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RESEARCH TECHNOLOGY OF CULTIVATION OF *SPIRULINA* ALGAE WITH THE USE OF CO_2 HIDDEN FROM THE SMOKE OF RICE HUSK BOILER

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ABSTRACT

This paper presents an investigation of Spirulina algae cultivation by the CO_2 gas emitted from the combustion of rice husk. The gas emitted from the rice husk combustion containing CO_2 but no toxic gas of SO_x. The CO_2 molecules are absorbed into the micro-algae cultivation medium and then converted into the HCO^{-}_3 by the assimilation of Spirulina. At the same time, the pH values are controlled to be from 8.5 to 9.5, which is suitable for Spirulina algae. At the first seven days of cultivation in Zarrouk medium the values of Spirulina algae biomass and pH increase from 0.05 g/l and 8.5 to 1.0 g/l and 10.2, respectively. On the 8th day, when the amount of 7,6 % CO_2 v/v under 35–40 ºC and 1 atm is introduced into the above medium, the decrease of pH from 10.2 to 8.6 is observed. This pH value, which is maintained over the following days, is optimal for the growth yield of the Spirulina. As a result, the biomass concentration increases from 1.0 to 1.4 g/l. The obtained results are compared with those of the control sample from Zarrouk medium without gas introduction. For the latter case, the biomass reaches the maximum and then decreases. On the basis of the obtained results, the cultivation of Spirulina algae by using the CO_2 molecules emitted from the combustion of rice husk can be applied practically.

Keywords: *CO_2 greenhouse gas; Cultivation of S. platensis for CO_2; Spirulina platenisis; Photobioreactor; Rice husk boiler.*

1. INTRODUCTION

Emissions containing CO_2 from industry, thermal power stations, fuel incinerators such as boilers and drying kilns, or from other sources such as biogas, alcohol fermentation tanks can be used to cultivate *Spirulina* [1, 2, 3].

However, different from other green plants, the *Spirulina platensis* does not absorb CO_2 as a source of carbon nutrients. It only assimilates CO_2 as a form of bicarbonate HCO^{-}_3 [4, 5, 6] as the following reaction:

$$n.HCO_3^- + n.H_2O \xrightarrow{h\nu} (CH_2O)_n + n.OH^- + n.O_2 \quad (a)$$

Thus, finding a technology that can utilize CO_2 from gas emissions to cultivate *Spirulina* is very important since it achieves two objectives. First, this reduces carbon emissions, greenhouse gas emissions and climate change. Second, it helps to reduce the production costs in making the *Spirulina*. There are two ways to collect CO_2. For gas emissions having a high level of CO_2 (40÷50)% such as biogas and gas from alcohol fermentation tanks, the liquid or solid CO_2 can be separated and collected by using the compression and cooling process and then throttling [6]. For gas emissions having a low level of CO_2 (6÷14)%, CO_2 can be collected by directly absorbing into the medium [2].

According to Zarrouk [4], an amount of 450 kg of CO_2 is used for producing a ton of *Spirulina* and creates 1,200 kg of oxygen. The

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reaction (a) shows that the photosynthetic process of *Spirulina* not only consumes the greenhouse gases in the form of HCO^{-}_3, but also produces OH^{-} that increases the pH value exceeding the appropriate pH ranges of *Spirulina* (from 8.5 to 9.5) [1, 2, 5]. A solution to adjust the pH as in the above reaction and provide extra carbon nutrients for *Spirulina* is to absorb CO_2 into the cultivation medium[5]. However, to our best knowledge, there are few studies in the literature that collect CO_2 from gas emissions, and especially from rice husk boilers. This paper shows the results from a study of using the rice husk fired boiler to blow the steam into the medium to cultivate *Spirulina*. The experimental results from our study were compared with other methods with or without using CO_2.

2. THE FUNDAMENTALS OF TECHNOLOGY FOR *SPIRULINA* CULTIVATION

The nutrient medium is Zarrouk medium (Table 1), *Spirulina* was developed very well as the following indexes [5, 6]:

pH :8.5 ÷ 9.5

Temperature: 30 ÷ 38 ^oC

Luminous intensity: 2.5 ÷ 3.5 klux

Agitator: shaker, blade (open tank), or aeration (closed tank).

According to reaction (a), when *Spirulina* assimilates HCO_3^{-} to create oxygen and increase the pH value.

If CO_2 is transferred into the cultivation medium (water) [5], the following reactions happen:

$$CO_{2\,k} \rightarrow CO_{2\,ht} \tag{1}$$

$$CO_{2\,th} + H_2O \rightleftharpoons H_2CO_3 \tag{2}$$

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \tag{3}$$

$$HCO^{-}_3 \rightleftharpoons H^+ + CO^{2-}_3 \tag{4}$$

Reactions (2), (3) and (d) increase HCO_3^{-} and reduce the pH value.

