EUROPRENEURSHIP & SUSTAINABILITY

Scientific editors

Tomasz Kusio
Alexandra Borges
Janusz Rosiek

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Tomasz Kusio, Alexandra Borges, Janusz Rosiek

Reviewers

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Table of Contents

Introduction 7

EUropreneurship for sustainable development 11

PART I: EUROPRENEURSHIP

Ch. 1. Sustainability and entrepreneurship: Entrepreneurial attitude of Romanian start-ups (*Antonia-Ioana Gagu*, *Tomasz Kusio*) 21

Ch. 2. Entrepreneurship in Georgia under the funded projects provided by the European Union (*Jemma Saakyan*) 35

Ch. 3. Homeland entrepreneurship in Polish fashion industry – an overview (*Irene Martínez Rodríguez*) 43

Ch. 4. Homeland entrepreneurship in Poland fashion industry – an overview (*Maja Maziarz*) 53

Ch. 5. Commercial viability of an online pharmacy (*Helena Silva*, *Maria Mourão*, *Pedro Carvalho*) 61

Ch. 6. Digitalization and Entrepreneurship: The Case of Indonesia (*Beni Suranto*, *Kholid Haryono*) 75

Ch. 7. Sustainable Human Resources Management (*Olga Kuryło*) 94

Ch. 8. Managerial background of sustainable event organization process (*Emiliia Hladun*) 101

PART II: SUSTAINABILITY

Ch. 9. Energy Sector Crisis and its Implications for Public Health and Sustainable Development in Europe (*Avtandil Svianadze*, *Ana Svianadze*) 119

Ch. 10. Promoting energy efficiency in an eco-school environment (*Ricardo Brito*, *Paulo J. Costa*, *Alexandra Borges*) 133

Ch. 11. The evolution of Corporate Social Responsibility disclosure and its relationship with the Sustainable Development Goals (*Ana Rute Silva*, *Marta Guerreiro*, *Susana Oliveira*, *Alexandra Borges*) 149

Ch. 12. The relevance of environmental accounting. An implementation proposal in the automotive sector (*Sara Costa*, *Marta Guerreiro*, *Susana Oliveira*, *Alexandra Borges*) 167

Ch. 13. Sustainability in the client's policy-related activities (*Mariia Baranovska*) 184
Ch. 14. The Role of Microalgae in a Sustainable Development (*Ingride Carvalho*, *Guilherme Fonseca*, *Paulo J. Costa*, *Alexandra Borges*) 194
Ch. 15. Industrial use of bioenergy and high-value molecules extracted from winemaking by-products. Ecological aspects (*Ourania Klapa*, *Paulo Costa*, *Mário Barros*, *Duarte Alves*, *Preciosa Pires*) 209
Ch. 16. Produced Energy Storage System at the Braking of a Train (*José Vicente*, *Agostinho Rocha*, *Rui Brito*, *Paulo J. Costa*) 232

Index of Tables 258
Index of Figures 260

Chapter 14

The Role of Microalgae in a Sustainable Development

Ingride Carvalho
Instituto Politécnico de Viana de Castelo, Portugal
Guilherme Fonseca
Instituto Politécnico de Viana de Castelo, Portugal
Paulo J. Costa
Instituto Politécnico de Viana de Castelo, Portugal, SYSTEC - Research Center for Systems and Technologies, Faculdade de Engenharia da Universidade do Porto
Alexandra Borges
Instituto Politécnico de Viana de Castelo, Portugal

Abstract

Today, climate change is a reality that can change the balance of ecosystems. When talking about sustainability and innovation, it is important to keep in mind that we must have a different vision and find new solutions. Microalgae are photosynthesizing microscopic organisms that grow rapidly under different environmental conditions due to their simple cellular structure. These organisms are considered fundamental for the maintenance of the life of our planet, since they are responsible for the production of most of the oxygen from the atmosphere, they account for 40% of the total photosynthesis of the planet. These microalgae have a biological, ecological, and economic importance. Biological because, in addition to producing 40% of the planet's photosynthesis, they sustain life in the seas and oceans. Also, it's important to refer that their Ecological importance since microalgae are fundamental in maintaining ecosystems. And, finally, the economic significance is seen in its diversity in commercial application. The use of these microorganisms promises to be an excellent solution to combat global warming and reduce greenhouse gas emissions. This work presents a development of a project of a Photobioreactor from the first design to its tuning and operation. The main idea of this project is to build a Photobioreactor that will response to the requisites to produce a specific type of microalgae. The main work activity is to find the right technologies for this project, making a perfect integration and control system. This equipment is important and contribute(s) to environmental sustainability and innovation.

