Biological carbon fixation: A study of *Isochrysis* *sp.* growth under actual coal-fired power plant’s flue gas

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**Abstract:** Preliminary study on the growth of marine microalgae *Isochrysis* *sp.* was carried out using actual flue gas from a coal-fired power station. The species was cultured using a 2x10-L customized bubble column photobioreactor skid under specified culture conditions. With an initial culture density of 0.459 Abs (optical density at 560 nm wavelength), the species was found able to survive - observed by increases in optical densities, number of cells and weights - in the presence of actual coal-fired flue gas containing on average 4.08 % O₂, 200.21 mg/m³ SO₂, 212.29 mg/m³ NOₓ, 4.73 % CO₂ and 50.72 mg/m³ CO. Results thus add value to the potential and capability of microalgae, especially for *Isochrysis* *sp.*, to be the biological carbon fixer in neutralizing carbon emissions from power plants.

1. Introduction

Many literatures have identified phototropic microalgae as an alternative method among available carbon capture technologies [1],[2]. The use of its natural, more efficient photosynthesis process, and the potential of valuable downstream products it can generate, make it eligible to be a more sustainable method [3].

Several experiments and demonstration projects have been documented using microalgae to fix CO₂ from actual flue gas. Microalgae species used in these works include *Chlorella* *sp.* [4], [5], *Dunaliella tertiolecta* [6] and *Botryococcus braunii, Scenedesmus sp.*, [7].

As a first step in selecting suitable species for biological carbon fixation, a marine microalgae species *Isochrysis* *sp.* has been screened and found dominant in sea waters in the vicinity of a coastal coal-fired power plant in Manjung, Perak [8]. Comparison of its carbon fixation ability, under simulated flue gas in laboratory conditions, has proved that it has a better fixation rate over *Tetraselmis* *sp.* and *Nannochloropsis Oculata* [9], [10]. This work thus offers a preliminary extended study to verify the species’s suitability to be used as a biological carbon fixer in a coal-fired power station, while enriching the database on species growth under actual flue gas conditions.

2. Materials And Method

2.1 Site Location

The experiment was carried out at the Sultan Azlan Shah Power Station. This is a 3 x 700 MW coal-fired power plant located in the district of Manjung, Perak, along the Straits of Malacca, west coast of Malaysia. Approximate geographical coordinates are 4° 9’30.52” North and 100° 38’ 27.63” East.
2.2 Photobioreactor
A customized skid-mounted photobioreactor (PBR) was used in the experiment. The PBR is of bubbling column type, having double cylindrical columns of 10-L each as the reactor vessel. The material of the reactor column is of polycarbonate having dimension 3 mm thick, 200 mm diameter and 800 mm high. The PBR skid was placed inside the flue gas stack structure, as depicted in Figure 1 below.

![Flue gas tube](image)

**Figure 1.** The setup PBR inside the stack structure house

2.3 Source of Flue Gas
Portions of actual flue gas were tapped after the station’s Continuous Emission and Monitoring System’s (CEMS) analyzers. Small bore polypropylene tubes was used to route this spent gas into the PBR, where the flow was regulated with a needle valve to be at around 0.15 ± 0.03 l/min.

2.4 Microalgae Species
Isochrysis sp. was used in the study. This species’s taxonomy, in accordance to *Phylum / Class / Order / Family / Genus / Species* sequence is *Haptophyta / Prymnesiophyceae / Isochrysidales / Isochrysidaceae / Isochrysis.*

Its physical appearance can be characterized by having slightly elongated motile cells, a stigma and two smooth flagella. Mainly benthic and typically in spherically round shape. It measures about 3 x 6 µm. The species has been known to be used as aquaculture diet and has been proposed as a source of docosahexanoic acid (DHA) for nutraceuticals. To a lesser extent too, it has been tried for lab-scale biodiesel production [11].

