Bioethical considerations for algal biotechnology

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ABSTRACT: In this manuscript we discuss different aspects and applications of algal biotechnology and how they are seen through the prism of bioethics. We review how algae have been considered to solve problems on Earth and to ease human suffering. We also take a look at the current state of the production of algal biomass and we offer our suggestions and considerations based on the fact that the biomass is an expensive product and yet its quality is very good.

Keywords: microalgae, cultivation, biomass, bioethics, growth, biochemical composition

INTRODUCTION: Although the term "bioethics" was first used by Potter in the early 1970s [1], long after the cultivation of microalgae became a common practice, we could argue that some of the driving principles of the use of algae in the biotechnological industries have been bioethical since the early beginning.

It is undeniable that the ecological impact of people on nature has been huge since the start of the Industrial Revolution in the nineteenth century, with the human population increasing from 1 billion in 1835 to 6 billion in just a little more than 150 years [2]. This growth in population has been positively influenced by the so called Green Revolution – research and development in agriculture between the 1930s and the late 1960s, which led to an increase in agricultural production worldwide [3]. Yet, in the 1950s, it was argued that the supply of food will not be enough, as the population was increasing more rapidly than the output of agriculture, and several alternatives were considered – one of which was the cultivation of green algae like *Chlorella* and *Scenedesmus* for food [4]. Such an argumentation could nowadays be considered as bioethical, as it touches many important issues related to the subject – the growth of the human population, its potential impact on nature, and the question of what the good things are that can be done in order to support the exponential growth of the population, without putting too much stress on nature and agricultural resources.

Since the 1950s, the prospects of the cultivation of microalgae received support from many proponents with regards to their potential applications. With the coming of the space age in the 1960s and 1970s, it was considered that the algae could be used to feed cosmonauts, as well as to terraform planets of the Solar System [5]. These prospects have raised many bioethical issues on their own, such as whether it is good or bad to spread life beyond the cradle of the Earth, whether we have the right to endanger extraterrestrial species or whether human expansion to the Solar System is justified [6]. Another argument for the necessity of microalgae cultivation which was presented during the early years of algal biotechnology is that most of the studied algal species contain important biologically active substances and as such could be used in medicine and pharmacy [7], which is undoubtedly bioethical as it is in favor of easing human suffering.

During the last 15-20 years, microalgal cultivation once again received considerable public attention, because some supporters suggested that algal biomass could be used for the production of biofuels [8]. This idea has also been analyzed through the prism of bioethics. Certain researchers have claimed that developing biofuels could be treated as an ethical duty, and algae are one of the potential biofuel sources [9]. Algae biofuels have also been considered to be part of the second generation of biofuels because it is thought they do not compete with land and food resources and they do not negatively affect the environment and local populations, compared to conventionally produced biofuels [10]. Standard biofuels are often viewed as ethically controversial, because arable land instead of being used to grow food would be used to grow fuel [11]. The advantage of algae is that they are being grown in photobioreactors and thus could hopefully help to avoid the abovementioned dilemma and in the meantime, offer a viable solution.

In this manuscript we will discuss the current state of the production of algal biomass in the light of its bioethical implications.

DISCUSSION: No matter how algae are considered to help humanity or are involved in solving ethically controversial issues, there is one simple fact that defines the current state of algal biotechnology – it is the truth that the algal biomass remains an expensive product. Cultivation of microalgae is a challenging process – they need to be provided with a suitable nutrition medium, CO_2 also ought to be ensured, cultures need to be stirred and, in the end, water must be evaporated if we want to obtain dry biomass. The high cost has dire consequences on certain algal applications and most notable of these is biofuels. It is calculated that a kilogram of biodiesel is obtained from 12 kg of microalgal biomass, and just for producing this quantity 2kg urea, 0.530 kg KH_2PO4, 0.370 kg $MgSO_4$ and some other micronutrients are needed – the overall cost of these salts is close to the cost of 1 kg of conventional diesel [12]. Back in 2017, the price of wheat on the market in Chicago was estimated to be $151.90 per ton and for corn – $134.48 [13]. It is difficult to calculate the exact production cost of algal biomass, as projected economics from public literature range from $270-$2450 per ton [14]. But even if we take the lowest value, which is hardly achievable, produced algal biomass would still have a very high price compared to most commonly used crops worldwide.

It would only be ethical and morally right to present this fact, rather than give false hopes about certain prospects. Is it feasible to replace conventional food and biodiesel with algae? No, it is not yet possible according to the current state of technological development, and the price of algal biomass has always been high even though the technology for algal cultivation has existed for decades.

