

BUKTI KORESPONDENSI
ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul artikel : Techno-economic of Integrated Multitrophic Clarias catfish and Arthrospira with Different Agitation Period

Jurnal : Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society

Penulis : Marini Wijayanti, Yohanes Setiawan, Tanbiyaskur Tanbiyaskur, Dade Jubaedah, Mirna Fitriani, Mohamad Amin

No.	Perihal	Tanggal
1	Bukti konfirmasi submit artikel dan artikel yang disubmit	13 Desember 2021
2	Bukti konfirmasi review dan hasil review pertama	8 Desember 2022 dan 8 Desember 2022
3	Bukti konfirmasi submit revisi pertama, respon kepada reviewer, dan artikel yang diresubmit	18 Desember 2022
4	Bukti konfirmasi review dan hasil review kedua	19 Desember 2022
5	Bukti konfirmasi submit revisi kedua, respon kepada reviewer, dan artikel yang di resubmit	22 Desember 2022
6	Bukti konfirmasi artikel accepted	13 Januari 2023
7	Bukti konfirmasi artikel published online	13 Januari 2023

Bukti konfirmasi submit artikel dan artikel yang disubmit (13 Desember 2021)

Manuscript reception confirmation Unread Siapa Mengirim

muntean.gc@gmail.com Sen, 13 Des 2021, 20:56 ☆ ↶ ⋮

kepadanya ▾

Inggris → Indonesia • Terjemahkan pesan Naskah untuk Inggris x

Dear Dr. Nani Wijanti,

This is a message of confirmation regarding the reception of your manuscript "Technoeconomic of Integrated Multitrophic Clarias catfish and Arthropoda with Different Agitation Period", submitted to our journal 'Aquaculture, Aquarium, Conservation & Legislation'.

If you sent this manuscript to multiple editors or e-mail addresses at our publishing house (other than pubonaps004@vafoc.com) please let me know.

I will contact you with further information regarding your manuscript.

For any questions, please contact me.
Please try to keep one message thread (respond/ask with "Reply") for an easier message management.

Thank you for considering our journal.

Best regards,
George Muntean
Editor, Bioflux SRL
Visit our journals:
Aquaculture, Aquarium, Conservation & Legislation www.bioflux.com.ro/aac
Advances in Environmental Sciences www.aes.bioflux.com.ro
Human & Veterinary Medicine www.hvm.bioflux.com.ro
Advances in Agriculture & Botany www.aab.bioflux.com.ro
Animal Biology & Animal Husbandry www.abah.bioflux.com.ro
Extreme Life, Biogeology & Astrobiology www.eba.bioflux.com.ro
Porcine Research www.porc.bioflux.com.ro
Rabbit Genetics www.rg.bioflux.com.ro
ProEnvironment Promedy <http://journals.usamvcu.ro/index.php/promedy>
Poecilia Research www.pr.bioflux.com.ro



Submission letter


Article title: **Technoeconomic of Integrated Multitrophic *Clarias catfish* and *Arthrospira* with Different Agitation Period**

Name of the authors : Marini Wijayanti, Yohanes Setiawan, Tanbiyaskur, Dade Jubaedah, Mohamad Amin, Mirna Fitriani, Nuni Gofar

Hereby I would like to submit the manuscript entitled "**Technoeconomic of Integrated Multitrophic *Clarias catfish* and *Arthrospira* with Different Agitation Period**" to Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society.


This manuscript was not submitted or published to any other journal. The authors declare that the manuscript is an original paper and contain no plagiarized text. All authors declare that they are not currently affiliated or sponsored by any organization with a direct economic interest in subject of the article. My co-authors have all contributed to this manuscript and approve this submission.


Corresponding author & Author 1,

Marini Wijayanti 

Author 2,
Yohanes Setiawan..... 

Author 3,
Tanbiyaskur..... 

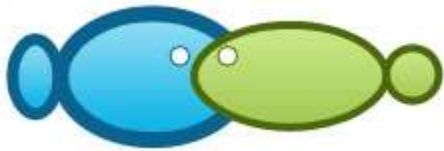
Author 4,
Dade Jubaedah..... 

Author 5,
Mohamad Amin..... 

Author 6,
Mirna Fitriani..... 

Author 7,
Nuni Gofar 

Date, December 10th, 2021



Technoeconomic of Integrated Multitrophic *Clarias catfish* and *Arthrospira* with Different Agitation Period

¹Marini Wijayanti*, ¹Yohanes Setiawan, ¹Tanbiyaskur, ¹Dade Jubaedah,
¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia.

*Corresponding author: mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multitrophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceway because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12

hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Keywords: *A. platensis*, b/c ratio, *Clarias* catfish rearing, raceway.

Introduction.

Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan, which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara, 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multitrophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2018; Widyantoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. *Arthrospira* biomass has a nutritional value of 55-70% protein, 6-10% lipid 20% carbohydrates, in addition to being rich in minerals, vitamins, and pigments (Vernes et al 2015; Borowitzka et al 2016; Wijayanti et al 2020). Phycocyanin is a pigment in *Arthrospira* that functions as an antioxidant, a source of food coloring, cosmetics, pharmaceuticals, and drugs (Tang et al 2020; Tiwari & Tiwari, 2020), anti-inflammatory, antioxidant, and anticancer (Liu et al 2013). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry per liter, the growth rate of 22.026%. day-1 and 11,347 mg.g⁻¹ phycocyanin

yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor has an effect on the important phytochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah and Khoirunisa, 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al. (2018) showed that 24-hour stirring resulted in a biomass concentration of $1.60 \pm 0.04 \text{ g L}^{-1}$, biomass productivity of $0.054 \pm 0.003 \text{ g L}^{-1} \text{ h}^{-1}$, and a specific growth rate of $0.05 \pm 0.002 \text{ h}^{-1}$ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density of $0.90 \pm 0.02 \text{ gL}^{-1}$, biomass productivity of $0.009 \pm 0.001 \text{ gL}^{-1} \text{ h}^{-1}$ and specific growth of $0.02 \pm 0.001 \text{ h}^{-1}$. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of spirulina in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method

This study was conducted at Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation methods: control using 24-hour aeration. day-1 (TC), stirring period 24 Hours. day-1(T24), stirring period 12 Hours. day-1 (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias* catfish- *Arthrospira* culture.

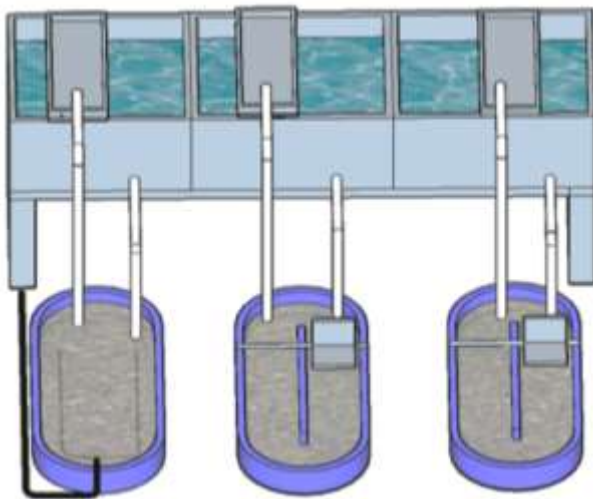


Figure 1. Design of integrated Clarias catfish- Arthrospira culture in this study

Preparation of Arthrospira Growing Media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance of catfish fed floating pellets protein 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and Harvesting Arthrospira platensis. *A. platensis* used was first cultured as initial stock inoculum with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani and Hermana, 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 RPM. The control was aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06.00 am -6.00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed the wet weight and then put into a porcelain crucible then dried in an oven at 40°C for 18 hours (Afriani et al 2018 Modification), then mashed using a mortar.

Phycocyanin Extraction. The dry biomass of *A. platensis* was taken 0.04 g and added 1 ml of phosphate buffer pH 7, homogenized, and then frozen in the freezer for 24 hours at -4°C. After 24 hours from the freezer, the thawing process was carried out (at room temperature) for 15 minutes. Samples were centrifuged for 30 minutes at 3000 rpm. The precipitate and supernatant were separated. The supernatant produced is phycocyanin which will be analyzed using the method of Bennett and Bogorad (1973).

Daily Density Measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40 oC for 18 hours. The dried water sample after the oven was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g.L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

Arthrospira platensis Daily Growth Rate. The daily growth rate of *A. platensis* can be calculated using the following formula (Vonshak, 2002):

$$\mu = \frac{\ln N_t - \ln N_0}{t} \times 100\%$$

μ = Daily growth rate (% day⁻¹)

N₀ = Initial density (g L⁻¹)

N_t = Density at time t (g L⁻¹)

t = Time (days) from N₀ to N_t

Reduction of Total Nitrogen Content. Reduction of total nitrogen content in the media

was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Measurement of Phycocyanin Yield. Measurement of phycocyanin yield was carried out after passing through the exponential phase (harvest), the measurement refers to Bennett and Bogorad (1973). The extracted supernatant was measured for absorbance using a spectrophotometer at wavelengths of 615 nm and 652 nm.

$$C\text{-phycocyanin (mg mL}^{-1}\text{)} = \frac{(OD\ 615) \cdot 0.474 (OD\ 652)}{5.34}$$

$$\text{Phycocyanin yield (mg g}^{-1}\text{)} = \frac{C\text{-phycocyanin} \times V}{DB}$$

C-phycocyanin = C-phycocyanin concentration (mg mL⁻¹)

V = Volume of solvent (ml)

DB = Dry Biomass (0.04 g)

0.474 and 5.34 = Coefficient of extinction (Bennett and Bogorad, 1973)

Business Analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

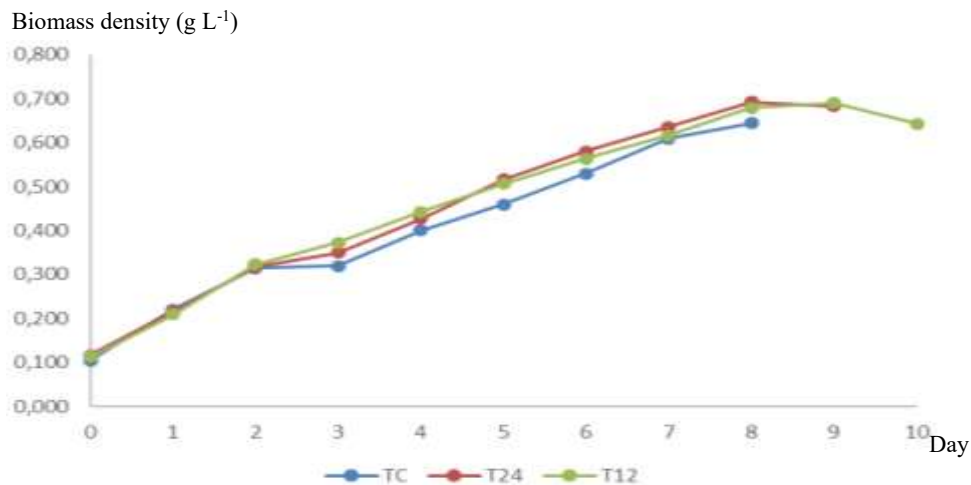
$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Maximum density of *A. platensis*. The daily density of *A. platensis* for each culture treatment. The time of achieving the highest peak density of *A. platensis* in each treatment was different. The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on each treatment can be seen in Figure 2.



Based on Figure 2, it can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment which had an average biomass of 0.645 g L⁻¹.

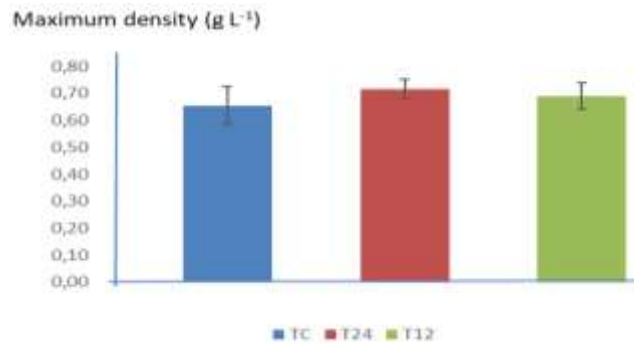


Table 1

Maximum density of *A. platensis* in treatment stirring on *A. platensis* culture media from Clarias waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66 ±0.14
T24	0.80	0.68	0.67	0.72 ±0.07
T12	0.80	0.66	0.61	0.69 ±0.10

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 with a biomass of 0.800 g L⁻¹ and after that, it decreased gradually to 0.662 g L⁻¹ and 0.600 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to (Budiardi et al. 2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly

exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific Growth Rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa, 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

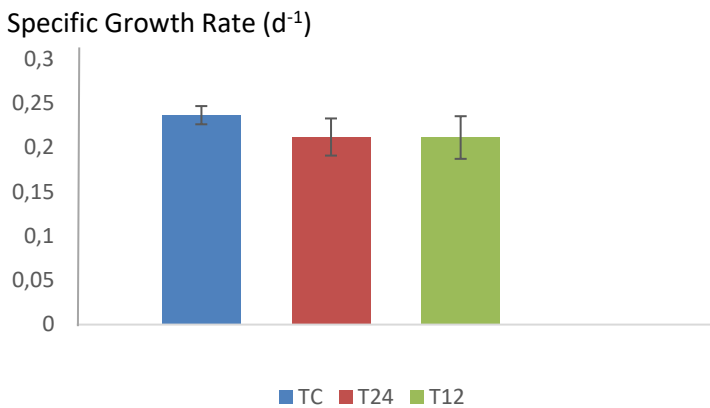


Table 2

Specific growth rate of *A. platensis* in treatment stirring and on *A. platensis* culture media from Clarias waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	15.05	22.19	21.08 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82

Based on the results in Table 2, the treatment control gave the best specific growth rate value of 23.625% per day. The 24 hours stirring gave the lowest growth rate value of 21.105% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos *et al.* (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka & Vonshak (2017), potential issues with the recycling of media are selective enrichment of culture-contaminating organisms or unwanted cell morphologies; build-up of specific ions which negatively affects the growth of the algae; build-up of autoinhibitory; an

increase in dissolved organic matter due to cell breakage during harvesting; and carry-over of flocculant leading to flocculation of the cells in the culture. The medium to be recycled may need some pre-treatment or conditioning before it is returned to the culture ponds. Medium recycling is successfully practiced by most large-scale commercial algal producers.

