FOUR NOVEL METHODS FOR THE HARVESTING OF MICRO-ALGAL BIOMASS

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ABSTRACT: The harvesting of micro-algal biomass is one of the most inefficient and costly steps in the whole biomass-to-liquids (BtL) value chain. Harvesting costs may contribute between 20–30% of the total cost of micro-algal BtL biodiesel production. One of the major obstacles in the economic production of microalgae, is the development of cost effective harvesting methods for the separation of micro-algal biomass from its growth medium. Four promising, unconventional harvesting methods were investigated to harvest micro-algal biomass from the Hartbeespoort Dam, 37 km west of South Africa's capital city Pretoria.
Keywords: biodiesel, biomass to liquid (BtL), harvesting, microalgae

1 INTRODUCTION

Renewable energy sources such as biomass are becoming more and more important as alternative to fossil fuels. One of the most exciting new sources of biomass is microalgae. The Hartbeespoort Dam, located 37 km west of Pretoria, has one of the dense populations of microalgae in the world, and is one of the largest reservoirs of micro-algal biomass in South Africa. The Dam has great potential for micro-algal biomass production and beneficiation, due to its high nutrient loading, stable climatic conditions, size and close proximity to major urban and industrial centres.

2 METHODS & MATERIALS

2.1 Growth plate harvesting

Micro-algal biomass from the Hartbeespoort Dam was cultivated successfully in a 135-litre glass tank bioreactor (Fig. 1), using a modified growth medium prepared according to the recipe set out by Krüger and Eloff [1], natural solar lighting, and externally supplied aeration. After every two weeks, one plate was removed from the tank and the micro-algal biomass scraped off manually with a scraper (Fig. 2). The biomass was placed on glass microfibre filter paper (Whatman cat. no. 40) and placed in a desiccator with silica gel to dry for seven days. The dried biomass and filter paper was weighed and the combined weight subtracted from the original filter paper weight to determine the dry weight yield of the biomass.

Figure 1: Cultivation of microalgae in 135-litre glass tank bioreactor with Perspex growth plates

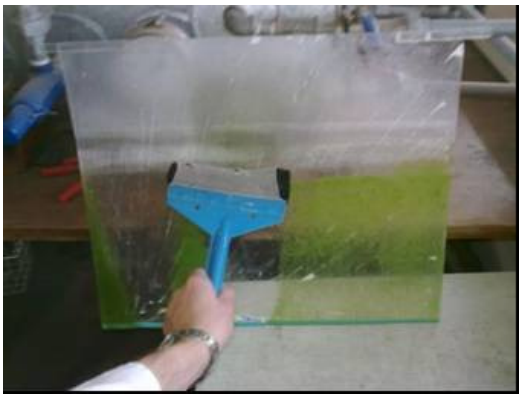

Figure 2: Cultivated Hartbeespoort Dam-sourced micro-algal biomass scraped off from growth plate

2.2 Natural buoyancy separation

A pulp sample was collected from the Hartbeespoort Dam and placed in a container and stirred for one minute to obtain a homogeneous mixture of algae and water.

Three measuring cylinders of different diameters (65, 83 and 38 mm respectively) were each filled with 200 mL of the mixture (Fig. 3). The time it took for the mixture to settle into two distinct layers (a bottom colourless aqueous layer, and a top green wet weight micro-algal biomass layer) was recorded. The volume of the top algae layer was recorded every 30 minutes over a period of 3.5 hours and also after 21.5 and 24 hours.

Figure 3: Conglomerated Hartbeespoort Dam micro-algal biomass separating at the top of the measuring cylinders after 24 hours

2.3 Gravity settling

Erlenmeyer flasks were used to cultivate Hartbeespoort Dam algae (Fig. 4). The flasks were filled to 4000 mL with a modified growth medium prepared according to the recipe set out by Krüger and Eloff [1]. A pipette was used to inoculate each 4-litre growth medium with 100 mL of Hartbeespoort Dam-sourced micro-algal biomass of 0.0114 g/L concentration. Continuous aeration was provided with air pumps at different flow rates for each bioreactor. The cultures were kept indoors, but exposed to a 12 hour day/night cycle. After six weeks of cultivation, the contents of the Erlenmeyer flasks were filtered through 0.7 µm glass microfibre filter paper (Whatman cat. no. 1001090), which was weighed prior to filtration, and then placed in an oven to dry for an hour at 110^{o}C. The dried filter paper was then weighed again in order to determine the dry weight accrual of biomass.

