Available online at www.sciencedirect.com
ScienceDirect
Bioresource Technology 99 (2008) 4755–4760
BIORESOURCE TECHNOLOGY

Comparison of two different pneumatically mixed column photobioreactors for the cultivation of *Artrospira platensis* (*Spirulina platensis*)

S. Oncel *, F. Vardar Sukan

Department of Bioengineering, Faculty of Engineering, University of Ege, 35100 Bornova, Izmir, Turkey

Received 24 January 2007; received in revised form 20 September 2007; accepted 22 September 2007
Available online 5 November 2007

Abstract

Internal loop airlift and bubble column photobioreactors (PBR) were compared with respect to their performances during cultivation of *Artrospira platensis* (*Spirulina platensis*). Culture conditions were kept the same and different parameters were examined through the experiments. It was observed that a higher dry biomass weight and chlorophyll-a concentration was obtained in the airlift PBR yielding a maximum growth rate of 0.45 day^{-1}, while 0.33 day^{-1} was reached in the bubble column PBR. Subsequently, a 17-day of production was carried out in the selected PBR to fully determine the performance of the PBR. Maximum growth rate of 0.47 day^{-1} was reached during long term cultivation.

Keywords: *Spirulina platensis*; *Artrospira platensis*; Photobioreactor; Airlift; Bubble column

1. Introduction

Microalgae are currently commercially utilized area in many applications (Apt and Behrens, 1999; Bosma and Wijffels, 2003; Chisti et al., 2003; Cohen, 2000; Lee, 1997; Ogbonna et al., 1997; Olaizola, 2003; Richmond, 2000; Tramper et al., 2003), and have thus attracted increasing interest in recent years. Microalgae have close interactions with their environments, consequently, the parameters which define their environment such as temperature, light, nutrient concentrations and pH, have to be at optimum levels (Fox, 1996; Lee, 1999; Tanaka et al., 1995a,b; 1996; Molina et al., 1999).

Light plays an important role in microalgal cultivation. Growth rate of microalgae increase directly proportionally with increasing light intensity at optimal intensities, up till saturation levels. Further increases in light intensity cause inhibition of cellular growth (Jansen et al., 2003; Lee, 2001; Lee et al., 2002; Ogbonna and Tanaka, 2000; Pulz, 2001; Tanaka et al., 1995a; Vonshak and Torzillo, 2003).

Pneumatically mixed photobioreactors are the systems where the dispersion of gas and nutrients is realised by the air fed into the system. These reactors can differ in their designs, possessing internal-loops, external-loops or divided column airlift systems and bubble columns (Borja et al., 2001; Borowitzka, 1999; Chisti, 1998; Degen et al., 2001; Walter et al., 2003). Aeration rates and bubble diameters are controlled via air spargers which provide optimal mixing and gas transfer in the reactor. Similarly, different light regimes may be maintained inside the system especially in down comer and riser sections which can also serve as photoinhibition barriers. The time a cell spends in light and dark zones may be related to the rate of circulation in the down comer and the riser (Becker, 1995; Chisti, 1989; Jansen et al., 2003). However, airlift systems have some problems in scale-up. The main problem arises due to unavoidable increases in the column dimensions which introduce physical constraints for optimal cultivation

* Corresponding author.
E-mail address: suphi.oncel@ege.edu.tr (S. Oncel).

0960-8524/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2007.09.068

conditions, in parallel to the increases in the volume of the culture (Chisti, 1998, 1989; Cornet et al., 1995; Lee, 2001; Vardar, 1994). Various microalgae species have been tested in different pneumatically mixed PBRs by different workers (Barbosa et al., 2003; Borja et al., 2001; Chisti et al., 2003; Csögör et al., 1999; Lee, 1997; Lee et al., 2002; Petkov, 2000; Tsavalos and Young, 1996; Walter et al., 2003) with variable degrees of success.

In this study, *Artrospira platensis* was taken as a model organism to compare internal loop airlift and a bubble column photobioreactors, since it is a well known organism produced commercially for it's nutritional content and potential to produce various valuable biochemicals (Becker, 1995; Borowitzka, 1999; Cohen, 2000; Lee, 1997; Olaizola, 2003; Oncel, 2004; Pulz and Gross, 2004; Richmond, 2000; Sanchez et al., 2003; Vonshak, 1997).

2. Methods

2.1. Microorganism

The strain of *A. platensis* (*S. platensis*) used was from the collection of EGE-MACC of Algae Research and Development Unit in Science and Technology Research and Application Center (EBILTEM). The origin of the strain is from Parachas lake in Peru and was obtained from ACMA (Association pour Combatre la Malnutrition par Algoculture) in France from Dr. Ripley Fox.