Reduction of Total Nitrogen Content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO₃⁻). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH₄⁺) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction can be seen in Table 3.

Table 3

Reduction of Total Nitrogen Content in *A. platensis* culture media

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	97,54	98,82	98,76	98,38 ± 0.73
T24	99,28	99,19	99,01	99,16 ± 0.14
T12	92,75	95,71	98,07	95,51 ± 2.66

Based on the results presented in Table 3 shows that the percentage reduction in nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater Clarias catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater Nile tilapia reared in biofloc system media can remove the nitrogen, such as NO₃-N uptake of 99%, 80% of TAN and 90% of NO₂-N for 10 days (de Moraes et al 2021). Ammonia can remove 87,77 ± 1,01% by *Spirulina platensis* cultured in wastewater Pangasius catfish reared for 10 days (Wijayanti et al 2018). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4

Phycocyanin(%) yield in *Arthrospira* dry biomass at 10 days after inoculation

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	5,098	1,192	5,315	3.87 ± 2.32

Table 6

Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{α0.05} = 0.069)	Mean of ROI value (HSD _{α0.05} = 6.882)	Feed Conversion Ratio (FCR) in Catfish rearing
TC	0.942±0.050 ^a	-5.756±5.025 ^a	1.38±0.33
T24	1.098±0.059 ^b	9.821±5.907 ^b	1.30±0.30
T12	1.120±0.068 ^b	12.013±6.842 ^b	1.04±0.40

In T12's first production cycle, the average cost of feed was IDR. 3,458, catfish was IDR. 12,780 and catfish earn IDR. 21,294, product *A. platensis* flour was IDR. 9,850 with a total income of IDR. 31,144 with a profit of IDR. 1,585 from production costs of IDR. 29,559 (*A. platensis* in 30 liters of media and 20 fish). If *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit will be obtained reached IDR. 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation

than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to Sriwijaya University for the funding of the Competitive Grant Batch II research in 2021: 0022/UN9/SK.LT12M.PT/2021.

References

- Afriani, S., Uju dan Setyaningsih, I., 2018. Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3), 471-479. [In Indonesian]
- Antara, 2021. <https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, 18 Januari 2021 19:41 WIB [In Indonesian]
- Bennett, A dan Bogorad, L., 1973. Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58, 419-435.
- Borowitzka, M.A., Beardall, J. and Raven, J.A. eds., 2016. *The physiology of microalgae* (Vol. 6). Cham: Springer International Publishing.
- Borowitzka, M.A. and Vonshak, A., 2017. Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4), pp.407-418.
- Budiardi, T., Utomo, N.B.P. and Santosa, A., 2010. Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2), pp.146-156.
- de Godos, I., Mendoza, J. L., Ación, F. G., Molina, E., Banks, C. J and Heaven, S., 2014. Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus, C.S., da Silva Uebel, L., Costa, S.S., Miranda, A.L., de Morais, E.G., de Morais, M.G., Costa, J.A.V., Nunes, I.L., de Souza Ferreira, E. and Druzian, J.I., 2018. Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresource technology*, 256, pp.86-94.
- Deyab, M., Mofeed, J., El-Bilawy, E. and Ward, F., 2020. Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2), pp.213-223.
- Fazal, T., Mushtaq, A., Rehman, F., Khan, A.U., Rashid, N., Farooq, W., Rehman, M.S.U. and Xu, J., 2018. Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82, pp.3107-3126.
- Hariyati R. Growth and biomass of *spirulina* sp in laboratory scale. *Bioma*. 2008;10(1):19-22.
- Jonker, J.G.G. and Faaij, A.P.C., 2013. Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102, pp.461-475.
- Jung, F., Jung, C.G., Krüger-Genge, A., Waldeck, P. and Küpper, J.H., 2019. Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2), pp.125-134.
- Knowler, D., Chopin, T., Martínez-Espiñeira, R., Neori, A., Nobre, A., Noce, A. and Reid, G., 2020. The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go?. *Reviews in Aquaculture*, 12(3), pp.1579-1594.
- Liu, H., Zhang, H., Niedzwiedzki, D.M., Prado, M., He, G., Gross, M.L. and Blankenship, R.E., 2013. Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162), pp.1104-1107.
- Mutiah, E dan Khoirunisa, E., 2013. Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor. *Jurnal Teknologi Kimia dan Industri*, 2 (2), 192-197. [In Indonesian]
- Naidoo, D., Roy, A., Kar, P., Mutanda, T. and Anandraj, A., 2021. Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16), pp.6218-6230.
- Ndubuisi, U.C., Chimezie, A.J., Chinedu, U.C., Chikwem, I.C dan Alexander, U., 2015. Effect

- of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3), 14-20.
- Oktafiani, M. dan Hermana, J., 2013. Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system. *Jurnal Teknik POMITS*, 2(2), 57-62. [In Indonesian]
- Ragaza, J.A., Hossain, M.S., Meiler, K.A., Velasquez, S.F. and Kumar, V., 2020. A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4), pp.2371-2395.
- Ramli, N.M., Verreth, J.A.J., Yusoff, F.M., Nurulhuda, K., Nagao, N. and Verdegem, M.C., 2020. Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8, p.1004.
- Santosa, A., 2010. Production of *Spirulina* sp. cultured by photoperiodic manipulation. Undergraduate Thesis. IPB University. [In Indonesian]
- Sharma, N.K., Tiwari, S.P., Tripathi, K. and Rai, A.K., 2011. Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6), pp.1059-1081.
- Sitio, M.H.F., Jubaedah, D dan Syaifudin, M., 2017. Survival and growth of catfish fry (*Clarias* sp.) in different media salinity. *Jurnal Akuakultur Rawa Indonesia*, 5(1) : 83-96. [In Indonesian]
- Tabar zad, M., Atabaki, V. and Hosseinabadi, T., 2020. Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. *Molecular biology reports*, 47(8), pp.6193-6205.
- Tang, D.Y.Y., Khoo, K.S., Chew, K.W., Tao, Y., Ho, S.H. and Show, P.L., 2020. Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304, p.122997.
- Tiwari, A.K. and Tiwari, B.S., 2020. Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1), pp.44-57.
- Vernès, L., Granvillain, P., Chemat, F. and Vian, M., 2015. Phycocyanin from *Arthrospira platensis*. Production, extraction and analysis. *Current Biotechnology*, 4(4), pp.481-491.
- Vonshak, A., 2002. *Spirulina platensis* (*Arthrospira*): Physiology, Cell-biology and Biotechnology. Taylor & Francis.
- Widyantoro, H., Wijayanti, M. and Dwinanti, S.H., 2018. Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater. *Jurnal Akuakultur Rawa Indonesia*, 6(2), pp.153-164. [In Indonesian]
- Wijayanti, M., Jubaedah, D., Gofar, N. and Anjastari, D., 2019. Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3), pp.108-112.
- Wijayanti, M., Syaifudin, M., Yulisman., Nurianti, Y., Hidayani, A dan Gofar, N., 2020. Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12), 5872-5883.
- Zhang, F., Man, Y.B., Mo, W.Y. and Wong, M.H., 2020. Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2), pp.582-599.
- Zhou, W., Li, Y., Gao, Y. and Zhao, H., 2017. Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245, pp.10-17.

Bukti Rejection dan boleh Resubmit (14 Januari 2022)

Manuscript rejection **Unread** **Check Mailbox**

muntean.gc@gmail.com
kepada saya

Jun 14, 2022, 20:20

Inggris → Indonesia • Terjemahkan pesan

Nisaktifkan untuk Inggris

Dear Dr. Matri Wijayanti,
This is a message regarding the rejection of your manuscript "Technoeconomic of Integrated Multitrophic *Clarias catfish* and *Arthrospira* with Different Agitation Period", submitted to our journal *Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society (AACL Bioflux)*.
Your manuscript was rejected due to detected plagiarism counts (see attachments). If you want us to reconsider your manuscript, you must rewrite the problematic issues and resubmit your manuscript. If you want to do so, you can resubmit your manuscript directly to me.

Best regards,
George Muntean
Editor, Bioflux SRL

Visit our journals:
Aquaculture, Aquarium, Conservation & Legislation www.bioflux.com.ro/aacl
Advances in Environmental Sciences www.aes.bioflux.com.ro
Human & Veterinary Medicine www.hvm.bioflux.com.ro
Advances in Agriculture & Botany www.aab.bioflux.com.ro
Animal Biology & Animal Husbandry www.abah.bioflux.com.ro
Extreme Life, Biospeology & Astrobiology www.ela.bioflux.com.ro
Porcine Research www.pors.bioflux.com.ro
Rabbit Genetics www.rg.bioflux.com.ro
ProEnvironment Fromediu <http://journals.usamvclj.ro/index.php/promediu>
Procellid Research www.pr.bioflux.com.ro

Procellid Research www.pr.bioflux.com.ro

9 Lampiran • Dipindai dengan Gmail

Duplichecker-Pla...
Duplichecker-Pla...
Duplichecker-Pla...
Duplichecker-Pla...
smallseotools-16...
smallseotools-16...
smallseotools-16...
smallseotools-16...
smallseotools-16...

Bukti Re-Submit (21 Januari 2022)



Submission letter

Article title: **Technoeconomic of Integrated Multitrophic *Clarias catfish* and *Arthrospira* with Different Agitation Period**


Name of the authors : Marini Wijayanti, Yohanes Setiawan, Tanbiyaskur, Dade Jubaedah, Mohamad Amin, Mirna Fitriani, Nuni Gofar

Hereby I would like to submit the manuscript entitled "**Technoeconomic of Integrated Multitrophic *Clarias catfish* and *Arthrospira* with Different Agitation Period**" to Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society.


This manuscript was not submitted or published to any other journal. The authors declare that the manuscript is an original paper and contain no plagiarized text. All authors declare that they are not currently affiliated or sponsored by any organization with a direct economic interest in subject of the article. My co-authors have all contributed to this manuscript and approve this submission.


Corresponding author & Author 1,


Marini Wijayanti 


Author 2,
Yohanes Setiawan..... 

Author 3,
Tanbiyaskur..... 

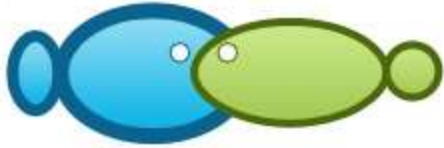
Author 4,
Dade Jubaedah..... 

Author 5,
Mohamad Amin..... 

Author 6,
Mirna Fitriani..... 

Author 7,
Nuni Gofar 

Date, January 23th, 2022



Technoeconomic of Integrated Multitrophic *Clarias* catfish and *Arthrospira* with Different Agitation Period

¹Marini Wijayanti*, ¹Yohanes Setiawan, ¹Tanbiyaskur, ¹Dade Jubaedah, ¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia.

*Corresponding author: mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multitrophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceway because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Keywords: *A. platensis*, b/c ratio, *Clarias* catfish rearing, raceway.

Introduction.

Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan, which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara, 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multitrophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the ecological impact around aquaculture

operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2018; Widyantoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari, 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry per liter, the growth rate of 22.026%. day⁻¹ and 11,347 mg. g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor has an effect on the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah and Khoirunisa, 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al. (2018) showed that 24-hour stirring resulted in a biomass concentration of $1.60 \pm 0.04 \text{ g L}^{-1}$, biomass productivity of $0.054 \pm 0.003 \text{ g L}^{-1} \text{ h}^{-1}$, and a specific growth rate of $0.05 \pm 0.002 \text{ h}^{-1}$ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil it's yield density of $0.90 \pm 0.02 \text{ gL}^{-1}$, biomass productivity of $0.009 \pm 0.001 \text{ gL}^{-1} \text{ h}^{-1}$ and specific growth of $0.02 \pm 0.001 \text{ h}^{-1}$. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of spirulina in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method

This study was conducted at Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation methods: control using 24-hour aeration. day⁻¹ (TC), stirring period 24 Hours. day⁻¹(T24), stirring period 12 Hours. day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated Clarias catfish- Arthrospira culture.



Figure 1. Design of integrated Clarias catfish- Arthrospira culture in this study

Preparation of Arthrospira Growing Media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance of catfish fed floating pellets protein 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and Harvesting Arthrospira platensis. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani and Hermana, 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 RPM. The control was aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06.00 am -6.00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed the wet weight and then put into a porcelain crucible then dried in an oven at 40°C for 18 hours (Afriani et al 2018 Modification), then mashed using a mortar.

Daily Density Measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40 oC for 18 hours. The dried water sample after the oven was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g.L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

Arthrospira platensis Daily Growth Rate. The daily growth rate of *A. platensis* can be calculated using the Vonshak formula(Vonshak, 2002).

Extraction and Measurement of Phycocyanin Yield. The dry biomass of *A. platensis* was taken 0.04 g for phycocyanin extraction. The method followed the previous study (Wijayanti et al 2020). Measurement of phycocyanin yield was carried out after passing through the exponential phase (harvest) (Bennett and Bogorad 1973).

