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LABORATORY SCALE PHOTOBIOREACTOR

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SUMMARY

A photobioreactor using three concentric glass cylinders, with a light source mounted on the axis within them is described. The space between two innermost cylinders is used as a waterjacket, while the culture of phototrophic microorganisms is in the chamber between the outer cylinder and the middle one. This chamber is also equipped with a stirrer. *Rhodobacter capsulatus* has been grown in the device at biomass concentration up to 550 mg/l without light limitation.

INTRODUCTION

Intensive cultivation of phototrophic microorganisms requires good exposure to light which can be accomplished in photobioreactors where the ratio of the surface area to its volume is very high. Photobioreactors using conventional fermentors with an additional light source are not suitable for intensive cultivation since they do not meet this requirement. Thin, rectangular light-transmitting chambers are also widely used as photobioreactors (Shtol and Mel'nikov, 1975; Gobel, 1978). However, gas and mass exchange in this type of photobioreactors is poor and can bring about limitation or inhibition of culture growth caused by gaseous substrates (e.g. N_2 and CO_2) and metabolism products (O_2 particularly). Tubular loop photobioreactors, given a good illumination, enable a much better gas and mass exchange due to the external gas exchanger (Pirt et al., 1983). However, since photosynthesis and gas and mass exchange do not occur simultaneously due to being spatially separated, the culture undergoes repeated changes of the conditions in this type of apparatus. Photobioreactors using three concentric cylindrical chambers, with a light source mounted on the axis within them, the space between the inner cylinders used as a temperature-regulating waterjacket, with the culture placed in the space between the outer cylinder and the one in the mid-position, have long been used (Myers and Clark, 1944). In these

photobioreactors good exposure of the culture to light is provided, but gas and mass exchange is rather low.

The present work describes a photobioreactor of the latest type with a relatively high gas and mass exchange.

MATERIALS AND METHODS

The simplified schematic diagram of the photobioreactor (Fig. 1) depicts no clamping studs, gas and liquid inlet and outlet coupling tubes, rubber packings etc. The device is made of three glass cylinders (1-3) closed by common bottom (4) and top (5) lids. The light source (6) is mounted on the axis in the inner cylinder. The space between cylinders 2 and 3 is a temperature-regulating waterjacket, while the outer chamber serves for cultivating phototrophic microorganisms. The stirring device consisting of a magnetic ring (7) with stirring plates (8) is mounted in the outer chamber. The sensors (9) are fixed in cylinder 1 just above the stirring plates. This position of the sensors increases the turbulence of the culture and thus prevents microorganisms from growing on the surface of the sensors.

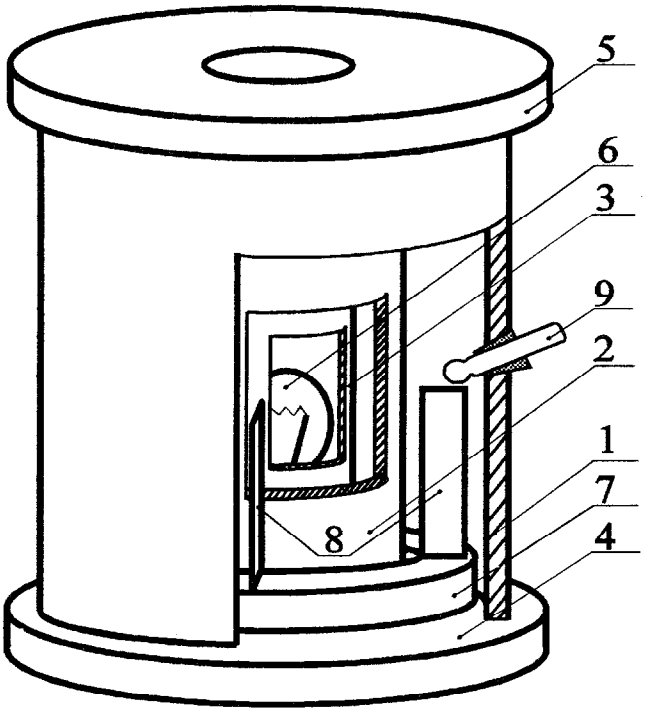

Fig. 1. Photobioreactor. 1, 2, 3 - outer, middle and inner glass cylinders, respectively; 4, 5 - bottom and top covering plates; 6 - light source; 7 - magnetic ring stirrer; 8 - stirring plates; 9 - sensors.

The entire volume of outer chamber is equal to 1.3 l, with the working volume varying from 0.3 to 1.0 l. The cylinders are 250 mm high and the distance between cylinders 1 and 2 is 12-14 mm. The ratio of the surface area exposed to light to the volume is 69 m^2/m^3. Grated additional external illumination, it would reach 153 m^2/m^3.

Gas is delivered into the culture through the bottom lid. The time required for pH to be equilized after adding 0.5 M acid or alkaline (0.5 ml) is taken as a conventional measure of agitation efficiency.