2.2. Culture media

The culture media used was Zarrouk's medium, sterilized is at 120 °C for 15 min (Becker, 1995; Borowitzka and Borowitzka, 1992).

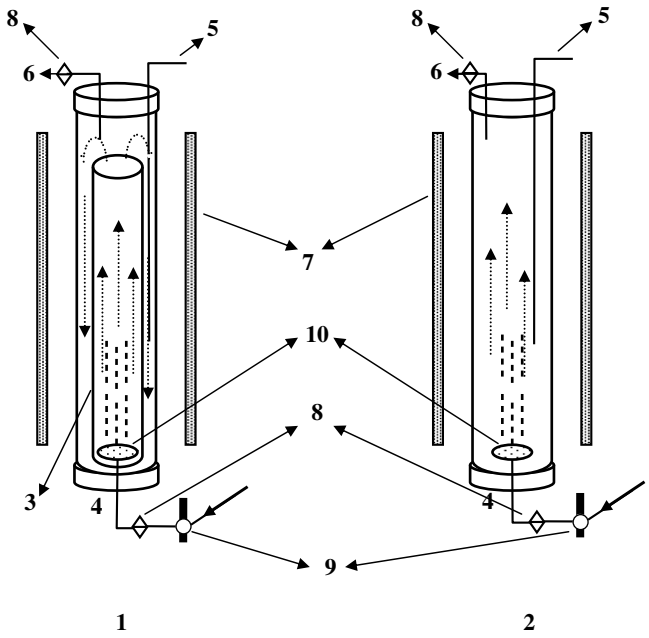

Fig. 1. Schematic diagram of the airlift (1) and bubble (2) PBR systems.

2.3. Photobioreactor (PBR)

Two identical column PBRs were used for the experiments (Fig. 1). One of which was an internal loop airlift PBR with a draft tube (1) and other was a bubble column PBR (2). Both reactors were made of glass with a thickness of 0.5 cm. The working volume was 1.5 l, the height and internal diameter was 75, and 5.5 cm, respectively. The height of the draft tube (3) of the airlift PBR was 60 cm with an internal diameter of 4 cm and thickness of 0.25 cm, resulting in a 1 cm optical path with the housing column. The top and the bottom of the columns were closed with *o*-ring covers made of polycarbonate (4). There were sample collection (5) and exhaust tubes (6) on the top lid. Continuous illumination was provided with two 18 W daylight florescent tubes (Philips TLD/54) attached to both sides of the columns (7). Measured intensities on the surface of the columns were 5200 lx at average. Sterile air was supplied through the 0.20 μm (GyroDisc CA) filter (8). Air flow rates were adjusted to 1.5 l/min with flowmeters (9). Disk spargers with a diameter of 3 cm, were employed to supply air from the bottom of the columns (10).

2.4. Seed cultures

The start-up culture was carried out in 250 ml Erlenmeyer flasks and was cultivated for 4 weeks with weekly aseptic transfers to a fresh medium inoculated with the seed culture at 1/10 (V:V) dilution. Dilution amount was controlled spectrophotometrically to have an absorbance (AB) of 0.175–0.180 at 560 nm wavelength. Culture dry weight of was fixed at an average concentration of 0.1 g/l at the start of the inoculation.

The average light intensity was 2000 lx on Erlenmeyer flask surface and 4000 lx on bottles. Temperature of the cultures was kept at 25 ± 1 °C. The light intensity was measured with a luximeter (LUTRON LX-105). Daylight florescent tubes (40 W) were employed (Philips TLD/54) for the illumination of the cultures. The color code "54" indicates that the fluorescent tube is a daylight 6500 K type. The conversion of lx to μmol/m^2 s was calculated by multiplying the "lux" value by a conversion factor. The conversion factor used for the Philips daylight TLD/54 florescent tubes was 0.014 (Fox, 1996; www.sylvania.com, 2000).

At the end of 4 weeks, the culture was transferred to 1 l Pyrex bottles at the same dilution rate.

2.5. Production cultures

Cultures were cultivated at constant temperature (25 ± 1 °C). The culture volume was 1.5 l. The PBRs were illuminated continuously with two daylight fluorescent lights (18 W). Although microalgae use CO_2 as an inorganic carbon source during cultivation, inlet air was not supplemented with CO_2 gas in order to compare the perfor-