Biomass and Bioenergy 97 (2017) 132–138

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Co-cultivation of *Chlorella* spp and tomato in a hydroponic system

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ARTICLE INFO

Article history:
Received 24 November 2015
Received in revised form
23 December 2016
Accepted 24 December 2016

Keywords:
Aeration
Biomass
Chlorella infusionum
CO_2 fertilization
Eco-hydroponic culture
Nutrients

ABSTRACT

In this study, a new cost-effective and environmentally sustainable microalgal production strategy was developed on the basis of the microalgae-crop symbiosis association. This method allowed the simultaneous production of microalgae and crops by using a simple eco-hydroponic system (EHS), with the input only for crop production. In glasshouse experiments, green algae *Chlorella infusionum* was successfully cultivated in a hydroponic culture system cultivating tomato. The algal and crop biomass productivities in the EHS were 32 ± 5 g m^{-3} d^{-1} and 54.24 ± 1.81 g dm^{-3} d^{-1} (n = 6 for each), respectively, which was significantly ($P < 0.05$) greater than the algal biomass productivity (16 ± 5 g m^{-3} d^{-1}, n = 6) in the algal monoculture and the crop biomass productivity (33.97 ± 7.58 g dm^{-3} d^{-1}, n = 6) in the crop monoculture without aeration. The enhancement of the biomass productions was mainly attributed to the aeration from algal photosynthesis and the CO_2 fertilization from crop root respiration in the EHS. Particularly, the nitrogen and phosphorus utilization efficiencies were high due to co-utilization of the nutrients by microalgae and crop in the EHS. This simple system could thus be applied as a model system for microalgal farming and hydroponic crop production.

1. Introduction

The cultivation of microalgae is a globally emerging industry with vast economic and commercial potential [1,2]. Currently, the main alternatives for cultivating photoautotrophic algae are raceway pond systems and photobioreactors (PBRs), but a considerable investment in technological development and technical expertise are required for the current culture systems to be economically viable and environmentally sustainable [1,3–6]. The optimal utilization of substrates, including energy substrate, has been suggested as an important strategy for increasing the cost-effectiveness of an algal culture system [3]. Therefore, application of low-cost resources, e.g. CO_2 from flue gas, nutrient-rich wastewaters, and inexpensive fertilizers, and using cheap culture systems are effective strategies for increasing the cost-effectiveness of algal culture systems [1,4].

Hydroponic crop production has significantly increased in recent years worldwide [7,8]. Hydroponic growing systems require aeration for optimal growth and commonly this is done through the growing technique like nutrient film technique (NFT), aeroponic growth system, and ebb or flow or static aerated systems [9]. These aeration systems are costly as power and equipment e.g. pump and pipe are needed. Microalgae occur spontaneously in hydroponics and have long been considered troublesome since they will cause problems e.g. nutritional competence, clogging and increasing the load of organic carbon. However, algal photosynthesis in nutrient solutions can supply O_2 for crop root respiration and growth.

In this study, a new cost-effective and environmentally sustainable crop and microalgal production strategy was proposed. This system allowed the co-cultivation of crop and algae by using a simple eco-hydroponic system (EHS). In this system, microalgae can be produced without requiring any additional inputs at the time of hydroponic production of crops. In particular, light, water, and nutrients are adequately available for both microalgae and crops since both are cultured in mediums with high nutrient concentrations in a transparent container, and the symbiotic association between crop root respiration and algal photosynthesis provide the gaseous resources—CO_2 and O_2—which are crucial for the successful culture of algae and crops, respectively.

2. Materials and methods

2.1. Microalgal and crop cultures

A culture experiment was conducted in a greenhouse with

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http://dx.doi.org/10.1016/j.biombioe.2016.12.024
0961-9534/

Fig. 1. Photo of an eco-hydroponic system.

ambient air, light (mean daily photosynthetically active radiation of 343 μmol m^{-2} s^{-1} during the entire culture period and 12 h photoperiod), controlled temperature (daily maximum of 33.4 °C and daily minimum of 15.6 °C during the culture period), and humidity (16.5–69.6% average daily relative humidity (RH) throughout the culture period) from November 2014 through March 2015 at the Zhejiang University Experimental Farm, Hangzhou, China. Besides the sunlight, artificial light was supplied. Four treatments, including eco-hydroponic culture (EHC), algal monoculture (AMC), crop monoculture without aeration (CMC1) and crop monoculture with aeration (CMC2) during the day-time (8:00–20:00) were conducted in this study. The EHC system included a transparent container, algae-inoculated nutrient solution, and materials for crop fixation. In this study, a glass beaker of 22 cm height and 18 cm diameter was used as the container, and 2 cm thick polyethylene foam sheet and sponge strip were used for crop fixation (Fig. 1). In CMC2, the nutrient solution was aerated by bubbling air at a flow rate of 2 dm^{-3} min^{-1} through an aeration pump. The green algae *Chlorella infusionum* strain was isolated from the waste water in the Experimental Farm, Zhejiang University, and cultured in Shuisheng-4 medium having the following composition: $Ca(H_2PO_4)_2 \cdot H_2O + 2(CuSO_4 \cdot H_2O)$, 30 mg dm^{-3}; $(NH4)_2SO_4$, 20 mg dm^{-3}; $MgSO_4\,7H_2O$, 80 mg dm^{-3}; $NaHCO_3$, 10 mg dm^{-3}; KC1, 2.5 mg dm^{-3}; $FeCl_3$ (1%), 0.15 mg dm^{-3}; soil extract solution, 0.5 cm^3 dm^{-3}. The nutrient solution was prepared according to the modified Hoagland prescription: $Ca(NO_3)_2 \cdot 4H_2O$, 1250 mg dm^{-3}; KNO_3, 410 mg dm^{-3}; $NH_4H_2PO_4$, 280 mg dm^{-3}; $MgCl_2 \cdot 6H_2O$, 624 mg dm^{-3}; $FeSO_4 \cdot 7H_2O$, 60 mg dm^{-3}; EDTA-Na_2, 80 mg dm^{-3}; H_3BO_3, 6 mg dm^{-3}; $MnCl_2 \cdot 4H_2O$, 4 mg dm^{-3}; $ZnSO_4 \cdot 7H_2O$, 0.04 mg dm^{-3}; and $CuSO_4 \cdot 5H_2O$, 0.04 mg dm^{-3}. The algae were inoculated into the nutrient solutions by adding 50 cm^3 of the algal solution (OD_{680} = 1.0) prepared with the algae cultured in Shuisheng-4 medium, filtrated with a Whatman filter paper and washed for 4 times with de-ionized water. The treatments without algal inoculation received addition of 50 cm^3 of de-ionized water. Three cycles of algal culture were conducted for both EHC and AMC,

Fig. 2. The algal solution after 10 days of culture in the tomato eco-hydroponic culture (EHC, left) and the algal monoculture (AMC, right). The photo shows that the algae were visually denser in the solution and on the beaker bottom and interior walls in the EHC than in the AMC.