 2023. *Microorganisms*, 11(2), 1-13.

Caudal, F., Tapissier-Bontemps, N., Edrada-Ebel, R. A., 2022. Impact of Co-Culture on the Metabolism of Marine Microorganisms. *Mar Drugs*, 20(2), 153.

Kapoore, V.R., Padmaperuma, G., Maneein, S., Vaidyanathan, S., 2021. Co-culturing microbial consortia: approaches for applications in biomanufacturing and bioprocessing, Critical Reviews in Biotechnology, 42(1), 46-72.

Liu, S., Moon, C.D., Zheng, N., Huws, S., Zhao, S., 2022. Opportunities and challenges of using metagenomic data to bring uncultured microbes into cultivation, *Microbiome*, 10, 76.

Madhuri, J.R., Saraswathi, M., Gowthami, K., Bhargavi, M., Divya, Y., Deepika, V., 2018. Recent Approaches in the Production of Novel Enzymes From Environmental Samples by Enrichment Culture and Metagenomic Approach of the. *Recent Developments in Applied Microbiology and Biochemistry*, 251-262.

Nichols, D., Cahoon, N., Trakhtenberg, M. E., Pham, L., Mehta, A., Belanger A., Kanigan, T., Lewis, K., Epstein, S.S., 2010. Use of Ichip for High-Throughput In Situ Cultivation of "Uncultivable" Microbial Species. *Appl Environ Microbiol*, 76(8), 2445-50.

INFOGRAPHIC no. 2

Aasen, I.M., Ertesvåg, H., Heggeset, T.M.B., Liu, B., Brautaset, T., Vadstein, O., Ellingsen, T.E., 2016. Thraustochytrids as production organisms for docosahexaenoic acid (DHA), squalene, and carotenoids. *Appl Microbiol Biot*, 100, 4309-4321.

Contreras, P., Oviedo, C., 2023. Potential and future perspectives of thraustochytrids in bioremediation. Int J Environ Sci Technol 20, 4483–4498.

Kalidasan, K., Vinithkumar, N.V., Peter, D.M., Dharani, G., Dufossé, L., 2021. Thraustochytrids of mangrove habitats from Andaman Islands: Species diversity, PUFA profiles and biotechnological potential. *Mar Drugs*, 19(10), 571.

Lewis, T.E., Nichols, P.D., McMeekin, T.A., 1999. The biotechnological potential of thraustochytrids. *Mar Biotech*, 1, 580-587.

Lyu, L., Wang, Q., Wang, G., 2021. Cultivation and diversity analysis of novel marine thraustochytrids. *Marine Life Science & Technology*, 3, 263-275.

Marchan, L.F., Lee, Chang, K.J., Nichols, P.D., Polglase, J.L., Mitchell, W.J., Gutierrez, T., 2017. Screening of new British thraustochytrids isolates for docosahexaenoic acid (DHA) production. *J Appl Phycol*, 29, 2831-2843.

Morabito, C., Bournaud, C., Maës, C., Schuler, M., Cigliano, R.A., Dellero, Y., Maréchal, E., Amato, A., Rébeillé, F., 2019. The lipid metabolism in thraustochytrids. *Prog in Lipid Res*, 76, 101007.

Patel, A., Mu, L., Shi, Y., Rova, U., Christakopoulos, P., & Matsakas, L. 2020. Novel biorefinery approach aimed at vegetarians reduces the dependency on marine fish stocks for obtaining squalene and docosahexaenoic acid. *ACS Sustain Chem Eng*, 8(23), 8803-8813.

INFOGRAPHIC no. 3

Gao, G., Wang, Y., Hua, H., Li, D., Tang C., 2021. Marine Antitumor Peptide Dolastatin 10: Biological Activity, Structural Modification and Synthetic Chemistry. *Mar Drugs*, 19 (7), 363.

Singh, S.B., 2022. Discovery and Development of Dolastatin 10-Derived Antibody Drug Conjugate Anticancer Drugs. *J Nat Prod*, 85 (3), 666-687.

INFOGRAPHIC no. 4

AstaFactor, [online], https://astafactor.com/ [accessed: 15.05.2023].

Villaró, S., Ciardi, M., Morillas-España, A., Sánchez-Zurano, A., Acién-Fernández, G., Lafarga, T., 2021. Microalgae Derived Astaxanthin: Research and Consumer Trends and Industrial Use as Food. Foods, 10(10), DOI: 10.3390/foods10102303.

Stefansson, T., 2018. How to Manufacture Astaxanthin. Vitafoods insights [online], https://www.vitafoodsinsights.com/ [accessed: 11.04.2023].

Panis, G., Carreon, J.R. 2016., Commercial astaxanthin production derived by green alga Haematococcus pluvialis: a microalgae process model and a techno-economic assessment all through production line. Algal Res, 18, 175-190.

Nguyen, K.D., 2013. Astaxanthin: a Comparative Case of Synthetic vs. Natural Production. [online], Knoxville, University of Tennessee, https://trace.tennessee.edu/utk_chembiopubs/94 [accessed: 01.04. 2023].

INFOGRAPHIC no. 5

Detrell, G., 2021. Chlorella Vulgaris Photobioreactor for Oxygen and Food Production on a Moon Base-Potential and Challenges. *Front Astron Space Sci*, 8, 700579, DOI: 10.3389/fspas.2021.700579.

Lasseur, C., 2008. Melissa: The European project of a closed life support system. *Gravitional and Space Biology*, 23(2), 3-12.

Salisbury, F.B., Gitelson, J.I., Lisovsky, G.M., 1997. Bios-3: Siberian experiments in bioregenerative life support. *Bioscience*, 47 (9), 575-85.

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