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Research Article

The Solution is Out There, Focus on Microalgae

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Introduction

Many more of ours needs in food, medicine, could be covered with products of nature, and often with molecules contained in microalgae. "**The solution is out there, focus on microalgae**".

In this overview we are going to define some basic concepts to understand this amazing world of microalgae

Our planet is colonized everywhere by microalgae. Microalgae are present in all aquatic ecosystems, lakes, rivers, oceans, live in fresh, brackish, salty or even hypersaline waters. We know that the 30,000 currently cataloged are only the tip of the iceberg Figure 1.

The biotechnology sector is using them every day more, enhancing and taking advantage of this great capacity in biosynthesis of molecules that are useful for our society.

Never forget the bases

Each cell of microalgae is a small molecule factory that produce and stock many kinds of molecules for its life, multiplication, etc.

To set up suitable industrial culture methods, we must respect the structures, needs and behaviors of each species in culture. Many time good project and big team collapse forgotten this basis. The microalgae are simple eukaryotic plants organisms. In general, they are photosynthetic, autotrophic but certain species can pass to mixotrophy to adapt them or to resist in difficult condition.

Many times, a same structure, behavior or composition can have a good aspect for a phase of the production chain and bad for other. They present an infinity of shapes, they are suspended in the water column, mobile or immobile and belong to phytoplankton. Figure 2.

But certain species present a trend to the sedimentation in culture conditions. It can be a bad thing, among other, fooling in the bottom of the open pond and the wall of the tubes. This fooling reduces the entrance of light so the productivity of the culture, also it can be a focus of death cells, contamination and can reduce the quality of the whole biomass harvested. But nevertheless, this trend to sedimentation can be a factor to concentrate them in harvest or some downstream treatment.

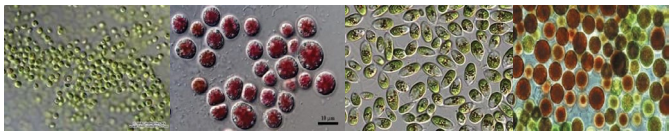

Figure 1

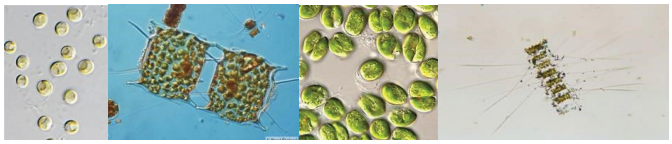

Figure 2

Certain species have a weak cellular wall which can be damage in the culture medium with mechanic stress, injection of gas (CO2 and air) and bubbling, in culture or downstream process. Others present a strong cellular wall that complicated the rupture of the cell and the extraction.

They have an important metabolic plasticity and can use different metabolic pathways for the synthesis. Their metabolism and composition of biomass will depend on the species and the culture conditions.

Many times, the production is focus overly on the microalgae, light and temperature, but never we have to forget of the determinant importance of medium and the quality of water use and reused, fresh, brackish, artificial or sea water.

Microalgae are opportunistic, in eutrophic area, appear blooms of high concentration of microalgae. These blooms random, seasonal, and human population on the shore of the lakes, seas, oceans harvested and used them like source of food or others. Figure 3.

These blooms are random, and we could not sustain an industry on an unreliable production. To this end, structures called photobioreactors, have been designed, for the cultivation of photosynthetic species.

The first structure was the "open" pond, which means in direct contact with atmosphere. They are used for resistant rustic microalgae such as spiruline for the production of protein-rich food, pigments such as phycocyanin and haematococcus for the extraction of a valuable pigment, astaxanthin. Figure 4.

Figure 3

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Figure 4

In open pond, the installation cost is lower, (CAPEX) and operation cost (OPEX) but the control of the culture parameters is limited. This system of culture allows

1.A basic control on parameters of production

2.Obtain culture with single species, monospecific culture.

3.Maintain production in cycle between two harvests

But certain microalgae that are more sensitive to temperature change, pH, sedimentation, aggregation and contamination, cannot be cultivated in open pond or with great risk of failure.

To increase the control on culture, what is known as "closed" photobioreactors was designed. They are built with different materials, polycarbonate, methacrylate, glass. Figure 5.

In this case, algae are separated from the environment by a transparent wall, which allows to protect the culture from the hostility of the outside, and to control the culture conditions. They are much more expensive in cost of facilities but have higher productivity in biomass.

These reactors have more versatility and in addition to spiruline and haematococcus, many more species of microalgae can be grown to produce w3, EPA, DHA, Exopolysaccharides etc.

There are also other options for reactors such as vertical flat panel, sleeves or raceway, plastic channel, which are an evolution of the open pond. It can also be grown under greenhouse to reduce the hostility of the environment.

But be careful because the more complex a photobioreactor is, the more expensive is.