Keywords: Microalgae, Photobioreactors, Environmental Sustainability, Innovation

1. Introduction

Microalgae are photosynthetic microscopic organisms that grow rapidly in different environmental conditions due to their simple cellular structure. They are found on our planet, on land, in water and in the air. These organisms are considered fundamental for the maintenance of life on our planet, since they are responsible for producing most of the oxygen in the atmosphere, that is, they are responsible for 40% of the total photosynthesis on the planet. There are thousands of species of microalgae, of which only 100 have been studied and about 20 are regularly exploited commercially.

Microalgae have biological, ecological, and economic importance. Biologically, they are important since, they responsible for producing 40% of the planet's photosynthesis, they support life in the seas and oceans. The ecological one is because microalgae are fundamental in the maintenance of ecosystems. Finally, the economic importance is due to its diversity in commercial application. The use of these microorganisms promises to be one of the best solutions accessible to humanity to combat global warming and reduce the greenhouse gas emissions we produce (Trigal, 2021; Aqualgae,2021).

Among the various applications of microalgae, the following can be mentioned (*Cultivo de microalgas,* 2018):

- Aquaculture – microalgae are the main food source used in the nutrition of aquatic organisms in captivity. It is also used as a supplement in the diet of fish or as a means of maintaining water quality, Figure 14.1.

Figure 14.1. The half black angelfish feeds on Spirulina, seaweed, shrimp, among others
Source: (Cultivo de microalgas, 2018).

- Water treatment – Microalgae have mechanisms to absorb inorganic and organic compounds dissolved in water as nutrients for their metabolism. The high adaptability of these organisms and their high rate of growth allow them to be used in the treatment of water from anthropic industries, or aquatic systems that need some type of remediation, Figure 14.2.

Figure 14.2. Aquatic system
Source: (Cultivo de microalgas, 2018).

- Agriculture – developed fertilizers and bio stimulants based on liquid algae extracts, as they increase crop resistance to pests. Also, they stimulate the growth, volume, and quality of a plant production, Figure 14.3.

Figure 14.3. Production of seedlings (plant) from microalgae
Source: (Cultivo de microalgas, 2018).

- Biomedicine and Pharmacology – Some species are used in weight loss diets and wound treatments; may have antibacterial, antifungal, antitumor and immune system regulatory activity, Figure 14.4.

Figure 14.4. Spirulina Pills
Source: (Cultivo de microalgas, 2018).

- Human and animal food – microalgae have been used as food for centuries. Rich in substances beneficial to health and with great potential in preventing numerous diseases, they are currently used in the form of dry biomass or in the extraction of supplements and natural dyes for food. It is also used as a supplement to animal feed, Figure 14.5.

Figure 14.5. Powder extract, detox juice based on Chlorella and Spirulina microalgae
Source: (Cultivo de microalgas, 2018).

- Chemical and food industry – Microalgae allow the biosynthesis and production of a wide range of substances of commercial interest, such as: vitamins, pigments, amino acids, polysaccharides, glycerol, enzymes, growth promoters in fermentation industries, waxes, phospholipids and lecithins, essential fatty acids and prostaglandins, Figure 14.6.

Figure 14.6. Line of cosmetics that have microalgae as a star ingredient
Source: (Cultivo de microalgas, 2018).

