RCMOS – Revista Científica Multidisciplinar O Saber.
ISSN: 2675-9128. São Paulo-SP.

Ano V, v.2 2025 | submissão: 05

Technical-Scientific Article - Atmospheric decarbonization and edible biomass production, a viable alternative

Artículo técnico-científico - Descarbonización atmosférica y producción de biomasa comestible: una alternativa viable

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Abstract

This article addresses the potential of biological absorption of atmospheric carbon dioxide (CO_2) by photosynthetic organisms (algae, cyanobacteria, and higher plants) as a viable strategy for atmospheric purification. The biochemical process involved, the equipment required for controlled-scale cultivation (algae bioreactors), basic calculations of CO_2 absorption and oxygen generation, economic profitability analysis, implementation costs, ideal production conditions, and safety measures are discussed.

Keywords: *biological absorption of CO* $_2$*, atmospheric purification by biological process, food production from pollution.*

Resumen

Este artículo aborda el potencial de la absorción biológica del dióxido de carbono atmosférico (CO_2) por organismos fotosintéticos (algas, cianobacterias y plantas superiores) como una estrategia viable para la purificación atmosférica. Se analizan el proceso bioquímico involucrado, el equipo necesario para el cultivo a escala controlada (biorreactores de algas), los cálculos básicos de la absorción de CO_2 y la generación de oxígeno, el análisis de rentabilidad económica, los costos de implementación, las condiciones ideales de producción y las medidas de seguridad.

Palabras clave: absorción biológica de CO_2, purificación atmosférica mediante procesos biológicos, producción de alimentos a partir de la contaminación.

Introduction

The growing concentration of carbon dioxide (CO_2) in the atmosphere poses a direct threat to global climate stability, making concrete action to reduce and purify it urgent. The accumulation of this gas intensifies the greenhouse effect, causing global warming, rising sea levels, and increasingly frequent and intense extreme weather events. Given this scenario, governments, businesses, and civil society must collaborate to develop and implement CO_2 capture and removal technologies, while also promoting a transition to clean energy sources. Purifying the atmosphere of excess CO_2 is not just an environmental measure—it is a matter of survival and a responsibility to future generations.

A promising alternative to mitigate this problem is biological CO_2 capture, exploiting the natural process of photosynthesis. Organisms such as microalgae have high rates of carbon fixation and can be cultivated in industrial systems (photosynthetic bioreactors) with the potential to purify urban air and produce oxygen.

1. Methodology

For this work, bibliographic research and a supporting experiment were **conducted using psyllium bacteria and saltwater algae (Phytoplankton), with an initial mass of 10%** in 1 liter of water, by bubbling CO_2 for 24 hour**s.**

2. CO_2 Absorption

Photosynthesis is the biochemical process by which autotrophic organisms convert CO_2 and water into organic compounds using light energy. The overall equation is:

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

In this process, atmospheric CO_2 is fixed into organic molecules through the Calvin-Benson cycle, while oxygen is released from the photolysis of water. Microalgae exhibit superior photosynthetic efficiency to terrestrial plants, with CO_2 uptake rates of up to 1.8 kg of CO_2 per kg of dry biomass formed.

3. Necessary Equipment

• Photosynthetic bioreactors (tubular, bubble column, or inclined planes)
• Lighting system (solar or LED adjusted to the 400–700 nm range) • Aeration and CO_2 bubbling system
• pH and nutrient control (specific culture media, such as BG-11 or Chu) • Biomass harvesting and separation system (centrifuge, filtration, flocculation) • O_2, CO_2, and temperature sensors
• Automated control unit (SCADA or PLC).

4. Profitability and Production Calculations

Considering a 1,000 L bioreactor cultivating Chlorella sp., with a productivity of 0.5 g/L/day of dry biomass:

• Daily biomass production: 500 g/day • Associated
CO_2 absorption: ≈ 0.9 kg CO_2 / day •
O_2 release:≈ 0.65 kg O_2 /day

On an industrial scale (100 m^3), it is possible to absorb around 90 kg CO_2 / day. With biomass being able to be used in feed, biofertilizers, or biofuels, there is parallel revenue generation.