3. APPARATUS, MATERIALS AND METHODS

3.1 Materials

The experiment was conducted at the boiler of Phong Phu Textile factory **(**2/241A Duong Dinh Hoi street, Tang Nhon Phu B ward, Thu Duc town, HCM City**).**

The gas emission from rice husk boiler contains an amount of CO_2 of 7.6%(v/v) and inlet temperature from 95^{o}C to 100^{o}C by the pipe that has a diameter of 20mm, length of 10m and are cooled to oultet temperature about (35^{o}C÷ 40^{o}C). This gas was aerated into the cultivation medium as shown in Table 2.

3.2 Apparatus

The device for cultivating *Spirulina* has a volume of 1.0 liters and dimensions (ΦxHxδ is 80x220x0,5 mm); pump-stirred aerator.

Cylindrical porous stone noozle has dimensions (dxh=20x20 mm).

Compressor capacity: 5W/220V/50hz.

Glassware: 250 ml and 500 ml of glass jars; 100 ml and 500 ml of volumetric flasks; pipettes 2 and 10 ml; cylinder of 10 and 100 ml.

Other measuring tools: alcohol thermometer (scale:0÷100^{o}C) from France; Model HI98172 for pH from Hanna; The American Beckman Coulter DU 750 's spectrophotometer (measured at 750 nm) with conversion factor k = 0,73 g/l [3]:

$$C\ (g/l) = k.OD_{750} \tag{5}$$

3.3 Methods

We conducted two experimental samples at the same time with the same conditions of the Zarrouk's nutrient medium. The first sample was agitated by aeration. The second sample was stirred by aeration in the first seven days as the first stage. Then, it absorbed CO_2 by the gas from the boiler for 30 minutes on the 8th day based on reactions from (2) to (4).

Experimental steps of the technology for cultivating *Spirulina* from CO_2 collected from the gas of rice husk boiler are shown in table 2.

Table 1. *Element of Zarrouk medium*

№	Chemical formula	Zarrouck, g/L
1	$NaHCO_3$	16.8
2	K_2HPO_4	0.5
3	$NaNO_3$	2.5
4	NaCl	1.0
5	K_2SO_4	1.0
6	$MgSO_4 \times 7H_2O$	0.2
7	$FeSO_4 \times 7H_2O$	0.01
8	$CaCl_2 \times 2H_2O$	0.04
9	EDTA	1,0 ml/L
10	Micronutrient solut. 1	1,0 ml/L
11	Micronutrient solut. 2	1,0 ml/L
Micronutrient solution 1, mg/L		
1	H_3BO_3	2.86
2	$MnCl_2 \times 4H_2O$	1.81
3	$ZnSO_4 \times 7H_2O$	0.22
4	$CuSO_4 \times 5H_2O$	0.08
5	MoO_3	0.01
Micronutrient solution 2, mg/L		
1	NH_4VO_3	0.023
2	$NiSO_4 \times 7H_2O$	0.048
3	Na_2WO_4	0.018
4	$Ti_2(SO_4)_3$	0.040
5	$Co(NO_3)_2x6H_2O$	0.044

The temperature of the *Spirulina* cultivation's medium is measured every hour (from 7 a.m. to 5 p.m.) of the sunny, rainy and shady days. Experimental results are shown in Figure 1. We measured the pH and OD_{750} from the medium at seven a.m. every day. The experimental results are shown in figure 2 for pH and in figure 3 for biomass concentration C, g/l over time.

4. RESULTS AND DISCUSSION

4.1 Temperature variations

The temperature is a main factor that significantly affects to the CO_2 absorption process into the medium and the growth of *Spirulina*. The medium temperature of the photobioreactor (PBR) was measured from 7 a.m to 17 p.m on three typical days: the third day which was a sunny day, the fifth day which was a cloudy day, and the eighth day which was a rainy day. Figure 1 shows the medium temperatures measured in a month from April 15th to May 15th of 2021.

Table 2. *Experimental plan*

Date	1	2	3	4	5	6	7	Biomass increase the quantity 1 g/l	
Medium	Zarrouk								
Blow	Air								
Bow regime	Từ 9 giờ đến 15 giờ								
Measuring data	t °C, pH, OD_{750}								
Date	8	9	10	11	12	13	14	15	16
Medium	Zarrouk + CO_2								
Blow	Blowing the smoke has 7,76 % of CO_2 (v/v) within 30 minute at 7 am								
Bow regime	Blowing the air from 9 am to 15 pm								
Measuring data	t °C, pH, OD_{750}								

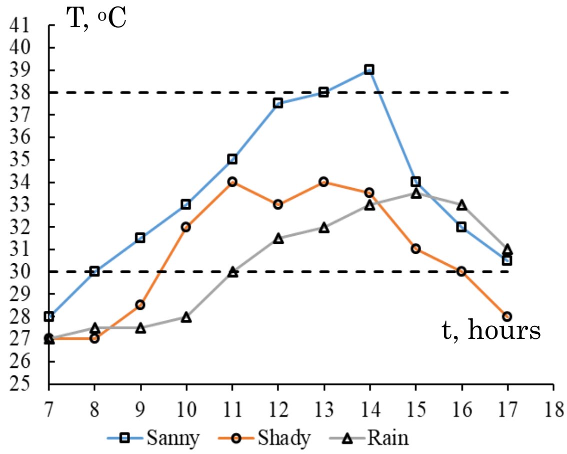

Figure 1. *The temperature variations from the environment in the sunny, rainy and shady day*