Reduction of Total Nitrogen Content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business Analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

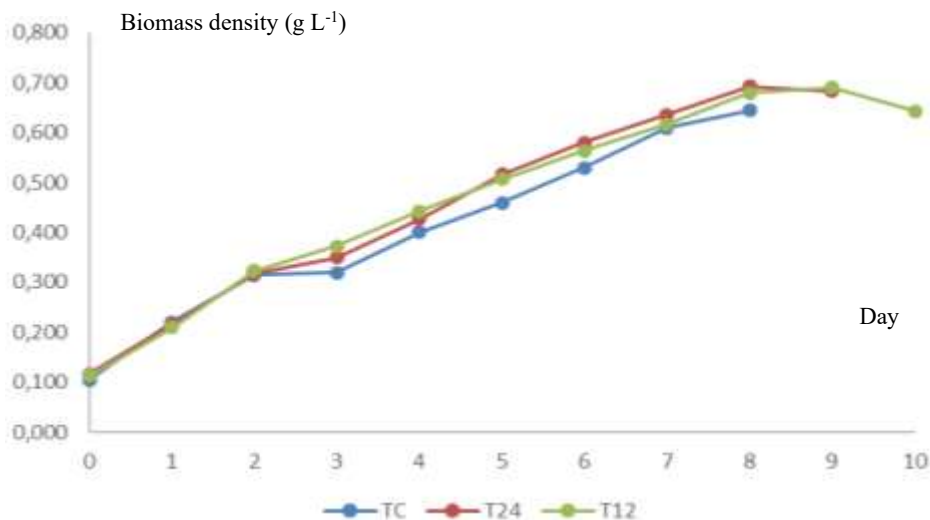


Figure 1. Biomass density of *Arthrospira platensis* for 10 days

The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment, 0.645 g L⁻¹.

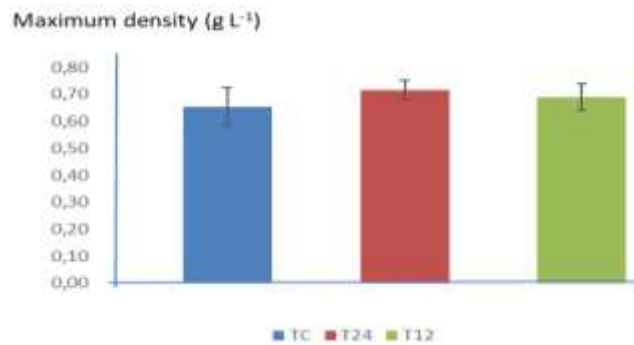


Figure 2. Maximum density of *A. platensis* biomass

Table 1

Maximum density of *A. platensis* in treatment stirring on *A. platensis* culture media from Clarias waste water

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 with a biomass of 0.800 g L⁻¹ and after that, it decreased gradually to 0.662 g L⁻¹ and 0.600 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to (Budiardi et al. 2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific Growth Rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa, 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

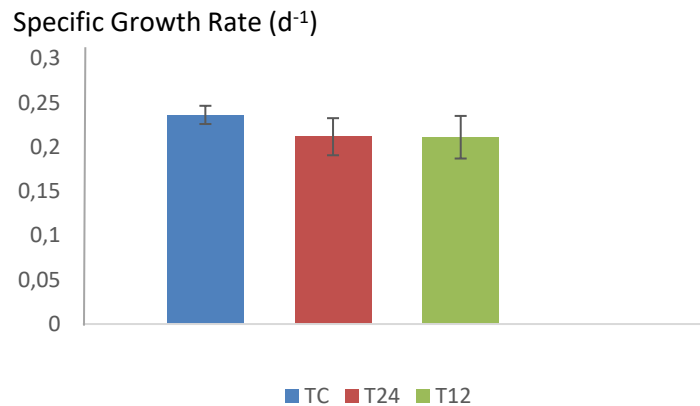


Figure 3. Specific growth rate of *A. platensis* in growth phase

Table 2
Specific growth rate of *A. platensis* in treatment stirring and on *A. platensis* culture media from Clarias waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	15.05	22.19	21.08 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82

Based on the results in Table 2, the treatment control gave the best specific growth rate value of 23.625% per day. The 24 hours stirring gave the lowest growth rate value of 21.105% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos *et al.* (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka & Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. The medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of Total Nitrogen Content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3

Reduction of Total Nitrogen Content in *A. platensis* culture media

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater Clarias catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater Nile tilapia reared in biofloc system media can remove the nitrogen, such as $\text{NO}_3\text{-N}$ uptake of 99%, 80% of TAN and 90% of $\text{NO}_2\text{-N}$ for 10 days (de Moraes et al 2021). Ammonia can remove 87,77 \pm 1,01% by *Spirulina platensis* cultured in wastewater Pangasius catfish reared for 10 days (Wijayanti et al 2018). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4

Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 3) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma and Tiwari (2011) stated that the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business Analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/ C Ratio and ROI in each treatment and group. Business analysis has been shown in Table 5 and Table 6.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is efficient and profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient or harmful. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI : ROI is positive, then the business is efficient and profitable, ROI = 0, then the farm is break-even, and ROI is negative, so it is not efficient or detrimental.

The results of the Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. But, treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5

Components of production costs and revenues to calculate Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with Clarias catfish rearing systems

Components	Value (IDR)	Value (IDR) per cycle								
		TC			T24			T12		
		G1	G2	G3	G1	G2	G3	G1	G2	G3
Production cost										
Investment cost										
Dynamo	18000	0.00	0.00	0.00	173.08	173.08	173.08	173.08	173.08	173.08
Pinwheel	30000	0.00	0.00	0.00	288.46	288.46	288.46	288.46	288.46	288.46
Aerator	37000	474.36	474.36	474.36	0.00	0.00	0.00	0.00	0.00	0.00
Container	80000	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82
Tube lamp	47000	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92
Asahi cloth	18000	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08
Variable cost										
Fish feed	11000	2546.17	3942.40	2079.00	3627.91	4400.00	3069.00	3092.21	4400.00	2882.00
Electricity	1444.7	13695.76	13695.76	11892.77	10921.93	11615.39	11615.39	10921.93	10921.93	10921.93
Fish	19000	6000.20	8763.37	15038.50	6093.30	10352.72	18483.20	6591.10	11762.14	19986.10
Coarse salt	5000	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
Total production cost		24654.31	28813.71	31422.45	23042.50	28767.47	35566.95	23004.60	29483.43	36189.39
Income										
Catfish	22000	10147.06	17413.00	20086.00	11987.36	21401.60	25539.80	13619.32	23141.80	27121.60
Product <i>A. platensis</i> flour	500	10500.00	9675.00	7800.00	11250.00	10200.00	10050.00	10500.00	9900.00	9150.00
Total income		20647.06	27088.00	27886.00	23237.36	31601.60	35589.80	24119.32	33041.80	36271.60
Profit		-4007.25	-1725.71	-3536.45	194.86	2834.13	22.85	1114.72	3558.37	82.21
R/C		0.84	0.94	0.89	1.01	1.10	1.00	1.05	1.12	1.00
ROI		-16.25	-5.99	-11.25	0.85	9.85	0.06	4.85	12.07	0.23

Table 6
Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{α0.05= 0.069})	Mean of ROI value (HSD _{α0.05= 6.882})	Feed Conversion Ratio (FCR) in Catfish rearing
TC	0.942±0.050 ^a	-5.756±5.025 ^a	1.38±0.33
T24	1.098±0.059 ^b	9.821±5.907 ^b	1.30±0.30
T12	1.120±0.068 ^b	12.013±6.842 ^b	1.04±0.40

In T12's first production cycle, the average cost of feed was IDR. 3,458, catfish was IDR. 12,780 and catfish earn IDR. 21,294, product *A. platensis* flour was IDR. 9,850 with a total income of IDR. 31,144 with a profit of IDR. 1,585 from production costs of IDR. 29,559 (*A. platensis* in 30 liters of media and 20 fish). If *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit will be obtained reached IDR. 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Srivijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

References

- Afriani, S., Uju dan Setyaningsih, I., 2018. Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3), 471-479. [In Indonesian]
- Antara, 2021. <https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, 18 Januari 2021 19:41 WIB [In Indonesian]
- Bennett, A dan Bogorad, L., 1973. Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58, 419-435.
- Borowitzka, M.A., Beardall, J. and Raven, J.A. eds., 2016. *The physiology of microalgae* (Vol. 6). Cham: Springer International Publishing.
- Borowitzka, M.A. and Vonshak, A., 2017. Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4), pp.407-418.
- Budiardi, T., Utomo, N.B.P. and Santosa, A., 2010. Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2), pp.146-156.
- de Godos, I., Mendoza, J. L., Acien, F. G., Molina, E., Banks, C. J and Heaven, S., 2014. Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus, C.S., da Silva Uebel, L., Costa, S.S., Miranda, A.L., de Morais, E.G., de Morais, M.G., Costa, J.A.V., Nunes, I.L., de Souza Ferreira, E. and Druzian, J.I., 2018. Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresour Technol*, 256, pp.86-94.
- Deyab, M., Mofeed, J., El-Bilawy, E. and Ward, F., 2020. Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2), pp.213-223.
- Fazal, T., Mushtaq, A., Rehman, F., Khan, A.U., Rashid, N., Farooq, W., Rehman, M.S.U. and Xu, J., 2018. Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82, pp.3107-3126.
- Hariyati R. Growth and biomass of *spirulina* sp in laboratory scale. *Bioma*. 2008;10(1):19-22.
- Jonker, J.G.G. and Faaij, A.P.C., 2013. Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102, pp.461-475.
- Jung, F., Jung, C.G., Krüger-Genge, A., Waldeck, P. and Küpper, J.H., 2019. Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2), pp.125-134.
- Knowler, D., Chopin, T., Martínez-Espiñeira, R., Neori, A., Nobre, A., Noce, A. and Reid, G., 2020. The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go?. *Reviews in Aquaculture*, 12(3), pp.1579-1594.
- Liu, H., Zhang, H., Niedzwiedzki, D.M., Prado, M., He, G., Gross, M.L. and Blankenship, R.E., 2013. Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162), pp.1104-1107.

- Mutiah, E dan Khoirunisa, E., 2013. Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor. *Jurnal Teknologi Kimia dan Industri*, 2 (2), 192-197. [In Indonesian]
- Naidoo, D., Roy, A., Kar, P., Mutanda, T. and Anandraj, A., 2021. Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16), pp.6218-6230.
- Ndubuisi, U.C., Chimezie, A.J., Chinedu, U.C., Chikwem, I.C dan Alexander, U., 2015. Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3), 14-20.
- Oktafiani, M. dan Hermana, J., 2013. Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system. *Jurnal Teknik POMITS*, 2(2), 57-62. [In Indonesian]
- Ragaza, J.A., Hossain, M.S., Meiler, K.A., Velasquez, S.F. and Kumar, V., 2020. A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4), pp.2371-2395.
- Ramli, N.M., Verreth, J.A.J., Yusoff, F.M., Nurulhuda, K., Nagao, N. and Verdegem, M.C., 2020. Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8, p.1004.
- Santosa, A., 2010. Production of *Spirulina* sp. cultured by photoperiodic manipulation. Undergraduate Thesis. IPB University. [In Indonesian]
- Sharma, N.K., Tiwari, S.P., Tripathi, K. and Rai, A.K., 2011. Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6), pp.1059-1081.
- Sitio, M.H.F., Jubaedah, D dan Syaifudin, M., 2017. Survival and growth of catfish fry (*Clarias* sp.) in different media salinity. *Jurnal Akuakultur Rawa Indonesia*, 5(1) : 83-96. [In Indonesian]
- Tabarzad, M., Atabaki, V. and Hosseinabadi, T., 2020. Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. *Molecular biology reports*, 47(8), pp.6193-6205.
- Tang, D.Y.Y., Khoo, K.S., Chew, K.W., Tao, Y., Ho, S.H. and Show, P.L., 2020. Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304, p.122997.
- Tiwari, A.K. and Tiwari, B.S., 2020. Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1), pp.44-57.
- Vernès, L., Granvillain, P., Chemat, F. and Vian, M., 2015. Phycocyanin from *Arthrospira platensis*. Production, extraction and analysis. *Current Biotechnology*, 4(4), pp.481-491.
- Vonshak, A., 2002. *Spirulina platensis* (*Arthrospira*): Physiology, Cell-biology and Biotechnology. Taylor & Francis.
- Widyantoro, H., Wijayanti, M. and Dwinanti, S.H., 2018. Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater. *Jurnal Akuakultur Rawa Indonesia*, 6(2), pp.153-164. [In Indonesian]
- Wijayanti, M., Jubaedah, D., Gofar, N. and Anjastari, D., 2019. Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3), pp.108-112.
- Wijayanti, M., Syaifudin, M., Yulisman., Nurianti, Y., Hidayani, A dan Gofar, N., 2020. Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12), 5872-5883.
- Zhang, F., Man, Y.B., Mo, W.Y. and Wong, M.H., 2020. Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2), pp.582-599.
- Zhou, W., Li, Y., Gao, Y. and Zhao, H., 2017. Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245, pp.10-17.



muntean.gc@gmail.com

07 Jun 2022, 19:47

Inggris > Indonesia > Terjemahkan pesan

Terjemahkan untuk Inggris >

Dear Dr. Marini Wijayanti,
Thank you for paying the processing fee. After my editor-in-chief confirms that your payment, I will begin the reviewing process.