Stating this fact does not mean that the application of microagal biotechnology has no ethical basis at all. In order to provide a sound ethical justification, however, the focus ought to be shifted. Algal biomass, while being expensive, is a product of high quality. As such, the priorities are altering as well – in the food industry, the asset of algal biomass is not as a basic product, but rather as a supplement [15]. Here we ought to stress that the food supplement industry is well developed and dates back to the 1960s, starting in Japan, USA, Taiwan, Australia, and China [16]. It is well known, for example, that *Spirulina* as a food supplement contains a variable combination of substances, including ones that are absent in common food, and dry biomass of this alga has 60-70% protein, 10-20% carbohydrates, 1-14% lipids, 4% nucleic acids and 4-6% minerals [17]. The high protein content is well-balanced in amino acids and this alga is also a source of beta carotene and iron, and it is thought to be the world's richest natural source of vitamin B-12 and essential fatty acids [18]. These qualities cannot be underestimated and they are what makes algal biomass such an important product in the food industry, even if it is expensive.

The high quality of biomass makes it applicable in other biotechnological fields as well. Certain species are able to accumulate highly valuable compounds – for example – *Dunaliella salina* produces beta carotene, *Hematococcus pluvialis* produces astaxanthin, *Porphyridium cruentum* – polysaccharides, *Lyngbya majuscule* – immunomodulators [19]. The fact that the biomass is a costly product does not disprove the fact that it is a good source of these products, and, as such, does not downplay the critical role of algae in medicine, pharmacy and cosmetics. Moreover, even if those valuable compounds are contained in other species, algae are still the primary natural source of these compounds in many food chains. A very good example can be given with long-chain PUFAs. PUFAs can be obtained from fish and fish oil, yet, safety issues have been raised because of the possible accumulation of toxins in fish. There are also problems with unpleasant taste, fishy smell and poor oxidative stability, and that is why algae are considered to be a promising and advantageous source [20]. Once again, the focus is on quality of the algal biomass as a justification for its use.

When we discuss biotechnology and bioethics, it is also important to consider the public awareness of the subject. People in developed countries, an example of which is Japan, have been strongly influenced by the usage of the prefix "bio" in the industry, government and marketing [21]. The so-called "bio"- products have gained extreme popularity, because they are considered to be healthier, safer and ecologically clean. The high quality of the compounds produced by algae, which have applications in cosmetic, food production and pharmacology can be described with the term "bioproducts" [22]. To sum it up, microalgae can not only be useful and practical in certain biotechnological fields, but they can be attractive as well.

CONCLUSIONS: An ethical dilemma, or an ethical paradox, is defined as having to choose between two possible moral imperatives. Choosing either one of these would breach a moral principle. In the case of algal biotechnology, the dilemma is between quality and quantity. Should we pursue production of large quantities of algal biomass, or rather we should focus on the quality of the product? Choosing the first one is a requirement if we want to feed the hungry or save the world from the eventual depletion of fossil fuels, but that would mean ignoring more realistic and economically feasible applications. Choosing the second one means that we will give up on solving the problem of poverty or obtaining biofuels, but instead we can pursue new opportunities in medicine and pharmacology, which, however, will be sustainable.

Our solution to the ethical dilemma is: pursue quality over quantity. This is the driving ethical principle which should push the algal biotechnology and production in the days ahead. Our review of the scientific literature, which we have done in the previous chapter, shows that algae are not a sustainable way to feed the hungry, because the biomass is expensive. Neither will they fuel our transport for the same reason. This could change if there is a major breakthrough leads to a drastic decrease of the biomass cost, but the current prospects for this continue to be very slim [23]. The ethically right decision in this case would be to re-evaluate our priorities about the prospects of algal biotechnology and to acknowledge that certain efforts during the past 10-15 years have failed. It was reported in 2016 that algae biofuels programs, such as the one run by Exxon Mobil Corp., fell flat due to their lack of success to achieve economically viable results [24]. It is not to say that such programs have been scientifically useless. Quite the opposite, many important scientific papers have been written in the pursuit for a better, ecologically cleaner world. But the expected practical results have not come. It is high time the world faced the truth. We suggest that the focus that should drive fundamental research is to work on new ways to lower the cost of the biomass – this is a noble and ethical goal that is worth pursuing in the years and decades to come. This does not justify investing in unrealistic and futile projects and constructing large facilities just to meet certain aims, while we are still waiting for the future.

Meanwhile microalgae are finding their realistic application in healthcare, medicine and cosmetics, where they are already helping to make our world better. Microalgal cultivation is a promising branch of biotechnology and the benefits are already in use.

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