Figure 5

Taking advantage of microalgae but without burn the necessary steps:

The scale up of production and the project is a huge aspect. Many industrial projects were based on laboratory results, with short assay in condition very different of the real conditions in outdoor. The outdoor biotic values are lower than in indoor photobioreactor culture [1].

In other among, inertia of the big volume, changes of temperature, light, have an important influence in the response of the microalgae, on their productivity, composition and quality of the biomass produce.

Each species, in each production systems, must be test and maintain in industrial production no less than 6 months. (better 12 months) before to conclude and carry out safe, reliable and profitable business. We can't avoid the pilot phase, and pre-industrial phase. Figure 6.

The pression for the cost a of R+D+i are high, push to shorten this phase, but with a new species, understanding a species not used in culture until the date, we need about 10 years, to developed, check, new production systems, photobioreactors, downstream, etc. to secure the production and satisfy a market and customers.

With the background obtain in research and development we have knowledges about several species to carry out reliable and profitable culture. In this case, we can settle our experience on this background, but always we need to test the strain in real outdoor condition of the area of culture, the quality of water use and is necessary treatment, also the photobioreactors designed and the method of culture chosen.

In some case it is convenient to think about protecting intellectual property, but this topic is complex and not well defined in this sector yet.

Patent or license on photoreactors, methods of culture, strains or both in what country? The approach of the legislation aspects is very different regarding with the country we select to produce microalgae. Exist also a duality between exchange information's with the public sector to justify and pretend to obtain public finance or protect the background in a private business company. The frontier is complex and depend in the strategy of each company.

We could cite and discuss many more aspects, but in summary, in an overview, microalgae culture must be a global approach including biological, physical, chemical, financial, management, legislation aspects with a multidisciplinary team, to successful with the production and business. The biology of microalgae and his culture is a multifactorial network and we need to know the impact of each parameters but also the relationship and influence of all of them on

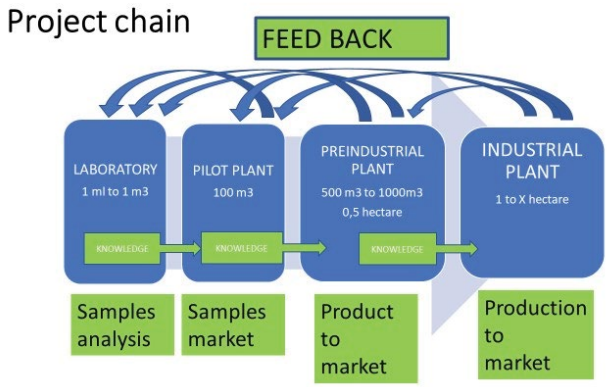

Figure 6

the culture, productivity and quality of the biomass produce. Figure 7.

Estimate dates and real dates:

Many times, the dates use to elaborate the business plan is based on data extrapolated from results of short-term laboratories and small volumes. These data may be overvalued and may not correspond to the results that will be obtained in industrial cultivation outdoor and large volumes.

Photosynthetic performance:

It is normal to see to use or announce photosynthetic yields of 5 and up to 10% when in reality in outdoor conditions in large volume, with most species and on average does not exceed 2 to 3% in the best case.

Specific grow rate: SGR

Values of growth rate around 1 had been used in some estimation for production calculations, this rate can be measured in a very specific and isolated case, but in general it is not over 0.3, in many cases it is close to 0.1.

$SGR=(Ln\ g/l_{t2} - Ln\ g/l_{t1})/(t_2 - t_1)$ (eq .1)

Ln= natural logarithm, t_1= time one in days, t_2= time one in days, Figure 8.

Duplication time: DT

Because of this used grow rate, the estimate duplication time is shorter than the real observed. This mistake can produce a huge error in the duration of the culture cycle in a semi continuous system for example.

DT= Ln (2)/ SGR (eq.2)