The table 14.1 below provides information on some species of microalgae available for human consumption:

Table 14.1. Main microalgae commercialized in the world for human consumption

Microalgae/Species	Application field	Main feature	Goal
Spirulina sp	Food Supplement	Great diversity of vitamins, minerals, amino acids, and antioxidants	Energize and fight aging
Chlorella sp	Food Supplement	Diversity of nutrients and compounds that help eliminate impurities	Nourish and purify
Haematococcus pluvialis	Antioxidant source	Rich in astaxanthin, nature's strongest antioxidant	Fight aging
Dunaliella Salina	Beta carotene source	Rich in beta-carotene (pro-vitamin A)	Combat aging, promote skin health and anti-inflammatory action
Nannochloropsis sp	EPA and DHA(Omega 3) source	Rich in Omega 3	Protect the nervous system and anti-inflammatory action

Source: (Microalgas – É de comer,2021)

To produce microalgae, it is necessary to study some requirements, such as: Site selection, Equipment and facilities, Selection of microalgae, Physical-chemical parameters, Culture medium and Mixture. Currently, there are two types of culture systems for microalgae production: open and closed systems. Each of them has several advantages and disadvantages. (Derner, 2021)

2. Research results

2.1. Open Systems

Cultures are developed mainly in tanks (cylindrical, rectangular, with an elliptical bottom or raceway type). They are called open systems because the culture is in contact with the atmosphere. They are less sophisticated, and do not allow the control of environmental parameters (light, pH, temperature, etc.) that have implications for crop growth, because of cultivation under natural conditions. They are more common and more profitable as they can be used for treating wastewater from different sources. Open systems are low cost, easy to build and operate, and highly durable, as seen in Figure 14.7.

2.2. Closed Systems

Closed systems, known as photobioreactors (FBR), in turn, have greater productivity compared to open systems, achieving greater efficiency in the use and fixation of injected CO_2. Different from open systems, the crop does not have contact with the atmospheric air, which allows the control of the environmental parameters that imply in the growth of the cultures. Several types of photobioreactors have been manufactured for the cultivation of microalgae, however, the most common types are vertical columns, vertical or horizontal flat panels (flat panel) and tubular photobioreactors (vertical or horizontal coils), built with tubes plastic, glass, or polycarbonate, as seen in Figure 14.8.

Nowadays, different microalgae production systems of different scales and uses are being studied and developed. Each of the systems has a series of advantages and disadvantages. In the first part, they worked in a more artisanal way, using traditional production systems.

Figure 14.7. Traditional microalgae production system

Source: own elaboration (Aqualgae Company).

The traditional production system has several disadvantages and some advantages over FBRs, table 14.2.

Table 14.2. Several disadvantages and some advantages of traditional production system over FBRs

Advantages	Disadvantages
• They are cheap systems. • They are simple, you don't need a lot of knowledge to assemble them.	• Low productivity. • The density reached by the cells is 5 to 10 times lower. • It is a disposable plastic material – greater environmental impact. • Area – productivity ratio is low. • High labor force. • No control over crop parameters.

Source: own elaboration (Derner, 2021).

Figure 14.8. Closed system - FBR machine
Source: own elaboration (Aqualgae Company).

Table 14.3. Several disadvantages and some advantages of Closed system – FBR machine

Advantage	Disadvantage:
High productivity. • Greater ease of continuous operation. • Control of culture parameters. • Glass material, sustainable. • 50-year lifetime/durability.	High initial investment.

Source: own elaboration (Derner, 2021).

2.3. Difference between vertical column FBR and tubular FBR

Photobioreactors provide the possibility of cultivating different species of microalgae, since it is possible to change the parameters (temperature, pH level, lighting, CO_2 injection) necessary for the best growth of microalgae. There are some types of photobioreactors but, this analyses will only focus in some differences between the vertical column FBR and the tubular FBR.

The great advantage of the vertical column FBR machine, Figure 14.9, is that all existing species of microalgae can be cultivated, while the tubular FBR machine, Figure 14.10, cannot cultivate all types of microalgae. The tubular FBR has the highest initial investment and higher productivity compared to the vertical column FBR.

Figure 14.9. Airlift type vertical column photobioreactor
Source: own elaboration (Aqualgae Company).

The project begins by studying all of the issues related with the microalgae system, and to define the type of photobioreactor and what technologies to use. This chapter is structured as follows: chapters 2 present the evolution of technical drawing and chapter 3 presents the drawing of vertical column FBR machine and the results achieved with the operation test of the system. The mains conclusions are outlined in chapter 4.