The weight of microalgae was measured to the nearest 0.1 mg with a Sartorius 1602 MP8-1 balance. In order to measure the micro-algal biomass content at different depths in the bioreactor, the first 50% of the volume was decanted and filtered, then the next 25%, and then the remaining 25% of the volume.

Figure 4: Gravitation settling comparison between well-mixed bioreactor (left) and bioreactor that was allowed to settle for 24 hours

2.4 Sand filtration and solar drying

Three samples of wet biomass were taken from the Hartbeespoort Dam in 500 mL plastic bottles and allowed to settle for one day. The bottom water layer was drained with a tube and the remaining top layer of concentrated micro-algal biomass pulp was poured onto metal palettes with a layer of approximately 500 g of building sand with a voidage of 40%. The palettes were then placed on top of a laboratory roof and allowed to dry for 24 hours (Fig. 5). A fourth palette contained only a layer of building sand to serve as the standard for the measurement of moisture loss after 24 hours of drying. The four metal palettes were weighed, filled with a layer of 0.484 m^2 (220 x 220 mm^2) of building sand, and weighed again. After drying in the sun for 24 hours, the palettes, building sand and dried micro-algal biomass were weighed again.

The dry weight of the dried micro-algal biomass was calculated by subtracting this weight from the weight of the sand-filled palettes. The moisture loss from the standard palette was obtained by subtracting the weight of the sand-filled palette before drying from its weight after drying. This value was divided by the original sand and palette weight to calculate the moisture loss fraction.

This moisture loss factor was used to adjust the weights of the other free palettes, to calculate the true dry weight yield of micro-algal biomass, after moisture loss was included.

Figure 5: Micro-algal biomass from the Hartbeespoort Dam drying in the sun on top of a base of building sand

3 RESULTS & DISCUSSION

3.1 Growth plate harvesting

Average temperatures between 24-26^{o}C, and aeration rates which are sufficiently strong to keep the biomass in suspension, delivered the best production rates, after the optimum growth period of 4 weeks. A maximum yield of 2.9557 g/m^2 of dry weight biomass per growth plate (0.3 m^2) were achieved after four weeks of cultivation.

Cultivation of micro-algal biomass was improved through the addition of growth plates in the bioreactors.

These growth plates mimic sheltered rock surfaces in the Hartbeespoort Dam, which create favourable conditions for algal blooming, by providing inoculums of cyanobacterial species. These growth plates also act as substrate on which the micro-algal biomass could grow and allow for easy manual harvesting.

3.2 Natural buoyancy separation

The separation rate of Hartbeespoort Dam micro-algal biomass from its aqueous phase, due to its natural buoyancy, followed a logarithmic trend, with a distinct biomass layer forming at the top of the measuring cylinder almost instantaneously, and stabilizing after 3.5 hours.

3.3 Gravity settling

Results show that over 90% (wt.) of the micro-algal biomass accumulated in the bottom quarter of the flask bioreactor after one day of gravity settling. After five days of settling, the micro-algal biomass accumulation in the bottom quarter of the bioreactor increased to nearly 95% (wt.), and after two weeks increased to almost 99% (wt.) of the total biomass content (Fig. 6).

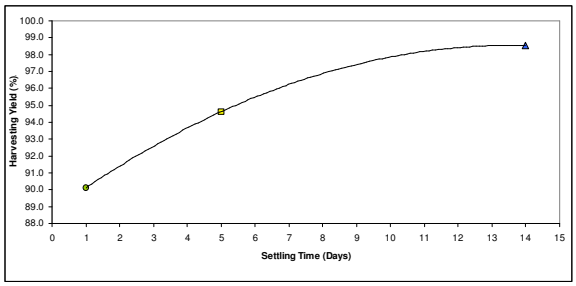

Figure 6: Harvesting yield of cultivated micro-algal biomass sourced from the Hartbeespoort Dam versus gravity settling time in the bottom 25% of three Erlenmeyer bioreactors: (○) bioreactor 1; (□) bioreactor 2; (Δ) bioreactor 3; The solid line does not constitute a fit, but just a visual guide.