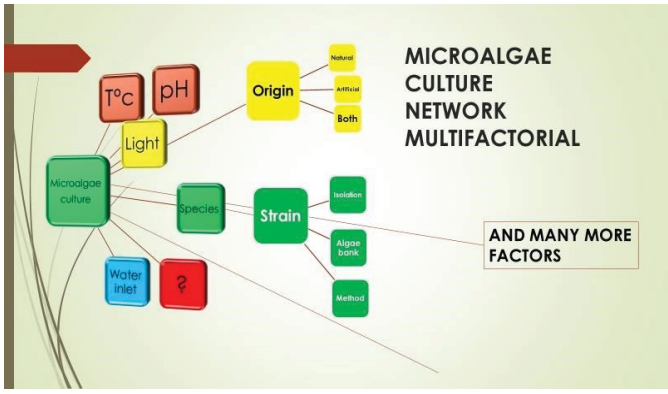

Figure 7

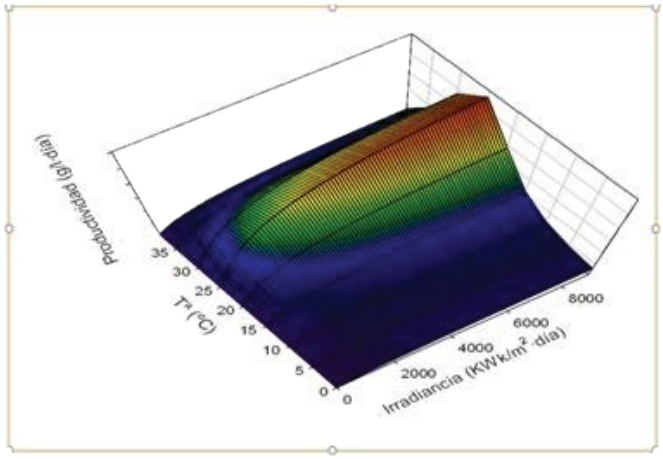

Figure 8

Figure 9.

Concentration harvest:

It appears a duality in the harvest concentration. High concentration in the culture harvest reduce the cost of filtration and centrifugation to concentrate and extract the biomass. But high cellular concentration in culture can reduce the penetration of the light in the culture and reduce the final productivity. Determine this optimal point, for each species and in each season, need time and replicate experiences.

Global composition, specific molecules and isomers:

A very important notion in the market study is the relationship that exists between the size of the market and the value of the product. Figure 10.

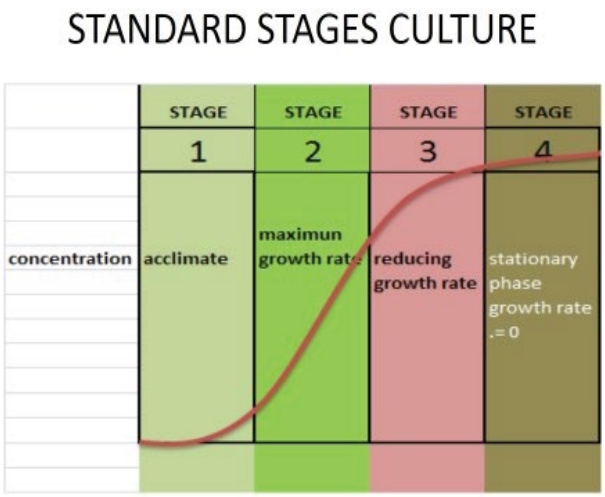

Figure 9

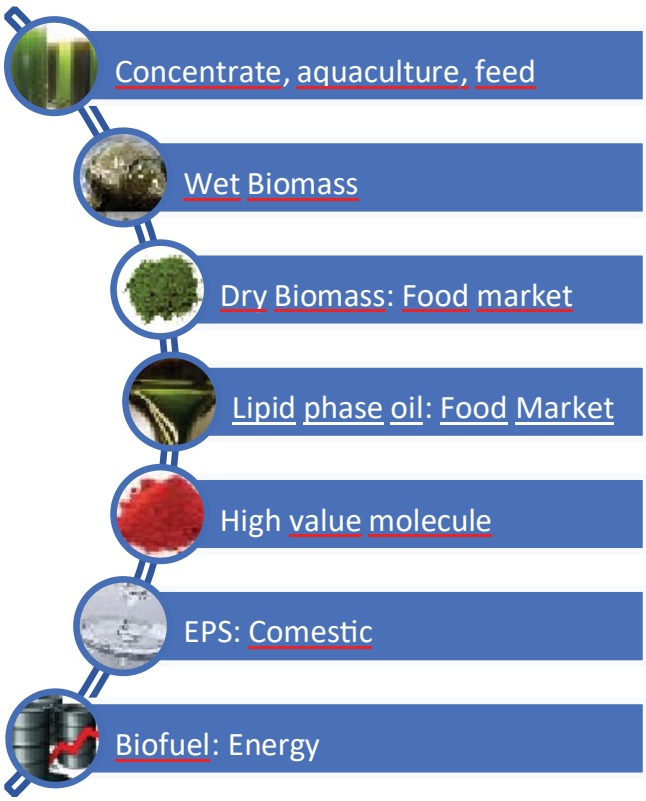

Figure 10

The potential of biofuel consumption and market is enormous, but the barrel of oil is currently sold at around 70 to 80 euros, so the production of microalgae to produce biofuel is currently difficult to make profitable due to CAPEX and OPEX. There is a great research work that is being done with this option to reduce material costs, crop control, downstream with different species.

Dry biomass, can be used as a product with the whole composition of the cell of the microalgae cultivates. It could be a source or ingredients food and a good choice between market size and product value. We are talking about 30 to 200 euros per kilo depending on the quality of the composition and in particular the presence of w3.