Figure 14.10. Tubular photobioreactor
Source: own elaboration (Aqualgae Company).

3. Evolution of technical drawing

According to the requisites demanded for this project (it means the type of microalgae to produce), the photobioreactor will be design by using a particular software. In the past, engineering drawings were all done by hand, using different types of pencils, erasers and *T-squares*. Even after all the manual work, if a change was necessary, the engineers and manufacturers had to start from scratch and redo the entire sketch. Currently, thanks to technological advances, such as the construction of machinery and equipment, technical drawings have been created. Technical drawing is a type of graphic representation in which it accurately transmits all the characteristics (dimension, type of material, views, cuts, scales, etc.) of the object it represents. Before the emergence of specific CAD (Computer Aided Design) software, there were already programs that facilitated graphic design, but their cost was high, and they were not as understandable as the programs we have today. Currently, there are several software on the market for creating technical drawings, such as: AutoCAD, Revit, DraftSight Free, LibreCAD, QCAD, ArchiCAD and SolidWorks. But AutoCAD and SolidWorks stood out. (Morais, 2012).

In 1982 the company Autodesk had the idea and initiative to create a CAD program that could run on a personal computer. The first version created was MicroCAD, which served as a guide to improve what would become AutoCAD, which began to evolve and become the most popular CAD software in the world. AutoCAD stood out because it is more versatile, it is used in different sectors, not only for architecture, but also for engineering, textile modeling, etc. It is excellent 2D drawing tool. However, in the 3D resource, its use is more complex, mainly due to the ease of handling and agility of the project. It is a complex program, as it requires memorizing certain command codes.

Therefore, its introduction in the academic world is important, so that the student obtains a broader understanding of the program, having an ease in handling the other programs available on the market, knowing that the vast majority had the influence of AutoCAD, as seen in Figure 14.11. While SolidWorks dispenses with memorizing command codes, as it has a highly developed interface, making it a major competitor within the CAD software market.

