Photobioreactors for microalga Chlorella Sorokiniana cultivation

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Abstract. This work presents various constructions of photobioreactors for microalgae Chlorella Sorokiniana cultivation. We studied dependence of biomass production rate on photobioreactor construction. We suggest special photobioreactor construction for pilot-scale biomass production. We explored the ways to use the obtained biomass as a source for lipids and carotinoids. We recommend to use waste biomass for obtaining of sorption materials for water purification. The spent sorption materials may be used as a co-substrate for fermentation of organic wastes.

Keywords: microalga, Chlorella Sorokiniana, photobioreactor, biomass, water purification

1. Introduction

Microalga Chlorella Sorokiniana (C. Sorokiniana) cultivation is carried out for synthesis of third-generation biofuel. High-speed synthesis of microalga biomass is carried out in special apparatus known as photobioreactor (PBR)1-4.

The aim of this work was to develop photobioreactor construction and select appropriate light conditions for high-speed synthesis of C. Sorokiniana biomass.

Two types of photobioreactors are used for microalga C. Sorokiniana cultivation: open and closed. Open photobioreactors are artificial basins, open containers, ponds, vessels. The disadvantages of open-type PBR are the following: the possibility of other algae type reproduction, inflecting by pathogenic bacteria and water level reduction due to evaporation.

The closed-type PBR do not possess the above-mentioned disadvantages. But there are problems connected with biomass adhered to vessel walls, and long-term presence of microalgae at unlighted reactor zone. In order to achieve optimum cultivation conditions, one should provide equal lightning throughout the photobioreactor volume.

In case of heterotrophic organisms, uniform light access is provided throughout the whole microalgae cultivation period. Light factor is an exception for autotrophic cell population, which rather fast becomes a limiting one due to optical properties of the culture which is a medium of high light-absorption. Constant growth of cell amount and biomass per time unit provides rapid achievement of
linear growth stage, despite the continuous cell amount growth. At this the culture density is various for reactors with various suspension width, however the surface cell concentration at the moment of this transition remains constant.

In dense culture which is in linear growth phase, the total photosynthesis productivity of the suspension is determined in each elementary time period as a work of cells, which are located at the irradiation zone. At this, a portion of cells at the irradiation zone carries out photosynthesis at the linear stage, another portion is at the plateau of photosynthesis light curve of a single cell. The other cells (outside the "photosynthesis area") are essentially ballast and do not make contribution to the general population photosynthesis, as the photosynthesis light reaction duration (about 10-3 s) is considerably shorter than cell migration period between transilluminated and non-transilluminated suspension zones (Figure 1), which is achieved by biomass mixture 6.

![Figure 1. Optical and functional structure of alga culture as a photosynthesising system: light distribution is on the right side, photosynthesis intensity of a single cell of microalgae population is on the left side.](image)

2. Materials and methods

Nutrient broth composition for microalgae *C. Sorokiniana* cultivation was experimentally selected and is presented in Table 1.

| Substance | Concentration, mg/l |
|-----------|---------------------|
| ZnSO₄·7H₂O | 100                 |
| CuSO₄·5H₂O | 10                  |
| CoSO₄·7H₂O | 100                 |
| MnCl₂·4H₂O | 500                 |
| H₃BO₃·WF   | 50                  |
| Na₂MoO₄·2H₂O| 100                 |
| FeCl₃·6H₂O | 4                   |
| Na₂EDTA·2H₂O| 6                   |
| KNO₃       | 1                   |
| KH₂PO₄     | 100                 |
| MgSO₄·7H₂O | 240                 |

The prepared microalgae *C. Sorokiniana* suspension is placed in PBR of 500 ml. During the cultivation process an intermittent mixing takes place using magnetic mixing machine, located at the bottom of PBR. The mixing regime is as follows: 15 ± 2 min of mixing, 120 min of rest. Mixing rate was 500 rpm. Microalgae suspension is permanently aerated by air using bubbler throughout the whole cultivation period. This device consists of aerator pump and atmospheric air supply tube with 1.5 ± 3 l/min consumption at 26 °C temperature. The cultivation was carried out at surface lightening with 2500 ± 300 lx daylight fluorescent lamp (DFL) of 12 hours photoperiod. In order to increase power of luminous flux, which goes through biomass suspension, we put lamps of two types into the PBR.

In the first case (PBR-1) we used waterproof aquarium lamp of red visible light with wavelength λ = 660 nm, which was directly put into the reactor (Figure 2). In the second case (PBR-2) the irradiation source was placed into protective glass casing with green-blue visible light λ = 555 nm (Figure 3). PBR irradiation intensity with internal and external lamps was 4000 lx. The lamps were constantly turned on.
3. Results and discussion

Microalga *C. Sorokiniana* biomass growth was determined from the suspension optical density using spectrophotometer UNICO 1208 at 750 nm wavelength. Optical density was further recalculated for counted cell number in ml at hemocytometer (Goryaeva chamber) \(7\). The initial optical density of the *C. Sorokiniana* suspension equal to 0.120 corresponds to 1.87 mln/ml cell number. PBR without a submersible lamp was used as a control. The cultivation process was carried out within 10 days. The results of biomass growth are presented in Figure 3. Lamps without internal lightning were used as a control.

The highest biomass growth for *C. Sorokiniana* microalga was observed when cultivating at PBR-1, Figure 4. The additional lamp is placed into the photobioreactor with red light, wavelength is 660 nm. The construction with submersible light source allows one to avoid non-photosynthesising areas.

Specially designed units PBR-3 (Figure 5) were used as pilot installations for biomass growth in laboratory conditions. These are narrowing down cylindrical vessels made of polymer. Sun and additional irradiation are used. Gas-air mixture supply is performed at the bottom of PBR-3, which provides aeration and suspension intermixing throughout the whole volume. PBR-3 volume is 100 l, it is equipped by sensors of medium pH, temperature and automatic system "day/night". PBR width is 10 cm, additional radiation is provided by day fluorescent lamps OSRAM DULUX S 11W/21-840, its' illumination intensity is 2200-2800 lx.
We developed an economically efficient method for extraction of products with high value addition, such as lipids and carotenoids from the obtained *C. Sorokiniana* microalga biomass (Figure 6). A part of the residual biomass will be used as an adsorbent for industrial wastewater purification from heavy metals and oil products. At the same time the microalga remained after extraction and spent sorption materials may be used as co-substrate for fermentation of organic wastes. Biogas, which generally consists of methane (CH₄) and carbon dioxide (CO₂) should be divided into components. Methane is recommended to use for housekeeping needs, for heat and power supply of the process. Carbon dioxide is formed during the fermentation process and after methane combustion for energy obtaining. It will be used at microalga *C. Sorokiniana* cultivation stage as a source for carbon at photoautotrophic microalga biomass synthesis.

**Figure 5. PBR-3.**

**Figure 6.** A scheme for *C. Sorokiniana* biomass processing.

### 4. Conclusions

During this work implementation we have selected photobioreactors for high-speed synthesis of *C. Sorokiniana* biomass and defined it zero waste management directions.

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