Best regards,
George Murtana
Editor, Bioflux SRL
Visit our journals:
Aquaculture, Aquarium, Conservation & Legislation www.bioflux.com.ro/aa
Advances in Environmental Sciences www.aes.bioflux.com.ro
Human & Veterinary Medicine www.hvm.bioflux.com.ro
Advances in Agriculture & Botany www.aab.bioflux.com.ro
Animal Biology & Animal Husbandry www.abah.bioflux.com.ro
Extreme Life, Bioprotection & Astrobiology www.elba.bioflux.com.ro
Porcine Research www.porc.bioflux.com.ro
Ratite Genetica www.rg.bioflux.com.ro
ProEnvironment Promedia <http://jurnal.usamvcluj.ro/indox.php?promedia>
Poultry Research www.pr.bioflux.com.ro

From: Marini Wijayanti <mariw@unin.ac.id>
Sent: Saturday, June 25, 2022 3:58 AM
To: muntean.gc@gmail.com
Cc: Marini Wijayanti <mariw@unin.ac.id>
Subject: Re: Preliminary acceptance letter

Dear



Marini Wijayanti

Kam, 10 Sep 2022, 11:26

Forwarded message — Dari Marini Wijayanti <mariw@unin.ac.id> Date: Jun, 12 Agu 2022 pukul 13:10 Subject: Status of manuscript



muntean.gc@gmail.com

Kam, 10 Sep 2022, 11:58

Inggris >

Inggris > Indonesia > Terjemahkan pesan

Terjemahkan untuk Inggris >

Dear Dr. Marini Wijayanti,

The review process is almost complete and we will soon move on to the final editing process for your manuscript. I will contact you when the review process is finalized.

Best regards,
George Murtana
Editor, Bioflux SRL
Visit our journals:
Aquaculture, Aquarium, Conservation & Legislation www.bioflux.com.ro/aa
Advances in Environmental Sciences www.aes.bioflux.com.ro
Human & Veterinary Medicine www.hvm.bioflux.com.ro
Advances in Agriculture & Botany www.aab.bioflux.com.ro
Animal Biology & Animal Husbandry www.abah.bioflux.com.ro
Extreme Life, Bioprotection & Astrobiology www.elba.bioflux.com.ro
Porcine Research www.porc.bioflux.com.ro
Ratite Genetica www.rg.bioflux.com.ro
ProEnvironment Promedia <http://jurnal.usamvcluj.ro/indox.php?promedia>
Poultry Research www.pr.bioflux.com.ro

Best



muntean.gc@gmail.com

07 Jun, 2022, 19:47

Inggris > Indonesia > Terjemahkan pesan

Terjemahkan untuk Inggris

Dear Dr. Marini Wijayanti,

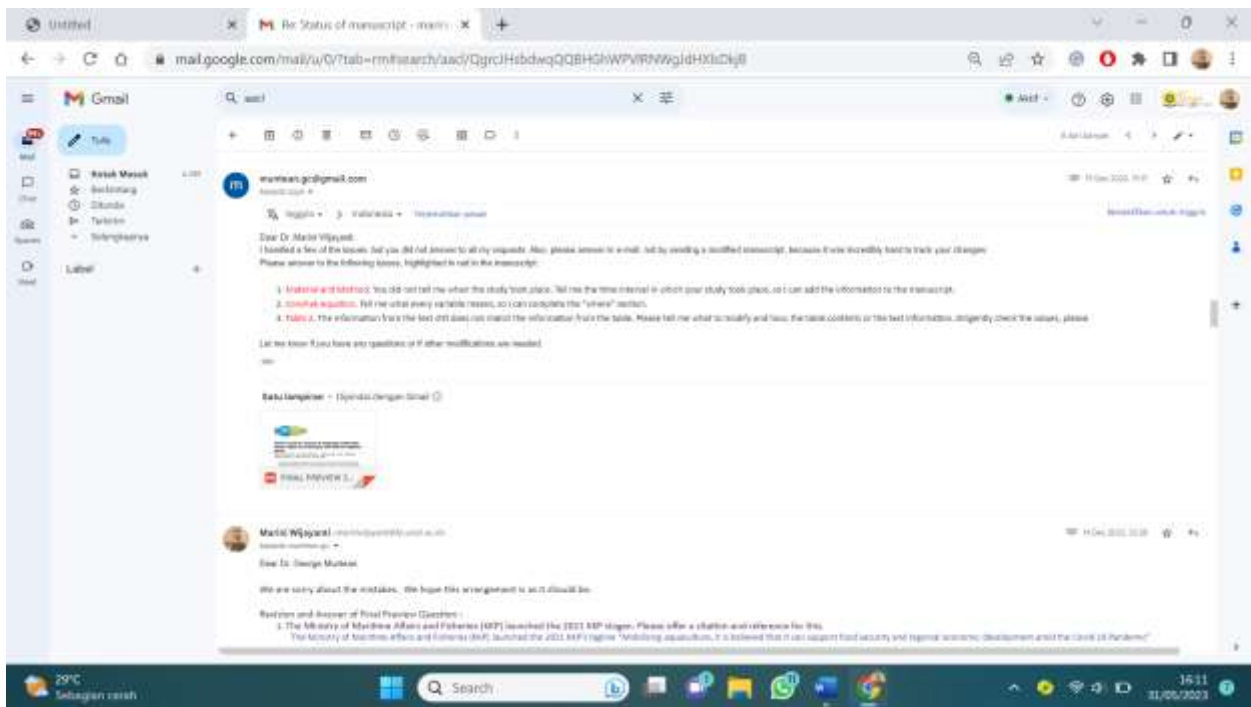
Please find attached the final version of your manuscript, which was edited based on the reviewers' comments and my analysis. I took care of the formatting and the minor issues, but there are still a few aspects that need to be addressed, which are highlighted in red throughout the manuscript. I will send you this e-mail about them and please answer by e-mail. Afterwards, I will make the final modifications and send the manuscript to you for the final approval.

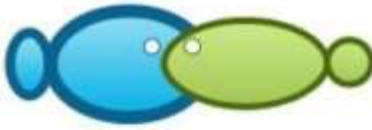
1. The identity of Marini's affiliation and address (2022) is missing. Please offer a citation and reference for this.
2. First 2022 citation. Are you sure this is not 2021? I find it online as 2020.
3. Abstract and Methods. Please tell me when the experiments took place, so I can mention it in text.
4. Chouhan & Anandya (2022). This citation and references are figured online as Chouhan & Anandya (2022). Please clarify.
5. The chemical formula (sucrose, 2020). Please provide formula.
6. Red sentences from abstract section, line 566. Please rephrase. Improve English.
7. See after Table 1. Are you sure the data from text or table are correct? Because they do not make any sense.
8. See after Table 1. Are you sure the data from text or table are correct? Because they do not make any sense.
9. N2O: N₂O? or nitrogen uptake?
10. N2O: N₂O? or nitrogen uptake?
11. N2O: N₂O? or nitrogen?
12. De Koning et al. (2022). Reference not in reference list. Please provide reference, so I can add it to the reference list.
13. Table 1. Image not acceptable. Please send me the table in software format, so I can add it to text.
14. Buzdugiu, remove reference in red. Not cited in text. Tell me where to cite.
15. Chouhan reference in red. Addressed issue in previous point.
16. Author information complete. Please tell me the e-mail addresses of your collaborators, so I can add them to the information complete.

Answer to these issues and I will make the necessary modifications. Also, make sure that everything you mention in the manuscript, especially the author information and affiliation has the beginning of the manuscript and in the information complete at the end of the manuscript. Let me know if you have any questions.

Best regards,
George Murtana
Editor, Bioflux SRL

Bukti konfirmasi submit revisi pertama, respon kepada reviewer, dan artikel yang diresubmit (18 Desember 2022)





Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period

¹Marini Wijayanti, ¹Yohanes Setiawan, ¹Tanbiyaskur, ¹Dade Jubaedah,
¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia. Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: *A. platensis*, b/c ratio, *Clarias* catfish rearing, raceway.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan, which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors

through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2018; Widyanoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil it's yield density was of 0.90 ± 0.02 g L⁻¹, biomass productivity of 0.009 ± 0.001 g L⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of *Spirulina* in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method. This study was conducted at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation

methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias* catfish-*Arthrospira* culture.

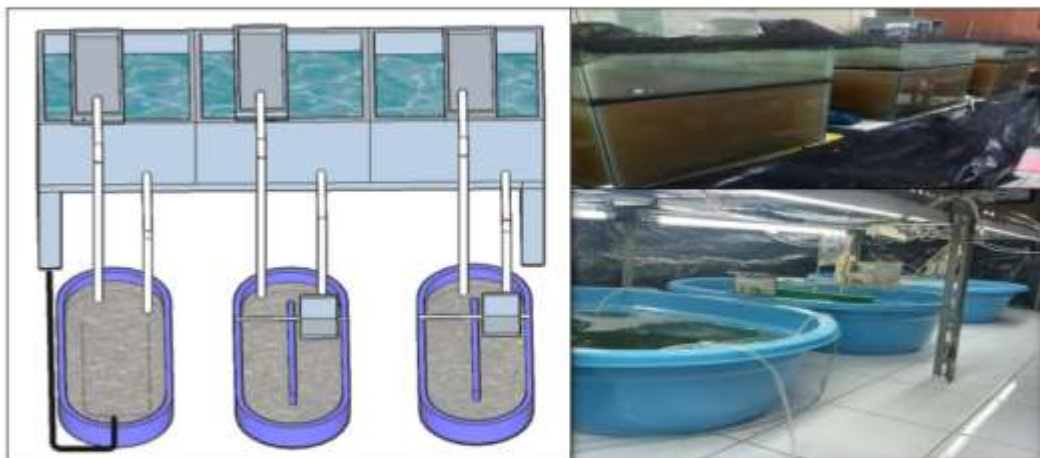


Figure 1. Design of integrated *Clarias* catfish - *Arthrospira* culture in this study.

Preparation of *Arthrospira* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am – 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

***Arthrospira platensis* daily growth rate.** The daily growth rate of *A. platensis* can be calculated using the Vonshak formula (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken 0.04 g for phycocyanin extraction. The method followed previous studies (Wijayanti et al 2020). Measurement of phycocyanin yield was carried out after passing through the exponential phase (harvest) (Bennett & Bogorad 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

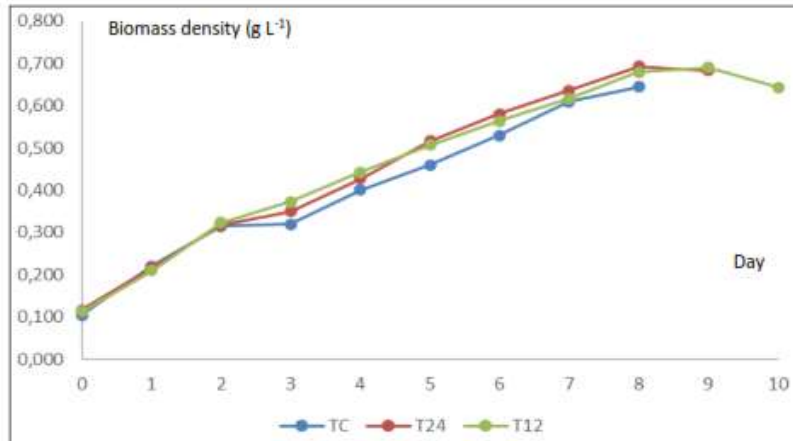


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment, 0.645 g L⁻¹.

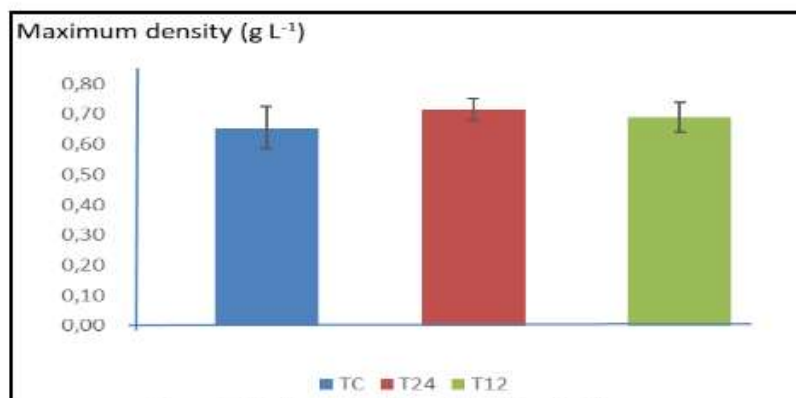


Figure 2. Maximum density of *A. platensis* biomass.

Table 1
Maximum density of *A. platensis* in treatment stirring on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66 ± 0.14
T24	0.80	0.68	0.67	0.72 ± 0.07
T12	0.80	0.66	0.61	0.69 ± 0.10

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 with a biomass of 0.800 g L⁻¹ and after that, it decreased gradually to 0.662 g L⁻¹, 0.600 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

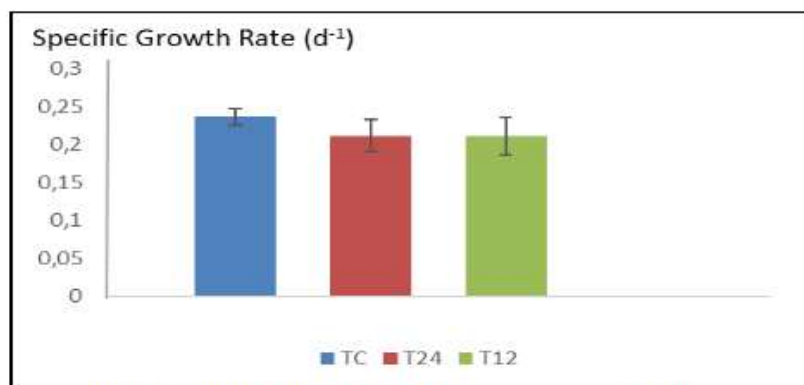


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate of *A. platensis* in treatment stirring and on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	15.05	22.19	21.08 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82

Based on the results in Table 2, the treatment control gave the best specific growth rate value of 23.625% per day. The 24 hours stirring gave the lowest growth rate value of 21.105% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content in *A. platensis* culture media

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in biofloc system media can remove the nitrogen, such as $\text{NO}_3^- \text{N}$ uptake of 99%, 80% of TAN and 90% of $\text{NO}_2^- \text{N}$ for 10 days (de Moraes et al 2021). Ammonia can remove $87.77 \pm 1.01\%$ by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2018). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL^{-1} . While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL^{-1} . The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day^{-1} (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day^{-1} (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that

the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Business analysis has been shown in Table 5 and Table 6.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is efficient and profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient or harmful. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, then the business is efficient and profitable, ROI = 0, then the farm is break-even, and ROI is negative, so it is not efficient or detrimental.