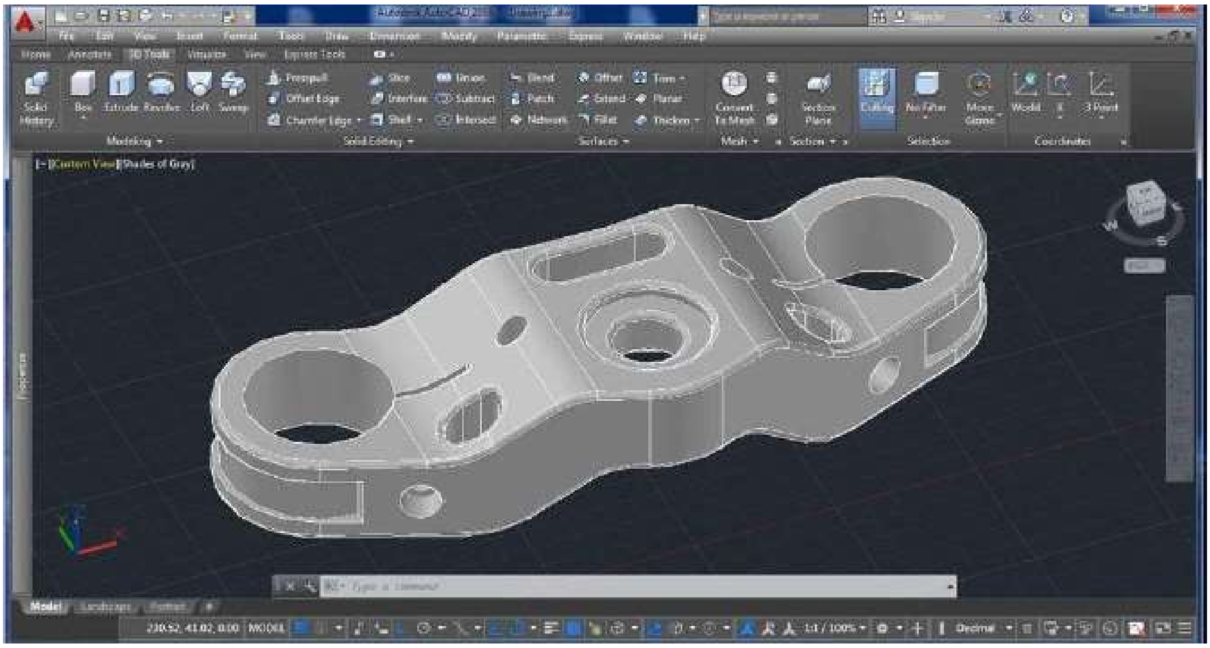

Figure 14.11. Drawing in AutoCAD
Source: own elaboration.

The demand of an easy-to-use program on Microsoft's operating system (Windows), to help building 3D models was required. It began to be developed in 1993, over the years the program evolved to the provision of 3D CAD technology, which allowed its users facilities, with quality tools and high performance, benefiting the development of better resources and products. SolidWorks, Figure 14.12, stood out because it is a program that optimizes work and increases designer productivity (Costa, 2016)

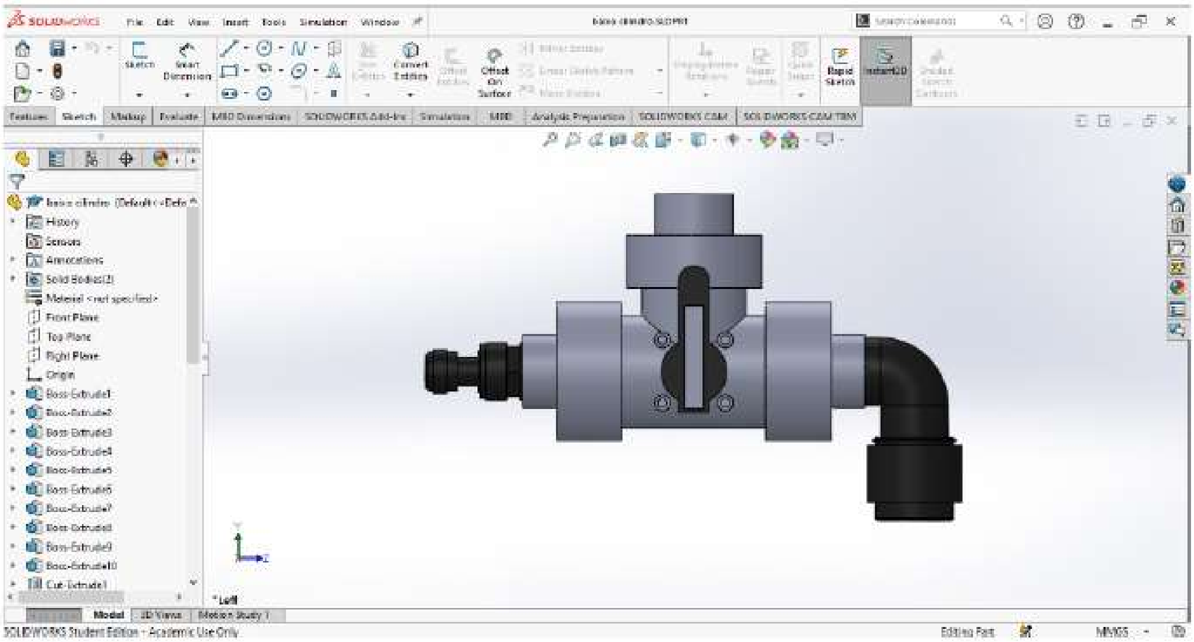

Figure 14.12. Drawing in SolidWorks
Source: own elaboration.