3.4 Sand filtration and solar drying

The fourth experiment studied the harvesting yield of drying micro-algal biomass (3% TSS) on a patch of building sand in the sun for 24 hours. An average harvesting yield of 157.6 g/m^2/d of dry weight micro-algal biomass from the Hartbeespoort Dam were achieved (Fig. 7, 8 and 9). The building sand substrate improves the separation of water from the wet micro-algal biomass. As water is absorbed into the sand, it increases the drying area and thus increases the drying rate of the micro-algal biomass. Solar radiation provides the energy to evaporate the moisture.

Figure 7: Sand-filtered, sun-dried Hartbeespoort Dam micro-algal biomass flakes

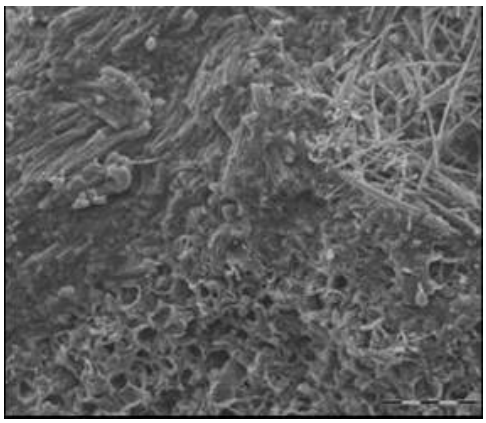

Figure 8: Scanning electron microscopy (SEM) image of dry filtered Hartbeespoort Dam micro-algal biomass at 20 microns

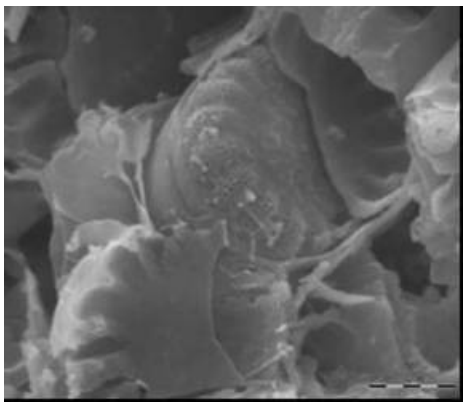

Figure 9: Scanning electron microscopy (SEM) image of dry filtered Hartbeespoort Dam micro-algal biomass at 2 microns

4 CONCLUSIONS

Experiments with growth plates in the 135-litre tank bioreactor revealed that the addition of artificial substrates in bioreactors could increase micro-algal biomass growth and allow for easy manual harvesting.

Screening experiments to harvest micro-algal biomass from the Hartbeespoort Dam, by utilizing the tendency of colonial Microcystis aeruginosa to float, revealed that it could be done practically and energy-efficiently. Results obtained suggest that primary separation equipment, like separation ponds or tanks, with a residence time of 3.5 hours would be sufficient to concentrate micro-algal biomass from 1.5% to 3% TSS. Additional residence time would not provide any substantial benefit with regards to TSS concentration, but would increase vessel capacity and cost unnecessarily.

Cultivated micro-algal biomass sourced from the Hartbeespoort Dam can easily be harvested by allowing it to settle with gravity when aeration is stopped. Results showed that gravity settling equipment, with residence times of 24 hours, should be sufficient to accumulate over 90% of cultivated micro-algal biomass. Using this method for primary separation could reduce the total cost of harvesting equipment dramatically, by separating more than 90% of the cultivated micro-algal biomass from over 75% of the water medium with minimal energy input.

Micro-algal biomass from the Hartbeespoort Dam was successfully harvested by sun-drying on beds of sand. This method holds great potential to reduce the energy consumption of drying biomass, as it utilizes renewable solar energy and sand filtration to dry the algae.

5 REFERENCES

[1] Krüger, G.H.J., Eloff, J.N. 1977. The influence of light intensity on the growth of different Microcystis isolates. J. Limnol. Soc. sth. Afr. 3:21-25.

6 ACKNOWLEDGEMENTS

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