To test the efficiency of the photobioreactor the purple non-sulphur bacterium *Rhodobacter capsulatus* st. B10 was used. Cultivation was carried out under continuous turbidostat regime using the Ormerod medium (Ormerod et al., 1961) with 60 mM of lactate as carbon source and electron donor (except otherwise qualified) and 10 mM of $(NH_4)_2SO_4$ at pH 7.0 and 30°C. The light intensity from inner tungsten lamp (100W) measured by thermocouple under SZS24 filter ($400<\lambda<800$ nm) was 60 W/m^2. Gas, argon, was delivered at 40 ml/min. To control growth of phototrophic microorganisms the computerized installation for continuous cultivation (Fig. 2) designed at the Institute of Soil Science and Photosynthesis RAS (Kisselev et al., 1986) was used. All assays were carried out in steady state after 5 culture doublings at least.

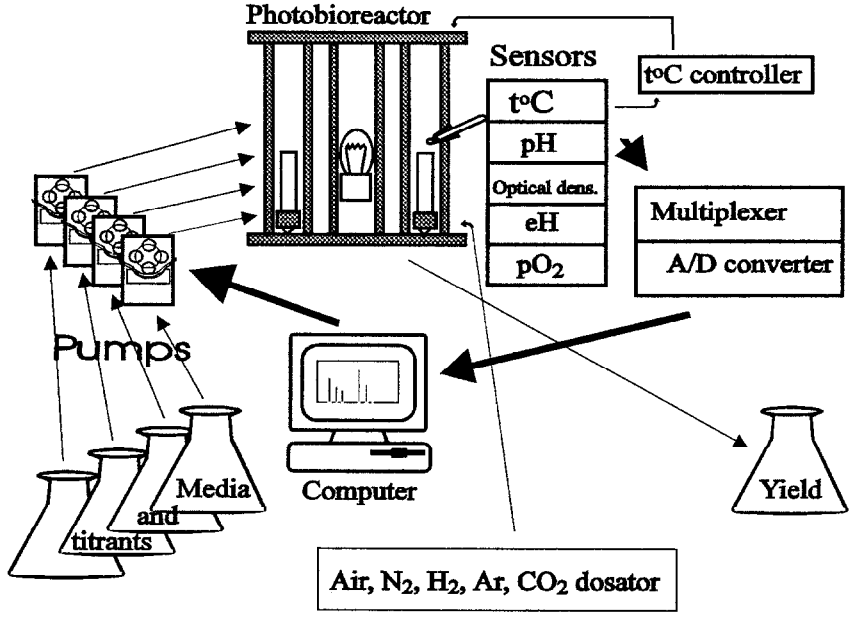

Fig. 2. Installation for continuous cultivation of phototrophic microorganisms.

RESULTS AND DISCUSSION

The time required for the pH in photobioreactor to be equalized after adding small amounts of acid and alkaline depended on the volume of the culture but not on the gas delivery rate. It took 2 s for 0.5 l of the culture to be entirely mixed and 7 s if the culture volume increased to 1.0 l, the rotating rate of the stirring device being 100 rev/min. If the photobioreactor was not equipped with a magnetic ring stirrer, it decreased with increase of gas flow delivery and took 40 s for 1.0 l of the culture medium at the gas flow rate 500 ml/min. Thus, the installation of the stirrer has proved to be a very useful modification increasing the efficiency of the photobioreactor.

Continuous cultivation of *Rb. capsulatus* showed that the growth rate was maximum when the biomass concentration increased as high as 550 mg of dry biomass

per litre (Table). Yet, it did go down with further increase of the steady state biomass concentration evidently due to the growth limitation caused by light, since all the nutrients available were in excess. The cultures investigated were not limited by lactate as judged from the measurements of lactate concentration in the culture medium. Moreover, these cultures were not limited by NH_4^+, since Eh of the culture was constant and equal to -160 mV. It is well known that NH_4^+-limitation of *Rb. capsulatus* would result in derepression of nitrogenase synthesis and, as a consequence, in hydrogen production leading to decrease of Eh. With the biomass concentration increasing as high as 2046 mg/l, the yield evaluated as the product of $\mu \cdot X$ was 266 mg dry biomass/l/h. However, when it increased further, the yield decreased. In this case the data obtained indicated that a slight increase in the biomass concentration resulted in a drastic culture growth limitation caused by light.

Table

Growth rate (μ, 1/h) and yield (P, mg/l/h) of *Rb. capsulatus* grown in turbidostat at different steady state biomass concentration (X, mg/l)

X	200	387	490	550	613	950	1280	1480	2046	2537	3193*
μ	0.31	0.30	0.30	0.29	0.27	0.22	0.18	0.16	0.13	0.10	0.063
P	62	116	147	160	166	209	230	237	266	254	201

**Lactate concentration in the input medium was 120 mM*

Thus, the modified photobioreactor enables the cultivation of *Rb. capsulatus* at light intensity 60 W/m^2 without light growth limitation at the biomass concentration as high as 550 mg/l, the maximum yield reaching 266 mg/l/h at 2.046 mg/l. Evidently, given additional external illumination, it might increase further. However, the overall dimensions of the installation would be much larger. The main ideas of this photobioreactor have been patented.

LITERATURE

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