Drawing of vertical column FBR (Photobioreactor) machine

This project will use the photobioreactor machine, with 5 vertical columns serves to produce microalgae, which will then serve as food for shrimp, which will be food for sole or turbot larvae (fish produced in aquaculture). In the next pictures, there are presented some views of the drawn machine, as seen in Figure 14.13 and Figure 14.14:

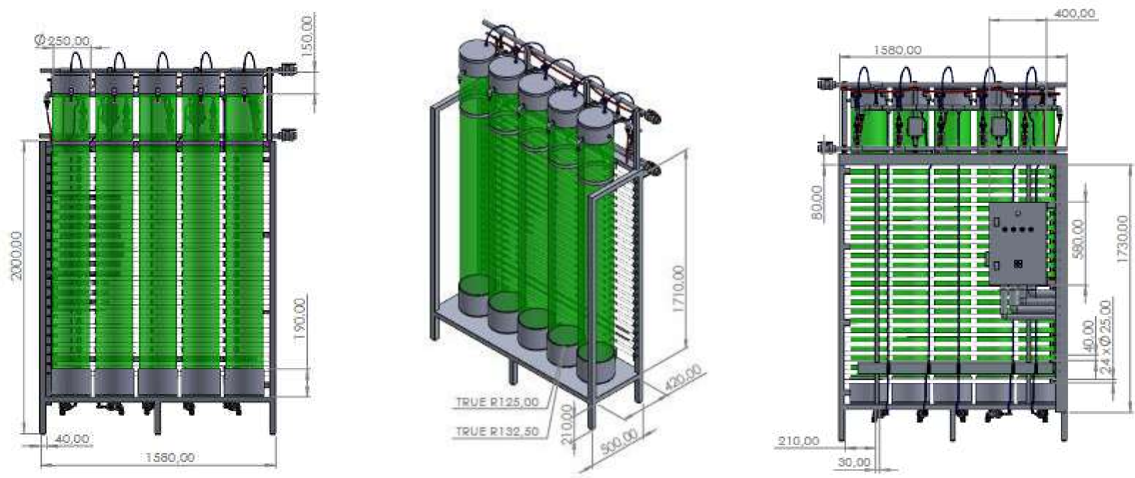

Figure 14.13. FBR machine: front, isometric and Rear views
Source: own elaboration (Aqualgae Company).

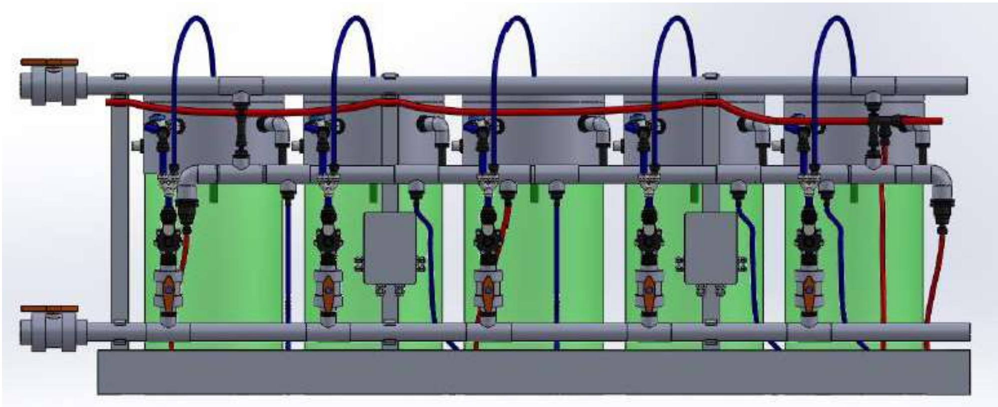

Figure 14.14. View of the connections part of the FBR machine
Source: own elaboration (Aqualgae Company).

3.1. Machine design process

To manufacture the machine, the first thing to do is necessary to purchase materials such as PVC material, acrylic columns, clamps, LEDS, solenoid valves, level sensors, tubes, etc. Then, it's time to make the metal structure, which took two weeks to make. After that, the columns took a week to be assembled. Finally, it was time to build the lighting tubes (LED), the electrical panel, the air pipes, and the water pipes, Figure 14.15. In general, the construction of the machine took about a month.

So, the first part is to build the metal structure (shelf), then the columns, the LED, the electrical panel and so on.