The results of the Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. But, treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5

Components of production costs and revenues to calculate Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems

Components	Value (IDR)	Value (IDR) per cycle								
		TC			T24			T12		
		G1	G2	G3	G1	G2	G3	G1	G2	G3
Production cost										
Investment cost										
Dynamo	18000	0.00	0.00	0.00	173.08	173.08	173.08	173.08	173.08	173.08
Pinwheel	30000	0.00	0.00	0.00	288.46	288.46	288.46	288.46	288.46	288.46
Aerator	37000	474.36	474.36	474.36	0.00	0.00	0.00	0.00	0.00	0.00
Container	80000	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82
Tube lamp	47000	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92
Asahi cloth	18000	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08
Variable cost										
Fish feed	11000	2546.17	3942.40	2079.00	3627.91	4400.00	3069.00	3092.21	4400.00	2882.00
Electricity	1444.7	13695.76	13695.76	11892.77	10921.93	11615.39	11615.39	10921.93	10921.93	10921.93
Fish	19000	6000.20	8763.37	15038.50	6093.30	10352.72	18483.20	6591.10	11762.14	19986.10
Coarse salt	5000	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
Total production cost		24654.31	28813.71	31422.45	23042.50	28767.47	35566.95	23004.60	29483.43	36189.39
Income										
Catfish	22000	10147.06	17413.00	20086.00	11987.36	21401.60	25539.80	13619.32	23141.80	27121.60
Product A. platensis flour	500	10500.00	9675.00	7800.00	11250.00	10200.00	10050.00	10500.00	9900.00	9150.00
Total income		20647.06	27088.00	27886.00	23237.36	31601.60	35589.80	24119.32	33041.80	36271.60
Profit		-4007.25	-1725.71	-3536.45	194.86	2834.13	22.85	1114.72	3558.37	82.21
R/C		0.84	0.94	0.89	1.01	1.10	1.00	1.05	1.12	1.00
ROI		-16.25	-5.99	-11.25	0.85	9.85	0.06	4.85	12.07	0.23

Table 6
Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{0.05= 0.069})	Mean of ROI value (HSD _{0.05= 6.882})	Feed Conversion Ratio (FCR) in Catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24

hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Srivijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [in Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Beardall J., Raven J. A., 2016 *The physiology of microalgae (Vol. 6)*. Cham: Springer International Publishing. 673 pp.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Acién F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Morais E. G., de Morais M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresource technology*, 256:86-94.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. *Bioma*. 10(1):19-22 [in Indonesian].
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Espiñeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? *Reviews in Aquaculture*, 12(3):1579-1594.
- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. *Jurnal Teknologi Kimia dan Industri*, 2(2):192-197 [in Indonesian].
- Naidoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16):6218-6230.

- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C., Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3):14-20.
- Oktafiani M., Hermana J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. *Jurnal Teknik POMITS*, 2(2):57-62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. *Jurnal Akuakultur Rawa Indonesia*, 5(1):83-96 [in Indonesian].
- Tabarzad M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. *Molecular biology reports*, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1):44-57.
- Vernès L., Granvillain P., Chemat F., Vian M., 2015 Phycocyanin from *Arthrospira platensis*. Production, extraction and analysis. *Current Biotechnology*, 4(4):481-491.
- Vonshak A., 2002 *Spirulina platensis* (*Arthrospira*): Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.
- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [in Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.
- *** Antara, 2021 [<https://www.antaraneews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, Accessed on 18 January 2021 19:41 WIB] [in Indonesian].

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX December 2022.

Authors:

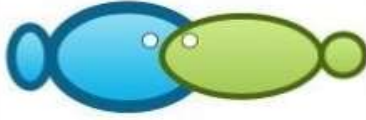
Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id
 Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail:

Tanbiyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, [e-mail](#):
Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, [e-mail](#):
Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, [e-mail](#):
Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, [e-mail](#):
Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, [e-mail](#):

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanbiyaskur, Jubaedah D., Amin M., Fitriani M., Gofar N., 2022 Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period. *AAFL Bioflux* 15(6):xxxx-xxxx.



Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period

¹Marini Wijayanti, ¹Yohanes Setiawan, ¹Tanbiyaskur, ¹Dade Jubaedah,
¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia. Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: *A. platensis*, b/c ratio, *Clarias* catfish rearing, raceway.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's tagline "Mobilizing aquaculture, it is believed that it can support food security and regional economic development amid the Covid-19 Pandemic" (<https://kkp.go.id/djpb>, 2022), which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara, 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors

through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2019; Widyantoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density was 0.90 ± 0.02 g L⁻¹, biomass productivity of 0.009 ± 0.001 g L⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of *Spirulina* in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method. This study was conducted at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation

methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias* catfish- *Arthrospira* culture.

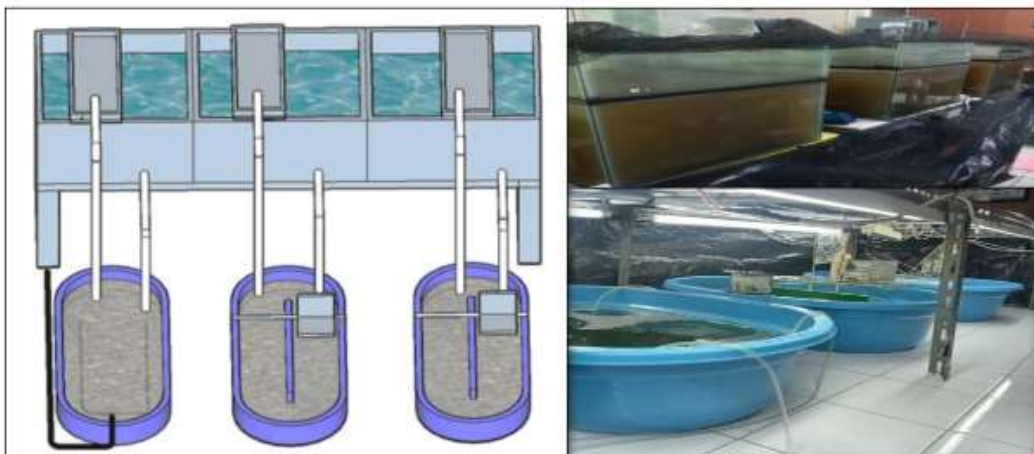


Figure 1. Design of integrated *Clarias* catfish - *Arthrospira* culture in this study.

Preparation of *Arthrospira* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am - 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

***Arthrospira platensis* daily growth rate.** The daily growth rate of *A. platensis* can be calculated using the Vonshak formula $\mu = \frac{\ln N_t - \ln N_0}{t} \times 100\%$ (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken at 0.04 g after passing through the exponential phase (harvest) for preparing phycocyanin extraction. The method of phycocyanin extraction followed previous studies (Wijayanti et al 2020). The absorbance of the extracted supernatant was measured using a spectrophotometer at a wavelength of 615 nm and 652 nm for determining phycocyanin yield with Bennett & Bogorard formulas : C-phycocyanin (mg mL^{-1}) = $((OD\ 615) - 0.474 (OD\ 652))/5.34$; and Phycocyanin yield (mg g^{-1}) = (C-phycocyanin x Solvent volume)/Dried Biomass (Bennett & Bogorard 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$\text{RCR} = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$\text{ROI} = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

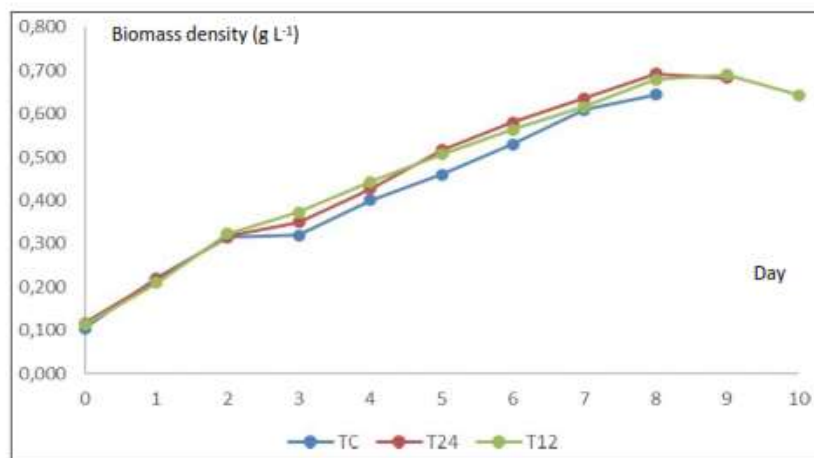


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was 0.645 g L^{-1} on day 8, in treatment T24 it reached 0.693 g L^{-1} on day 8, in treatment T12 it reached 0.690 g L^{-1} on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L^{-1} and T12 with an average biomass of 0.690 g L^{-1} , while the lowest density was in the TC treatment, 0.645 g L^{-1} .

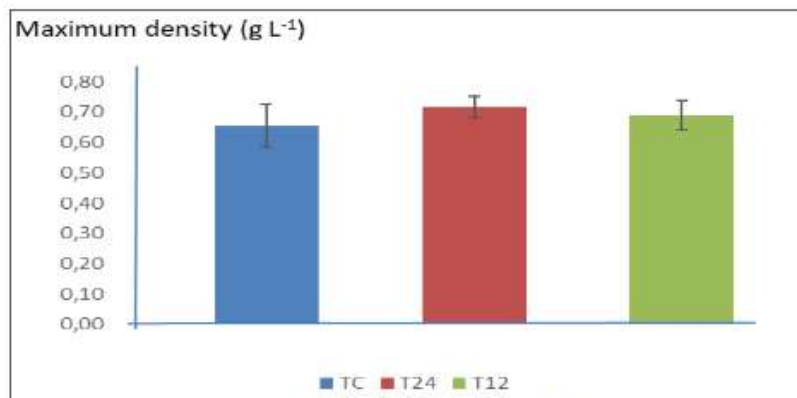


Figure 2. Maximum density of *A. platensis* biomass.

Table 1
Maximum density of *A. platensis* in treatment stirring on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66 ± 0.14
T24	0.80	0.68	0.67	0.72 ± 0.07
T12	0.80	0.66	0.61	0.69 ± 0.10
Mean	0.80 ± 0.00	0.66 ± 0.02	0.60 ± 0.08	

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 (first culture cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.66 g L⁻¹, 0.60 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

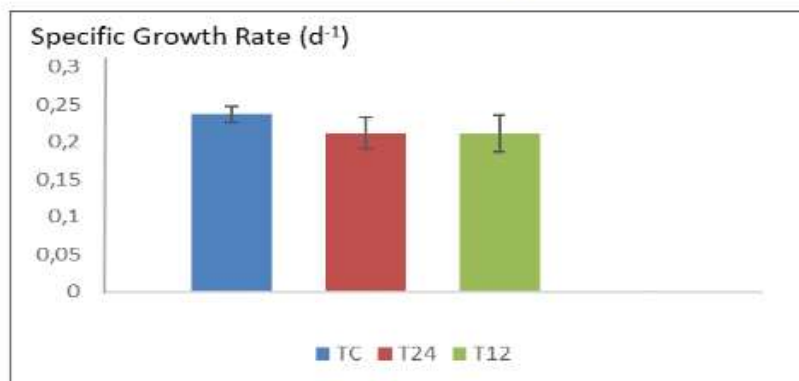


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate of *A. platensis* (%.day⁻¹) in treatment stirring and on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	22.69	22.19	23.63 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82
Mean	25.99±0.00	20.98±1.71	18.92±2.98	

Based on the results in Table 2, the treatment control gave the best specific growth rate value of 23.63% per day. The 24 hours stirring gave the lowest growth rate value of 21.11% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content in *A. platensis* culture media

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in bioflocsystem media can remove the nitrogen, such as Nitrate uptake of 99%, 80% of Total Ammonia Nitrogen and 90% of Nitrite for 10 days (de Moraes et al 2021). Ammonia can remove 87.77 ± 1.01% by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2019). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that

the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Business analysis has been shown in Table 5 and Table 6.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is efficient and profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient or harmful. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, then the business is efficient and profitable, ROI = 0, then the farm is break-even, and ROI is negative, so it is not efficient or detrimental.