5. Production Expenses and Conditions

• Initial cost of implementation: between US$ 150–300 per m³ of bioreactor installed • Operating costs: electricity for lighting and pumping, nutrients and maintenance (~20–30% of total cost) • Ideal conditions: temperature 20–30 ºC, pH 6.8–8.0, CO_2 concentration between 2–5 % (optimized for growth), light intensity of 100–200 μmol photons/m² s.

6. Safety and Environmental Aspects

• Avoid biological contamination by invasive strains. • Ensure that the The CO_2 injection system has safety valves.

• Use of PPE (gloves, goggles, lab coats) when handling nutrients and biomass. • Continuous monitoring of pH and O_2 to prevent excessive acidification and hypoxia in the environment. • Residual biomass must be treated before disposal or industrial use.

7. Food Use of Residual Biomass

Residual biomass from microalgae cultivated for CO_2 absorption has significant potential for application in the food industry, primarily due to its nutritional composition, which is rich in proteins, vitamins, minerals, and natural antioxidants. This use allows for the transformation of an atmospheric mitigation process into a circular and economically viable production chain.

7.1 Biomass Composition

Depending on the cultivated species, dry biomass may contain 40–70% proteins, 10–20% lipids (including polyunsaturated fatty acids), 10–25% carbohydrates, as well as vitamins (A, B1, B2, B12, C, E), minerals (iron, calcium, magnesium, zinc, potassium) and antioxidant pigments such as chlorophyll and carotenoids.

7.2 Processing for Consumption

Processing involves harvesting steps (such as centrifugation or flocculation), dehydration (using a spray dryer or freeze-drying), grinding, particle size standardization, and, optionally, deodorization to reduce odor and flavor.

7.3 Energy Bar Formulation

An example formulation per 100 g bar might include: 20–30% dry microalgae biomass, 30–40%

cereals (oats, quinoa, amaranth), 20–25% dried fruit paste (dates, raisins, bananas), 10–15% seeds/oilseeds (chia, flaxseed, chestnuts), 5–10% natural binder (honey, molasses, glucose syrup), and natural flavors (cocoa, vanilla, cinnamon). The process involves mixing, molding, pressing, and vacuum packaging.

7.4 Functional Benefits

Energy bars enriched with residual biomass have a high protein content (up to 25 g/100 g), provide natural antioxidants, minerals such as iron, and vitamins, and have a sustainable appeal, associating food consumption with CO_2 capture.

7.5 Standards and Safety

It is necessary to comply with ANVISA (Brazil) or EFSA (Europe) standards, including product registration, microbiological control (Salmonella, coliforms, aflatoxins), heavy metal monitoring (lead, arsenic, cadmium), and mandatory nutritional labeling.

8. Conclusion

The continued rise in atmospheric carbon dioxide (CO_2) concentrations is driving the planet toward a global climate imbalance, the consequences of which directly threaten the survival of the human species. The current rate of emissions, driven largely by intensive industrial activities, points to irreversible scenarios of ecological and social collapse. Planet Earth will persist as a physical system, but maintaining human life under habitable conditions will become unviable. In this context, the adoption of carbon capture and storage (CCS) technologies by the highest-emitting industries represents not only an effective mitigation measure but also an economically viable strategy. The implementation of these systems does not compromise industrial competitiveness and can even generate reputational and regulatory gains. By incorporating such technologies into their operations, these companies will have the opportunity to significantly contribute to global climate stability and the preservation of human civilization. The biological absorption of atmospheric CO_2 through photosynthesis in microalgae is a technologically viable and environmentally sustainable alternative for atmospheric purification. In addition to mitigating emissions, the process allows us to produce oxygen and value-added biomass for food production, thus solving two problems simultaneously. Large-scale implementation requires considerable investment but can be offset by the commercialization of byproducts.

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/10/2025 | aceito: 07/10/2025 | publicação: 09/10/2025

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