The results of Figure 1 show that the temperatures were increased from 7 a.m to 14 p.m everyday, then they gradually decreased. Especially, from 12 a.m to 14 p.m on sunny days, the temperatures exceeded the optimal temperature range of *Spirulina* (from 30 °C to 38 °C) but not to much, about one to two degrees and they occurred in a short time. The medium temperatures before 7 a.m and in the evening were under the optimal temperature range about three to four degrees of Celsius. At those periods of time, the *Spirulina* were not been photosynthesized. The experiment from [4] reports that the medium temperature of cultivating *S. platensis* in PBR are lower than those in a tubular photobioreactor (TPBR) from two to four degrees of Celsius. It is worthing to note that the experiment in the [4] was conducted in TPBR with closed devices and measured at the beginning of a dry season (October and November), while our experiment was conducted in PBR with open devices and measured at the beginning of a rainy season (April and May).

4.2 Effect of CO_2 from the aeration of furnace gas

Figure 2 shows the change of pH values in the first seven days, and in the following nine days with the use of furnace gas that contains 7.6 % CO_2 in 30 minutes.

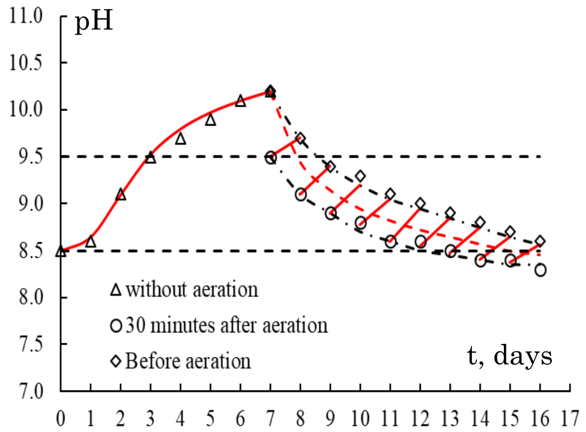

Figure 2. *The pH change of environment with time.*

Figure 2 shows that in the first seven days, the pH values were gradually increased from 8.5 to 10.2 based on reaction (1). For each following day, the pH values were decreased by an amount of 0.3 to 0.6 by thirty minutes of aeration based on the reactions (2)-(4). These values were increased again whenever the reaction (1) happened. Thus, the pH values were kept in an optimal range of 8.5 to 9.5 for *Spirulina platensis*.

4.3 Effect of pH and carbon nutrition on biomass growth from CO_2 aeration

Figure 3 shows the changes of biomass concentration's medium with or without using CO_2. These changes were affected by the changes in pH values and the amount of HCO^{-}_3.

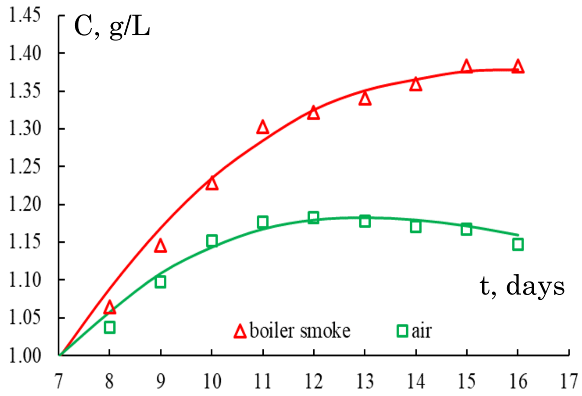

Figure 3. *The variants of biomass*

The results show that using CO_2 from furnace gas (with an amount of 7.6% purity CO_2) can maintain the pH values in an optimal range and provide HCO^{-}_3 for the growth of *Spirulina* with an increase of biomass from 1.0 g/liter to 1.4 g/liter. On the contrary, if the furnace gas was not used, the nutrient source from HCO_3 was decreased, whereas the pH values were increased and exceeded the optimal pH ranges. Consequently, the biomass was only increased to a maximum value, then it was gradually decreased

5. CONCLUSSION

In summary, we draw the following four conclusions based on the experimental results when using CO_2 from rice husk boiler's gas to cultivate *Spirulina*.

First, the temperatures of Vietnam's climate are suitable for cultivating *Spirulina* by uncovered equipment having gas aeration devices;

Second, after seven days of cultivation, the biomass concentration achieved the maximum value, while the pH values were quickly increased and the amount of HCO^{-}_3 was significantly decreased. Therefore, it is necessary to provide an extra amount of HCO^{-}_3 and reduce pH values to maintain the growth of *Spirulina*;

Third, we can use CO_2 from the rice husk boiler or use the gas from biomass burning in general to cultivate *Spirulina*. The gas should be adjusted to a temperature in the range of

35-40^{o}C before being transferred into the medium.

Finally, we recommend transferring the gas from the boiler into the medium for 30 minutes every morning to maintain the pH value in the optimal ranges and provide enough the amount of HCO^{-}_{3} for *Spirulina*.

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