The results of the Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. But, treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5
Components of production costs and revenues to calculate Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems

Components	Value (IDR)	Value (IDR) per cycle						
		TC			T24			
		G1	G2	G3	G1	G2	G3	G1
Production cost								
Investment cost								
Dynamo	18000	0,00	0,00	0,00	173,08	173,08	173,08	173,08
Pinwheel	30000	0,00	0,00	0,00	288,46	288,46	288,46	288,46
Aerator	37000	474,36	474,36	474,36	0,00	0,00	0,00	0,00
Container	80000	512,82	512,82	512,82	512,82	512,82	512,82	512,82
Tube lamp	47000	451,92	451,92	451,92	451,92	451,92	451,92	451,92
Asahi cloth	18000	173,08	173,08	173,08	173,08	173,08	173,08	173,08
Variable cost								
Fish feed	11000	2546,17	3942,40	2079,00	3627,91	4400,00	3069,00	3092,00
Electricity	1444,7	13695,76	13695,76	11892,77	10921,93	11615,39	11615,39	10921,93
Fish	19000	6000,20	8763,37	15038,50	6093,30	10352,72	18483,20	6591,00
Coarse salt	5000	800,00	800,00	800,00	800,00	800,00	800,00	800,00
Total production cost		24654,31	28813,71	31422,45	23042,50	28767,47	35566,95	23004,00
Income								
Catfish	22000	10147,06	17413,00	20086,00	11987,36	21401,60	25539,80	13619,00
Product <i>A. platensis</i> flour	500	10500,00	9675,00	7800,00	11250,00	10200,00	10050,00	10500,00

Total income	20647,06	27088,00	27886,00	23237,36	31601,60	35589,80	24119,
Profit	-4007,25	-1725,71	-3536,45	194,86	2834,13	22,85	1114,
R/C	0,84	0,94	0,89	1,01	1,10	1,00	1,
ROI	-16,25	-5,99	-11,25	0,85	9,85	0,06	4,

Table 6
Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{0.05=0.069})	Mean of ROI value (HSD _{0.05=6.882})	Feed Conversion Ratio (FCR) in Catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Srivijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [in Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Ación F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Morais E. G., de Morais

- M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresource technology*, 256:86- 94.
- de Moraes, L.B.S., Mota, G.C.P., da Silva Farias, R., Marinho, Y.F., Silva, L.O.B. and Gálvez, A.O., 2021. Growth and nitrogen uptake by *Arthrospira platensis* cultured in aquaculture wastewater from Nile tilapia reared in biofloc system. *Acta Scientiarum. Biological Sciences*, 43:e57549-e57549.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. *Bioma*. 10(1):19-22 [in Indonesian].
<https://kkp.go.id/djpb/artikel/26634-kkp-gerakkan-perikanan-budidaya-jadi-penopang-ketahanan-pangan-dan-pembangunan-ekonomi-daerah-di-tengah-pandemi>.
 Accessed at December 2022.
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Españeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? *Reviews in Aquaculture*, 12(3):1579-1594.
- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. *Jurnal Teknologi Kimia dan Industri*, 2(2):192-197 [in Indonesian].
- Naidoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16):6218-6230.
- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C., Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3):14-20.
- Oktafiani, M. and Hermana, J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. *Jurnal Teknik ITS*, 2(2): D57-D62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. *Jurnal Akuakultur Rawa Indonesia*, 5(1):83-96 [in Indonesian].
- Tabarzad M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of

- action. *Molecular biology reports*, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1):44-57.
- Vonshak A., 2002 *Spirulina platensis (Arthrospira)*: Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.
- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [in Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.
- *** Antara, 2021 [<https://www.antaraneews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, Accessed on 18 January 2021 19:41WIB] [in Indonesian].

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX December 2022.

Authors:

Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id
Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: yohanesst256@gmail.com

Tanbiyaskur Tanbiyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: tanbiyaskur@unsri.ac.id
Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: dadejubaedah@fp.unsri.ac.id
Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mohamadamin@fp.unsri.ac.id
Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: fitranimirna@gmail.com
Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; e-mail: gofarnuni@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanbiyaskur T., Jubaedah D., Amin M., Fitriani M., Gofar N., 2022 Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period. *AAFL Bioflux*15(6):xxxx-xxxx.

Bukti konfirmasi review dan hasil review kedua (19 Desember 2022)



munzan.g@gmail.com
19 Dec 2022, 15:27

Dear Dr. Marini Wijayanti,
I provided a list of the issues, but you did not answer to all my requests. Also, please answer in a mail, not by sending a modified manuscript, because it was incredibly hard to track your changes.
Please answer to the following issues. Highlighted in red in the manuscript.

- Material and Method**, You did not tell me when the study took place. Tell me the time interval in which your study took place, so I can add the information to the manuscript.
- Y-axis label**, Tell me what every variable means, so I can complete the "where" section.
- Table 3**, The information from the text still does not match the information from the table. Please tell me what to modify and how, the table contents or the text information. Diligently check the values, please.

Let me know if you have any questions or if other modifications are needed.

Batu lampiran • Ditinjau dengan Gmail

FINAL PROPOSAL.pdf

Dear Dr. George Marlon,
We are sorry about the mistakes. We hope this arrangement is as it should be.
Revision and footer of Final Project Quotation:
1. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan. Please offer a citation and reference for this.



Marini Wijayanti
19 Dec 2022, 03:26

Dear Dr. George Marlon,
We are sorry about the mistakes. We hope this arrangement is as it should be.

Revision and footer of Final Project Quotation:

- The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan. Please offer a citation and reference for this.
The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan. "Sustainable Aquaculture: It is expected that it can support food security and improve economic development until the year 2030." (Ministry of Maritime Affairs and Fisheries, 2021). <https://www.kkp.go.id/>
- Dear 2024 address. Are you sure this is not 2024? I read it twice as 2024.
We modified the year "Introduction of 2024"
- Material and Method**, Please tell me when the experiments took place, so I can complete it for you.
Introduction and Method. This study was conducted from April-December 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indonesia. (George Marlon, 2022).
- Graphical Abstract (GA)**. This abstract and reference are aligned under the header & reference 2022. Please clarify the text under "Introduction & reference 2022".
References: Marlon, G. and Marlon, G., 2022. Effect of substrate composition and bacterial concentration on algae productivity in a batch process bio-reactor system. *Journal of Marine Science and Technology*, 3(2), 302-307 (2022).
- The Y-axis label (Table 2). Please provide details.
The y-axis label is "Y-axis label: effect of substrate composition on algae productivity".
- Red sentence from abstract section (Table)**. Please explain (English).
red sentence and explanation of phytoplankton yield. The first sentence of a paragraph was taken as 100% after taking through the exponential phase. The method of phytoplankton counts followed previous study (Wijayanti et al. 2022). The abundance of the particular bacterium was measured using a spectrophotometer at a wavelength of 620 nm and 630 nm for measuring phytoplankton yield of 2021 and 2022. (Wijayanti et al. 2022) and (Wijayanti et al. 2022) "The effect of substrate composition and bacterial concentration on algae productivity in a batch process bio-reactor system".
- Text after Table 3**. Are you sure the values from text in table are correct? Because they do not relate actually.
Maximum density of *A. pinnatus* (2.1 x 10⁹) in treatment allowing and in *A. pinnatus* culture stock from control experiment

Treatment of starting media	Group of cycle			The effect of treatment (%)
	1	2	3	
T1	11.68	8.85	0.52	11.68 ± 0.14
T2	11.68	8.88	0.57	11.68 ± 0.27
T3	9.82	8.88	0.61	11.68 ± 0.40
Mean	11.03 ± 0.88	8.87 ± 0.12	0.54 ± 0.08	

Based on Table 3, the highest density of *A. pinnatus* was seen in replicate 1 (11.68 x 10⁹ cells) with a treatment of 0.50 ± 0.14 and after that, it decreased gradually to be 8.88 (1.1), to 0.61 (1.1).



Marini Wijayanti
19 Dec 2022, 03:26

7. Text after Table 3. Are you sure the values from text in table are correct? Because they do not relate actually.
Maximum density of *A. pinnatus* (2.1 x 10⁹) in treatment allowing and in *A. pinnatus* culture stock from control experiment

Treatment of starting media	Group of cycle			The effect of treatment (%)
	1	2	3	
T1	11.68	8.85	0.52	11.68 ± 0.14
T2	11.68	8.88	0.57	11.68 ± 0.27
T3	9.82	8.88	0.61	11.68 ± 0.40
Mean	11.03 ± 0.88	8.87 ± 0.12	0.54 ± 0.08	

Based on Table 3, the highest density of *A. pinnatus* was seen in replicate 1 (11.68 x 10⁹ cells) with a treatment of 0.50 ± 0.14 and after that, it decreased gradually to be 8.88 (1.1), to 0.61 (1.1).

8. Text after Table 3. Are you sure the values from text in table are correct? Because they do not relate actually.
The specific growth rate of *A. pinnatus* (day⁻¹) in treatment allowing and in *A. pinnatus* culture stock from control experiment:

Treatment of starting media	Group of cycle			The effect of treatment (%)
	1	2	3	
T1	0.2634	0.2499	0.2211	0.2634 ± 0.0086
T2	0.2634	0.2499	0.2211	0.2634 ± 0.0086
T3	0.2634	0.2499	0.2211	0.2634 ± 0.0086
Mean	0.2634 ± 0.0086	0.2499 ± 0.0086	0.2211 ± 0.0086	0.2634 ± 0.0086

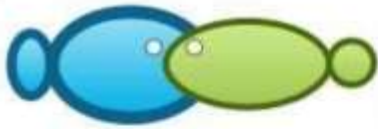
Based on the results in Table 3, the treatment allowed gave the best specific growth rate values of 0.2634/day per day. The 13 hours of starting gave the lowest growth rate value of 0.2211/day per day.

9. **REF: M. W. H. for citation updated?**
This is to update citation updates
The study of a procedure to production of bio-fertilizer (phytoplankton culture) based on *Spirulina maxima* sp. var *natans* (the algae), such as Nitrate Nitrogen uptake of 90%, 90% of total ammonia Nitrogen and 50% of Nitrate Nitrogen in total (100 hours at 100%).

10. **TAH: Explain abbreviation.**
TAH is Total Ammonia Nitrogen

11. **MSD: M. W. H. for citation?**
MSD: M. W. H. for citation

12. **de Marlon et al. (2021)**. Reference list to the reference list. Please provide a reference, so I can add it to the reference list.
Thank you. We look forward to the reference.



Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period

¹Marini Wijayanti, ¹Tanbiyaskur Tanbiyaskur, ¹Yohanes Setiawan,
¹Dade Jubaedah, ¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia. Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: *A. platensis*, b/c ratio, *Clarias* catfish rearing, raceway.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's tagline "Mobilizing aquaculture, it is believed that it can support food security and regional economic development amid the Covid-19 Pandemic" (<https://kkp.go.id/djpb>, 2022), which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara, 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors

through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabar zad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2019; Widyanoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density was of 0.90 ± 0.02 g L⁻¹, biomass productivity of 0.009 ± 0.001 g L⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of *Spirulina* in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method. This study was conducted from April to November 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation

methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias* catfish- *Arthrospira* culture.



Figure 1. Design of Integrated *Clarias* catfish - *Arthrospira* culture in this study.

Preparation of *Arthrospira* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am – 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

***Arthrospira platensis* daily growth rate.** The daily growth rate (μ) of *A. platensis* can be calculated using the Vonshak formula $\mu = ((\ln N_t - \ln N_0)/t) \times 100\%$, N_t is biomass concentration at t days culture, N_0 is initial biomass at 0 day culture (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken at 0.04 g after passing through the exponential phase (harvest) for preparing phycocyanin extraction. The method of phycocyanin extraction followed previous studies (Wijayanti et al 2020). The absorbance of the extracted supernatant was measured using a spectrophotometer at a wavelength of 615 nm and 652 nm for determining phycocyanin yield with Bennett & Bogorard formulas : C-phycocyanin (mg mL^{-1}) = $((OD\ 615) - 0.474 (OD\ 652))/5.34$; and Phycocyanin yield (mg g^{-1}) = (C-phycocyanin x Solvent volume)/Dried Biomass (Bennett & Bogorad 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$R/C\ Ratio = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

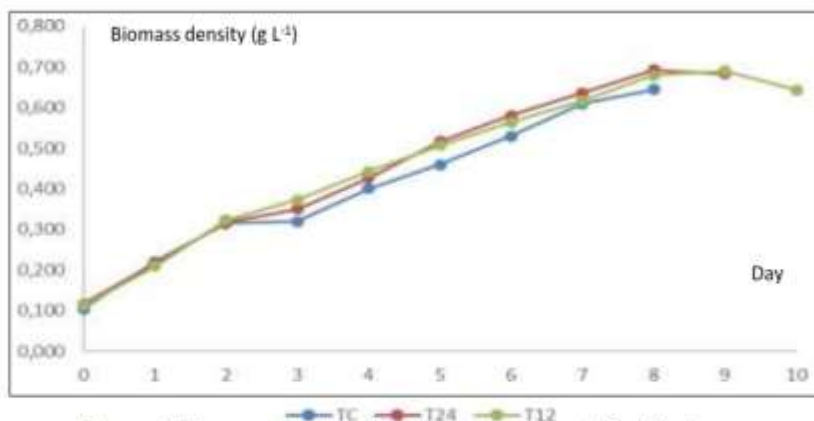


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was $0.645\ \text{g L}^{-1}$ on day 8, in treatment T24 it reached $0.693\ \text{g L}^{-1}$ on day 8, in treatment T12 it reached $0.690\ \text{g L}^{-1}$ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of $0.693\ \text{g L}^{-1}$ and T12 with an average biomass of $0.690\ \text{g L}^{-1}$, while the lowest density was in the TC treatment, $0.645\ \text{g L}^{-1}$.

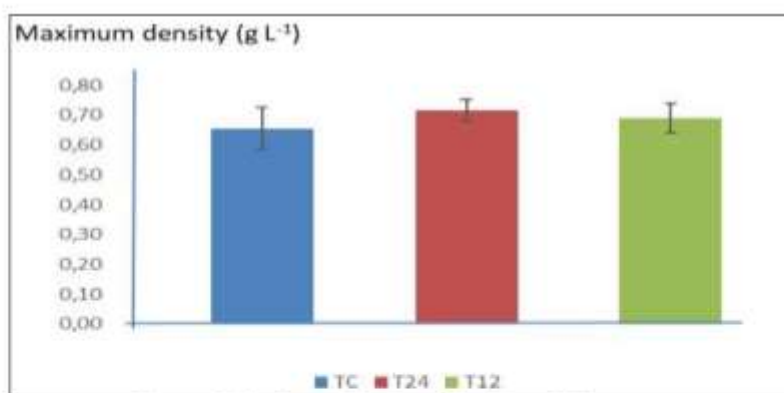


Figure 2. Maximum density of *A. platensis* biomass.