2.5 Culturing Conditions
The species was injected with 10 mL nitrate as nutrients. The culture temperature was left unregulated to ambient temperature, which ranged from 26.10 °C to 30.96 °C. Since it was rather dark inside the stack structure house, artificial illuminance, in the form of five units of T5-type tubular fluorescent bulbs were used with 12-hour timer-controlled activated. Average peak illuminance recorded was about 15 mol/m².s⁻¹. pH of the culture was maintained to be between 6 – 7 with the help of an air pump.

2.6 Procedures
The culture was introduced into the reactor column at an initial optical density of 0.459 Abs, measured at 560 nm wavelength. The culture was left for six consecutive days where 30 mL samples were withdrawn daily for optical density, weight and cell-count measurements. Culture’s pH was not regulated however on the last two days in the pure interest to observe the pH change and its effect on species growth.

2.7 Tools and Instrumentation
Culture’s pH was measured using EUTECH INSTRUMENT sensor (pH Range : -2.00-16.00, Relative accuracy : ±0.01). Temperature was measured using type-K thermocouple. Dissolved CO₂ was read
using METTLER TOLEDO’s InPro 5000(i) potentiometric sensor (accuracy ±0.1). Illuminance was recorded using a Skye’s high output Photosynthetically Active Radiation (PAR) sensor with linearity error of less than 0.2 %. All pH and temperature were automatically logged every 10-minute intervals using DEWE-43 data acquisition system. Culture’s optical density was measured using HACH’S DR 2800 spectrophotometer. Cell count was made possible upon use of Neuber-improved haemocytometer slide. Samples were filtered using magnetic vacuum filter, then dried-up in room temperature for 24 hours before weights were recorded using analytical balance. Flue gas compositions were extracted from station’s Plant’s Information System.

3. Results and Discussions
Figure 2 and Figure 3 below demonstrate that the species was able to survive in the culture supplied with the actual flue gas. Except for the last two days, the optical density increased from the initial 0.459 Abs to 0.638 Abs (Figure 2). Similarly, the number of cells has registered an increase by 18 % from the initial count of 290,000 cells (Figure 3). The dry weights of the culture were also observed to be on the rise, where it increased from about 0.003 mg/l to the maximum of 0.007 mg/l.

On average, the flue gas compositions were 4.08 % O₂, 200.21 mg/m³ SO₂, 212.29 mg/m³ NOₓ, 4.73 % CO₂ and 50.72 mg/m³ CO throughout the period. There were only minimal amount of particulates found accumulated at the bottom of the reactor vessel only on the first day of experiment.

As expected, the growth retards upon unregulated pH. Figure 5 illustrates the increase of accumulated dissolved CO₂ upon unregulated pH. The high amount of dissolved CO₂ – up to the maximum of 15.17 % - in last two days happened as the flue gas was supplied continuously without controlling the pH, deliberately done as part of experiment. Figure 4 below depicts that the pH was dropped to and lingered around pH 6 for about two consecutive days, which further dampened the growth. The cells’ density and count declined by about 40 % and 43 %, respectively, as the consequence.

4. Conclusions and Further Works
In this brief study, a marine microalgae species Isochrysis sp. was put into a field trial, cultured with CO₂ source from an actual flue gas from a coal-fired power station. It can be seen that with regulated
aeration, the pH was managed to be maintained at slightly above pH 6 and 7, giving a right culture condition for the species to survive and reproduce, within the flue gas compositions of 4.08 % O₂, 200.21 mg/m³ SO₂, 212.29 mg/m³ NOₓ, 4.73 % CO₂ and 50.72 mg/m³ CO. This conducive environment is expected to diminish once the culture’s pH dropped to 6 and lower. Despite of a short term conduct, valuable lessons has been acquired especially in the importance of the need and scheme of pH control meant for a bigger scale facility. In this experiment, aeration has proved to be one of effective and cheap means of pH control; however, its application might release the CO₂ bubbles that are supposedly to be dissolved and consumed by microalgae, other than introducing detrimental shear stress to the cells. Thus, enclosure design for a bubble column photobioreactor and regimes of flow velocity shall be further studied. Frequency of aeration can also be optimized to be inversely proportional to a denser culture, as to minimize electricity consumption of air pump/blower.

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