In this case we have check if the species is or not novel food, to permit is use as ingredients. In this moment, Spiruline (prokaryotes), Tetraselmis, Odontella can be use as food, Nannochloropsis is in period of acceptance. When we move to final products obtained by fine extraction, downstream costs are high, the market is a niche market, but the value of the product is very high, rising thousands of euros per kg with certain pigments.

What are the most interesting molecules that make microalgae present a great interest for the market? The composition of biomass varies in function of the species and the conditions of culture.

Culture in optimal conditions and "ad libutum nutrients"

These crops allow to reach a high level of productivity and a stable composition of the biomass characteristics of the species. It refers that all the parameters of culture are optimal or near the optimum of the species, that is the availability of all the necessary nutrients, the light, in intensity, duration and quality.

In this case, the composition of biomass is a standards composition, where we have the principal molecular families:

Figure 11.

Proteins: About 40% of the composition, are vegetable proteins, but in this case very close in balance of essential amino acids of animal proteins. But they have a certain deficiency in essential amino acids, among others in amino acids with sulfur, methionine, cystine, but also tryptophan, [2] which means that they cannot cover all the need for the supply of essential amino acids in human feed. They can be incorporated at a higher level than other kind of vegetable [3] like soy protein, for example, which is already a very valuable protein, which is incorporated up to 20 to 30% in feed for example in aquaculture for omnivorous or carnivorous fish like seabream, seabass.

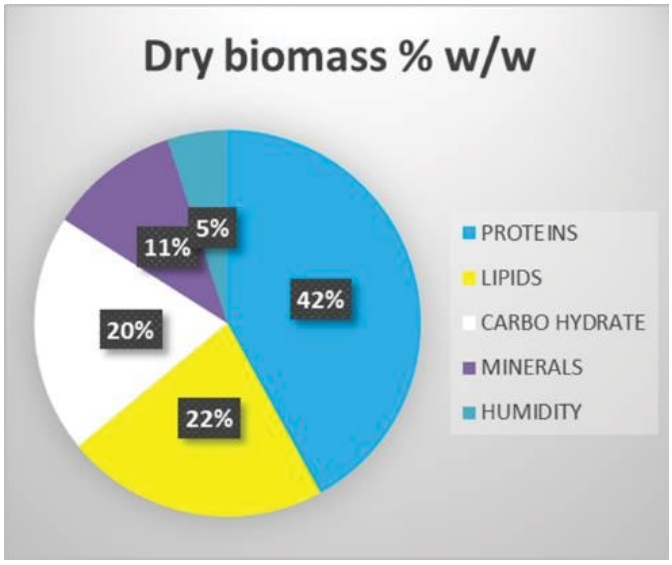

Figure 11

Lipids: about 20% lipids, microalgae produce polyunsaturated essential fatty acids, depending of the species (Becker, 2013b), rich in EPA, DHA, ARA.

Carbohydrates: about 20% of different carbohydrates.

11% minerals: potassium, magnesium, iron etc. very interesting as a source of trace elements as food ingredients. **Pigments**, depending on the species we can extract valuable antioxidants, natural colorants, markers, sunscreen and natural dyes. But be careful and analyses well which isomers are present and if they are active

Vitamins: Microalgae synthesize and contain several vitamins, generally one of them in low concentration [4,5].

Culture in "change conditions", deficiency, "stress"

In this case the crops are subject to modification of crop conditions. These changes must be strictly controlled because they should not be lost from crop control, but modification decided to modify or boost the synthesis of certain molecules.

It refers to these modifications can be a lack of nutrients in the medium, the modification of the model of illumination of the photobioreactors, intensity, photoperiod or composition of light, temperature, both or others parameters. These changes are going to boost certain metabolic pathways with certain species to increase the biosynthesis of molecules with high interest and value.

Nannochloropsis sp., In conditions of stress, lack in certain nutrients, for example, tend to produce more lipids, but mostly saturated that are concentrated in vacuoles, interesting for biofuel production.

In the case of Dunaliella sp., it can be observed a high intracellular concentration in β carotene. In the case of Porphyridium sp., it observed a production and exocytosis of exopolysaccharides, extracted as a gelatin, can be added in cosmetic creams. One time more, analyses well which isomers are present and if they are active for benefit sought. These molecules are of great interest because they have very interesting properties and give an added value to the biomasses produced.

Conclusion:

Many more other aspects could be analyses and in more details. This is an overview on the some very important aspects we cannot forget, and we have to take in account to fulfill a project and raise the target. Many project collapses not for a lack of knowledge or capacity but due in set aside finally some basic concept. The ultimate goal is not only to achieve the effectiveness of a technique but also to ensure that it is effective.

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