Table 1

Maximum density of *A. platensis* (g L⁻¹) in treatment stirring on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66 ± 0.14
T24	0.80	0.68	0.67	0.72 ± 0.07
T12	0.80	0.66	0.61	0.69 ± 0.10
Mean	0.80 ± 0.00	0.66 ± 0.02	0.60 ± 0.08	

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 (first culture cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.66 g L⁻¹, 0.60 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

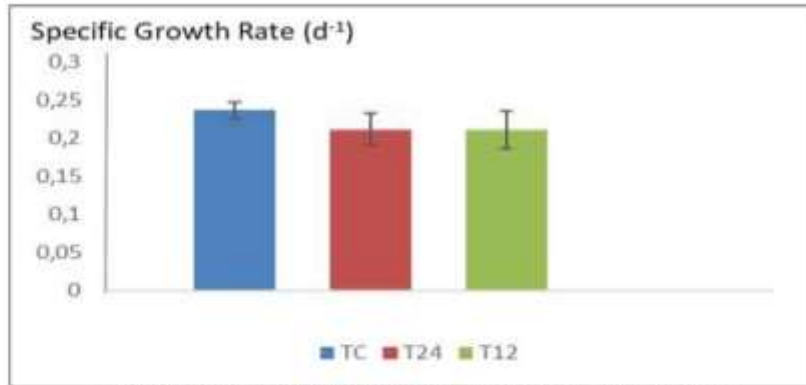


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate of *A. platensis* (%.day⁻¹) in treatment stirring and on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	22.69	22.19	23.63 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82
Mean	25.99±0.00	20.98±1.71	18.92±2.98	

Based on the results in Table 2, the treatment control gave the best specific growth rate value of 23.63% per day. The 12 hours stirring gave the lowest growth rate value of 21.11% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content in *A. platensis* culture media

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in biofloc system media can remove the nitrogen, such as Nitrate Nitrogen uptake of 99%, 80% of Total Ammonia Nitrogen and 90% of Nitrite Nitrogen for 10 days (de Moraes et al 2021). Ammonia can remove 87.77 ± 1.01% by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2019). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that

the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Business analysis has been shown in Table 5 and Table 6.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is efficient and profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient or harmful. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, then the business is efficient and profitable, ROI = 0, then the farm is break-even, and ROI is negative, so it is not efficient or detrimental.

The results of the Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. But, treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5
Components of production costs and revenues to calculate Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems

Components	Value (IDR)	Value (IDR) per cycle						
		TC			T24			
		G1	G2	G3	G1	G2	G3	G1
Production cost								
Investment cost								
Dynamo	18000	0,00	0,00	0,00	173,08	173,08	173,08	173,
Pinwheel	30000	0,00	0,00	0,00	288,46	288,46	288,46	288,
Aerator	37000	474,36	474,36	474,36	0,00	0,00	0,00	0,
Container	80000	512,82	512,82	512,82	512,82	512,82	512,82	512,
Tube lamp	47000	451,92	451,92	451,92	451,92	451,92	451,92	451,
Asahi cloth	18000	173,08	173,08	173,08	173,08	173,08	173,08	173,
Variable cost								
Fish feed	11000	2546,17	3942,40	2079,00	3627,91	4400,00	3069,00	3092,
Electricity	1444,7	13695,76	13695,76	11892,77	10921,93	11615,39	11615,39	10921,
Fish	19000	6000,20	8763,37	15038,50	6093,30	10352,72	18483,20	6591,
Coarse salt	5000	800,00	800,00	800,00	800,00	800,00	800,00	800,
Total production cost		24654,31	28813,71	31422,45	23042,50	28767,47	35566,95	23004,
Income								
Catfish	22000	10147,06	17413,00	20086,00	11987,36	21401,60	25539,80	13619,
Product <i>A. platensis</i> flour	500	10500,00	9675,00	7800,00	11250,00	10200,00	10050,00	10500,

Total income	20647,06	27088,00	27886,00	23237,36	31601,60	35589,80	24119
Profit	-4007,25	-1725,71	-3536,45	194,86	2834,13	22,85	1114
R/C	0,84	0,94	0,89	1,01	1,10	1,00	1
ROI	-16,25	-5,99	-11,25	0,85	9,85	0,06	4

Table 6
Revenue Cost Ratio (R/C) and Return of Investment (ROI) in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{0.05-0.069})	Mean of ROI value (HSD _{0.05-6.882})	Feed Conversion Ratio (FCR) in Catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Srivijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [in Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Acién F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Moraes E. G., de Moraes

- M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresource technology*, 256:86- 94.
- de Moraes, L.B.S., Mota, G.C.P., da Silva Farias, R., Marinho, Y.F., Silva, L.O.B. and Gálvez, A.O., 2021. Growth and nitrogen uptake by *Arthrospira platensis* cultured in aquaculture wastewater from Nile tilapia reared in biofloc system. *Acta Scientiarum. Biological Sciences*, 43:e57549-e57549.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. *Bioma*. 10(1):19-22 [in Indonesian].
<https://kkp.go.id/djpb/artikel/26634-kkp-gerakkan-perikanan-budidaya-jadi-penopang-ketahanan-pangan-dan-pembangunan-ekonomi-daerah-di-tengah-pandemi>.
 Accessed at December 2022.
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Espiñeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? *Reviews in Aquaculture*, 12(3):1579-1594.
- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. *Jurnal Teknologi Kimia dan Industri*, 2(2):192-197 [in Indonesian].
- Naidoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16):6218-6230.
- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C, Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3):14-20.
- Oktafiani, M. and Hermana, J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. *Jurnal Teknik ITS*, 2(2): D57-D62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. *Jurnal Akuakultur Rawa Indonesia*, 5(1):83-96 [in Indonesian].
- Tabarzad M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of

- action. *Molecular biology reports*, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1):44-57.
- Vonshak A., 2002 *Spirulina platensis* (*Arthrospira*): Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.
- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [in Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.
- *** Antara, 2021 [<https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, Accessed on 18 January 2021 19:41WIB] [in Indonesian].

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX December 2022.

Authors:

Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id
 Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: yohanesst256@gmail.com

Tanbiyaskur Tanbiyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: tanbiyaskur@unsri.ac.id
 Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: dadejubaedah@fp.unsri.ac.id
 Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mohamadamin@fp.unsri.ac.id
 Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: fitranimirna@gmail.com
 Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; e-mail: gofarnuni@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanbiyaskur T., Jubaedah D., Amin M., Fitriani M., Gofar N., 2022 Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period. *AAFL Bioflux*15(6):XXXX-XXXX.



muntean.gc@gmail.com

Kepada siapa

Inggris Indonesia Terjemahkan pesan

Dear Dr. Maimi Wijayanti,

I conducted the necessary changes to your manuscript. Please check again that everything is in order and I am looking forward to your final approval to publish the manuscript.

Best regards,

George Murtinan

Editor, BoFux SFL

Visit our journals:

Aquaculture, Aquarium, Conservation & Legislation www.bofux.com/iaac

Advances in Environmental Sciences www.aes.bofux.com/aj

Human & Veterinary Medicine www.hvm.bofux.com/aj

Advances in Agriculture & Botany www.aab.bofux.com/aj

Animal Biology & Animal Husbandry www.abah.bofux.com/aj

Extreme Life, Biogeology & Astrobiology www.elba.bofux.com/aj

Parasite Research www.parc.bofux.com/aj

Rabbit Genetics www.rg.bofux.com/aj

Pro-Environment Promedia <http://journal.ummat.ac.id/index.php/promedia>

Powchid Research www.pr.bofux.com/aj

From: Maimi Wijayanti <mwiyanti@um.ac.id>

Sent: Monday, December 15, 2021 8:20:34

To: murtinan.gc@gmail.com

Subject: Re: Status of manuscript

Dear Dr. George Murtinan,

We are sorry about the mistakes. We hope the arrangement is as it should be.

Revision and Answer of Final Preview Question:

1. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP slogan. Please offer a citation and reference for this.

The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's slogan "Membangun equifishus. Kita berkolaborasi untuk support food security and regional economic development amid the Covid-19 Pandemic" (<https://kip.go.id/kip>, 2021), which is to drive equifishus by paying attention to environmental sustainability and encouraging community economic recovery (Arifin, 2021).

We added 1) references <https://kip.go.id/kip/index/2021-11-14-gratifikasi-perikanan-hidriks-jadi-penyempul-entahasi-pangan-dan-pembangunan-ekonomi-dan-kehidupan-penduduk>, accessed at December 2021.

2. Your 2016 citation. Are you sure this is not 2019? I find it online as 2019.

We revised the year. ¹⁾Wijayanti et al 2019

3. Material and Method. Please tell me when the experiments took place, so I can mention it in text.

Material and Method This study was conducted from April to November 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia

4. Oktafani & Hermiana 2013. This citation and reference are figured online as Utami & Hermiana 2013. Please clarify.

We had edited "Oktafani & Hermiana 2013" in text

In Reference

Oktafani, M. and Hermiana, J., 2013 Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system. *Jurnal Teknik IT*, 2(2): 567-580 [in Indonesian]

5. The Vitrochloa formosa (Vitrochloa 2002). Please provide formosa.

The study growth rate (μ) of *A. platensis* can be calculated using the Monod-like formula $\mu = \frac{0.46 S_0}{S_0 + 0.02 S_0 + 100 S_0}$ to determine concentration of algae culture. For its initial biomass at 0 day culture (Vitrochloa 2002).

6. First sentence from extraction section. Ughuier. Please rephrase. Improve English.

Isolation and measurement of phytoplankton yield The dry biomass of *A. platensis* was taken at 0.05 g after passing through the experimental phase (bioreactor) for preparing phytoplankton extraction. The method of phytoplankton extraction followed previous studies (Wijayanti et al 2020). The absorption of the extracted supernatant was measured using a spectrophotometer at a wavelength of 670 nm and 752 nm for determining phytoplankton yield with biomass & nitrogen biomass. *C. phytoplankton* (y=0.0001x + 0.000002), *C. phytoplankton* (y=0.0001x + 0.000002) and *Phaeocystis* (y=0.0001x + 0.000002) phytoplankton a bioreactor (Dewanti & Sugandi 1979).

7. Text after Table 1. Are you sure the values from text or table are correct? Because they do not relate entirely.

Maximum density of *A. platensis* ($g \cdot L^{-1}$) in treatment stirring on *A. platensis* culture media from Chlorococcosiderator

Treatment of stirring media	Stage of cycle			The effect of treatment (L)
	I	II	III	
T0	0.80	0.85	0.52	0.50 ± 0.14
T24	0.80	0.60	0.47	0.29 ± 0.07
T12	0.80	0.60	0.51	0.40 ± 0.10
Mean	0.80 ± 0.00	0.68 ± 0.02	0.50 ± 0.09	

Based on Table 3, the highest density of *A. platensis* was seen in replicate 1 (3rd sub-cult cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.50 g L⁻¹, 0.00 g L⁻¹.

8. Text after Table 2. Are you sure the values from text or table are correct? Because they do not relate entirely.

The specific growth rate of *A. platensis* (% day⁻¹) in treatment stirring and on *A. platensis* culture media from Chlorococcosiderator

Treatment of stirring media	Stage of cycle			The effect of treatment (L)
	I	II	III	
T0	25.00	22.00	22.10	25.00 ± 0.00
T24	25.00	19.27	18.22	25.00 ± 0.00

h. Test after Table 2. Are you sure the values from text or table are correct? Because they do not relate entirely.

The specific growth rate of *A. platensis* (% day⁻¹) in treatment stirring and on *A. platensis* culture media from Okara wastewater

Treatment of stirring media	Stage of cycle			The effect of treatment (T)
	1	2	3	
T0	25.00	22.04	22.19	23.07%
T24	25.00	19.21	18.22	21.11%
T12	25.00	20.97	18.39	21.11%
Mean	25.00 ± 0.00	20.74 ± 1.71	18.22 ± 0.88	↓

Based on the results in table 2, the treatment control gave the best specific growth rate value of 23.07% per day. The 12 hours of stirring gave the lowest growth rate value of 21.11% per day.

i. NGS-N. N is for nitrogen uptake?

Yes, it is nitrate nitrogen uptake

The study of *A. platensis* in wastewater of Nile Sludge (Treated) in laboratory showed in bioreactor media can remove the nitrogen, such as Nitrate Nitrogen uptake of 80%, 80% of Total Ammonia Nitrogen and 80% of Nitrite Nitrogen for 10 days (Al-Hadidi et al 2021)

ii. TAN. Explain abbreviation

TAN is Total Ammonia Nitrogen

iii. NGS-N. N is for nitrogen?

NGS' N is Nitrate Nitrogen

12. dr Morans et al 2021. Reference not in the reference list. Please provide a reference, so I can add it to the reference list.

Thank you. We had added it in the reference.

dr Morans, L.S.S., 2020, G.D.P., dr Giza Fatma, H., Moshkha, T.T., Silva, L.D.B. and Gilani, S.G., 2021). Growth and nitrogen uptake by *Spirulina platensis* cultured in wastewater from Nile Sludge treated in bioreactor system. *Water Science & Technology*, 83(4), 1349-1354.

13. dr Morans et al 2021. Reference not in the reference list. Please provide a reference, so I can add it to the reference list.

Thank you. I had added it in Reference.

dr Morans, L.S.S., 2021, dr Moshkha, T.T., Morans, L.S.S. and Gilani, S.G., 2021. Growth and nitrogen uptake by *Aeromonas caviae* cultured in wastewater from Nile Sludge treated in bioreactor system. *Arabian Journal of Science and Engineering*, 45(7), 4759-4769.