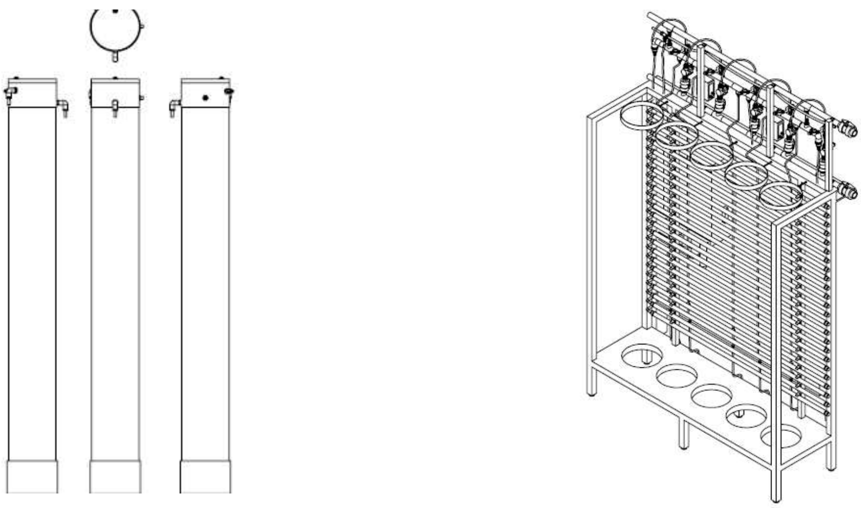

Figure 14.15. FBR machine: Some views of the machine column and metallic structure with the leds and connections
Source: own elaboration (Aqualgae Company).

3.1.1. Machine Operation

First, in a 500 L tank, the sea water is mixed with the nutrients, and through the filters, the water will be filtered, to obtain a water free of impurities, solids, and particles, being conducive to growth of the seaweed. Afterwards, this water will be sent to the columns through the pump. Each column has 100 L and, as there are 5, they take 500 L. They will fill up to 80% with water and the remaining 20% will be 10 L of microalgae. These quantities are controlled by the level sensors, which when it reaches the limit, automatically triggers/cuts the electrovalves, as seen in Figure 14.16.

As for luminosity, you start with low light (at 25%). After 4 days, you can change the light to 100%. Until the 8th day, the microalgae are going to grow with the light at maximum, because the right light conditions are necessary for the multiplication of microalgae. After the 8 days, you can start collecting the culture, removing 25% of the volume and then refill the columns with fresh water and nutrients. The cycle will be always the same, you must remove 25% of the volume and then add 25% of water. The machine works in this cycle. It has photoperiod, that is, the light turns on from 8 am to midnight. Then there's the nocturnal phase, which is where occur the division of microalgae (during night). The pH of the water is also controlled, and the ideal for microalgae is a pH around 8. That's because when microalgae are multiplying, the pH tends to rise to 9 to 10 and this is toxic for them. To solve this problem, CO2 is injected, since it reacts with water, originating carbonic acid and this acid is what makes it acidic, so it can control the pH, Figure 14.17.

Figure 14.16. Culture appearance on first day
Source: own elaboration (Aqualgae Company).

Figure 14.17. Appearance of the culture on the 8th day.
Source: own elaboration (Aqualgae Company).

So, the machine allows to establish the photoperiod, different lighting levels 25%, 50%, 75% and 100%, pH control through C02 injection and automatic filling with the level sensor.

4. Conclusions

In this chapter, we first introduced bioreactor design and different types of bioreactors that can be used for algal growth with high biomass production rates. Then we compared the advantages and disadvantages of these PBRs. We also summarized the computational modeling used in PBR design for algal growth. Microalgae can be cultivated in open-system (such as a raceway pond) and closed-system PBRs (such as tubular, bubble column, airlift, and flat panel). The comparison results indicate that both open and closed systems have advantages and disadvantages and should not be viewed as competing technologies. It is important also to identify optimal working conditions and reasonable costs in open and closed systems for algal growth. Microalgae are part of our lives, and we can only gain from its implementation in our daily lives. Some of these benefits are renewal of body cells and tissue; energy and focus; balance of the nervous system; healthier hair and skin; combating aging; heart health; control of diabetes and hypertension, among others. The objective of the project was achieved. Beginning with the requisites for a particular system of microalgae produce, a photobioreactor machine was designed and built, including all the sensors and motors needed.

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