14. Table 6. Incomplete. Please send me the table in table format, so I can add it to the reference list.

No change in table format, from Excel table. Thank you.

Component	Unit (ID)	Size (ID) per cycle									
		T0	T1	T2	T3	T4	T5	T6	T7	T8	
Production cost											14. Example. Items references in red. Not cited in text. Tell me where is cite. Revised from the reference. Thank you.
Investment cost											15. Double reference in red. Addressed issue in previous point. Revised the citation.
Dryer	1800	5.0	0.0	0.0	173.8	173.8	173.8	173.8	173.8	173.8	16. Status, H. and Verheul, L. (2012) Effect of substrate concentration and hydraulic concentration on algae production in a batch process (reactor system). <i>Water</i> 14(1), 121-127 (in Indonesian).
Filter	3000	5.0	0.0	0.0	28.4	28.4	28.4	28.4	28.4	28.4	17. Author information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.
Acetic	3000	44.5	47.3	47.3	0.0	0.0	0.0	0.0	0.0	0.0	18. No. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.
Control	8000	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	19. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.
Tank	4500	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	20. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.
Agar-agar	1800	173.8	173.8	173.8	173.8	173.8	173.8	173.8	173.8	173.8	21. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.
Variable cost											
Fuel fuel	1100	2542.7	262.4	270.9	272.9	440.0	339.0	330.2	440.0	380.0	
Electricity	1442	1586.76	1586.76	1586.77	1587.01	1592.24	1592.34	1592.35	1592.35	1592.35	
Oil	1800	400.0	380.0	370.0	360.0	350.0	340.0	330.0	320.0	310.0	
Control	300	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	
Total production cost		2484.7	2619.7	2442.4	2342.9	2870.47	2339.4	2264.6	2440.4	2190.3	
Income											
Output	2000	1514.0	1514.0	2098.0	1987.0	2140.0	2020.0	1870.0	2140.0	2120.0	
Product <i>A. platensis</i> for	50	1500.0	870.0	780.0	1100.0	1000.0	1000.0	1000.0	800.0	850.0	
Total income		2064.0	2384.0	2878.0	2227.0	2100.0	2020.0	2170.0	2240.0	2070.0	
Profit		-420.7	-234.7	-364.4	-144.9	-730.47	-339.4	-344.6	-200.4	-120.3	
BC		0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	
ROI		-16.2	-8.6	-15.2	-6.6	-33.6	-14.6	-15.7	-8.2	-5.5	

14. Example. Items references in red. Not cited in text. Tell me where is cite.

Revised from the reference. Thank you.

15. Double reference in red. Addressed issue in previous point.

Revised the citation.

16. Status, H. and Verheul, L. (2012) Effect of substrate concentration and hydraulic concentration on algae production in a batch process (reactor system). *Water* 14(1), 121-127 (in Indonesian).

17. Author information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.

revised

18. No. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.

19. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.

20. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.

21. I have information complete. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.

1. Table 6. Incomplete. Please send me the table in table format, so I can add it to the reference list.

No change in table format, from Excel table. Thank you.

2. Item reference. The reference is not in the reference list. Please provide a reference, so I can add it to the reference list.

Revised from the reference.

The cost of production of *A. platensis* can be calculated using the formula $Y = \frac{C}{Q}$ for 100%, the income is calculated as follows: $Y = \frac{R}{Q}$ for 100%, the profit is calculated as follows: $Y = \frac{R - C}{Q}$ for 100%.

3. Table 7. The information for the table is not in the reference list. Please follow the e-mail addresses of your collaborators, so I can add them to the information complete.

Revised from the reference.

Table 2

Specific growth rate of *A. platensis* (% day⁻¹) in treatment stirring and on *A. platensis* culture media from Okara wastewater

Treatment of stirring media	Stage of cycle			The effect of treatment (T)
	1	2	3	
T0	25.00	22.04	22.19	23.07%
T24	25.00	19.21	18.22	21.11%
T12	25.00	20.97	18.39	21.11%
Mean	25.00 ± 0.00	20.74 ± 1.71	18.22 ± 0.88	↓

Send me the table 2, the income complete for the profit calculation. Thank you.

Thank you for your contribution to our research.

Best regards,
Muthi Wijaya
Researcher Program
Department of Fisheries
Faculty of Agriculture
Universitas Sebelas Maret
South Sumatra, Indonesia

(20 Desember 2022)

Dear Dr. George Horner,

We checked again the accuracy and it still not ok, but for this approval to submit the financials. We added many zero in the Table and we would very much appreciate in the Table and only add. Thank you for your help to submit the manuscript.

Best regards,

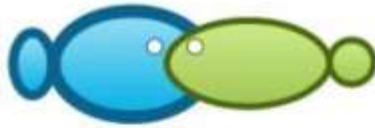
Wawan Wijayanti
 Assistant Program, Department of Finance,
 Faculty of Agriculture, Universitas Sebelas Maret
 South Eastern Indonesia

Dear Dr. George Horner,

Companies	Value (R10)	Value 2019, 2021, 2022			T24			T12			Peer-review Librarianship
		21	22	23	21	22	23	21	22	23	
PROKURSI USA											
Investment bank											
Dyemco	10000	0,00	0,00	0,00	173,00	173,00	173,00	173,00	173,00	173,00	173,00
Powertek	30000	0,00	0,00	0,00	398,40	398,40	398,40	398,40	398,40	398,40	398,40
Indosat	37000	474,30	474,30	474,30	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Caroline	80000	912,00	912,00	912,00	912,00	912,00	912,00	912,00	912,00	912,00	912,00
Toko online	47000	491,00	491,00	491,00	491,00	491,00	491,00	491,00	491,00	491,00	491,00
South bank	10000	173,00	173,00	173,00	173,00	173,00	173,00	173,00	173,00	173,00	173,00
Variable bond											
Fair bank	11000	2340,77	2340,40	2378,00	3027,91	4400,00	3000,00	3002,21	4400,00	3002,00	3002,00
Exoticus	1444,7	13001,70	13000,70	13002,77	10021,00	11010,00	11010,00	10021,00	10021,00	10021,00	10021,00

Selamat malam - Good night everyone!

Wawan Wijayanti



Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period

¹Marini Wijayanti, ¹Yohanes Setiawan, ¹Tanbiyaskur Tanbiyaskur,
¹Dade Jubaedah, ¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia;

² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia.

Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: *A. platensis*, *Clarias* catfish rearing, r/c ratio, raceway.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's tagline "Mobilizing aquaculture, it is believed that it can support food security and regional economic development amid the Covid-19 Pandemic" (KKP 2021), which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the

ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2019; Widyantoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density was of 0.90 ± 0.02 g L⁻¹, biomass productivity of 0.009 ± 0.001 g L⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of *Spirulina* in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method. This study was conducted from April to November 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias catfish*- *Arthrospira* culture.

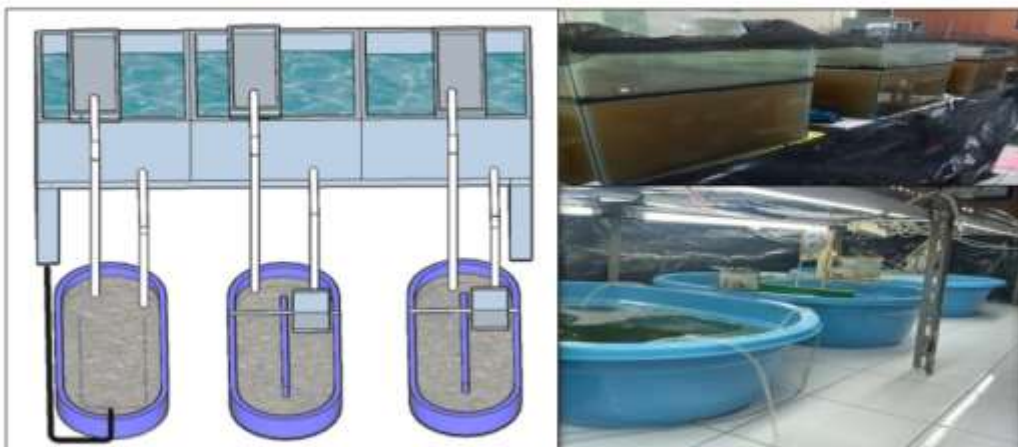


Figure 1. Design of integrated *Clarias catfish* - *Arthrospira* culture in this study.

Preparation of *Arthrospira* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am – 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

Arthrospira platensis daily growth rate. The daily growth rate (μ) of *A. platensis* can be calculated using the Vonshak formula $\mu = ((\ln N_t - \ln N_0)/t) \times 100\%$, where N_t is the biomass concentration at t days culture and N_0 is the initial biomass at 0 day culture (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken at 0.04 g after passing through the exponential phase (harvest) for preparing phycocyanin extraction. The method of phycocyanin extraction followed previous studies (Wijayanti et al 2020). The absorbance of the extracted supernatant was measured using a spectrophotometer at a wavelength of 615 nm and 652 nm for determining phycocyanin yield with Bennett and Bogorard formulas : C-phycocyanin (mg mL⁻¹) = $((OD\ 615) - 0.474 (OD\ 652))/5.34$; and Phycocyanin yield (mg g⁻¹) = (C-phycocyanin x Solvent volume)/Dried Biomass (Bennett & Bogorad 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

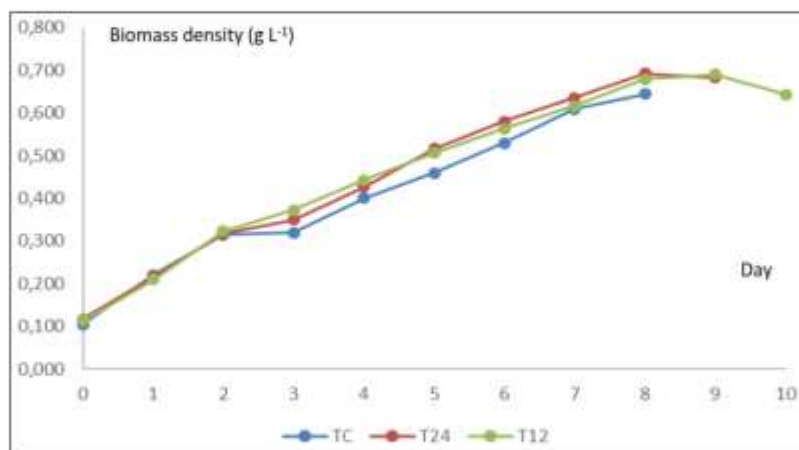


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment, 0.645 g L⁻¹.

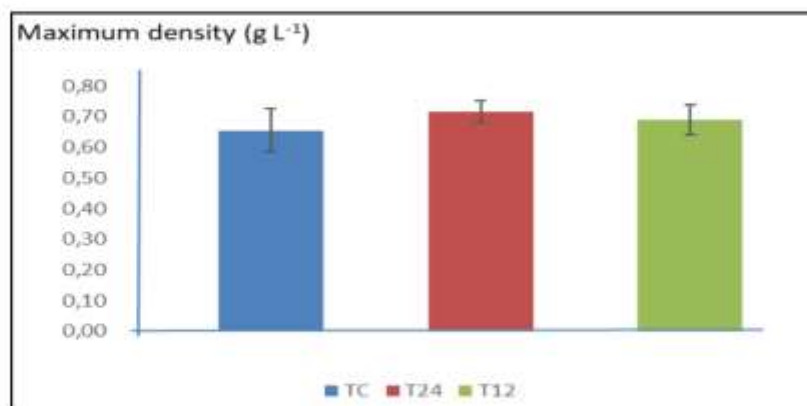


Figure 2. Maximum density (g L⁻¹) of *A. platensis* biomass.

Table 1
Maximum density (g L⁻¹) of *A. platensis* in treatment stirring on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66±0.14
T24	0.80	0.68	0.67	0.72±0.07
T12	0.80	0.66	0.61	0.69±0.10
Mean	0.80±0.00	0.66±0.02	0.60±0.08	

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 (first culture cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.66 g L⁻¹, 0.60 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture

medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

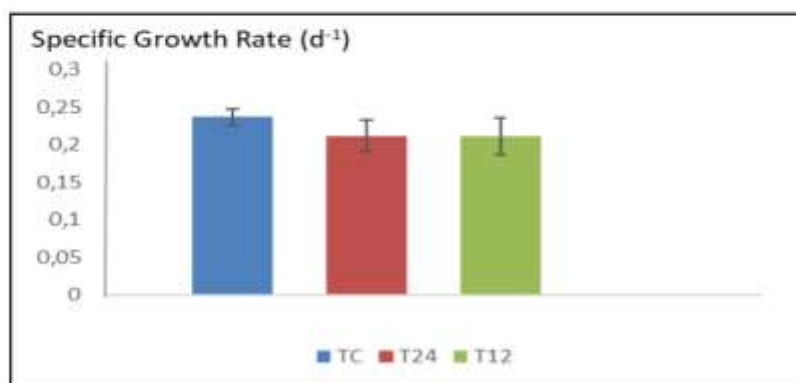


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate (% per day) of *A. platensis* in treatment stirring and on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	22.69	22.19	23.63±2.07
T24	25.99	19.27	18.22	21.16±4.22
T12	25.99	20.97	16.35	21.11±4.82
Mean	25.99±0.00	20.98±1.71	18.92±2.98	

Based on the results in Table 2, the control treatment gave the best specific growth rate value of 23.63% per day. The 12 hours stirring gave the lowest growth rate value of 21.11% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for

increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content (%) in *A. platensis* culture media

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in biofloc system media can remove the nitrogen, such as nitrate nitrogen uptake of 99%, 80% of total ammonia nitrogen (TAN) and 90% of nitrite nitrogen for 10 days (de Moraes et al 2021). Ammonia can remove 87.77 ± 1.01% by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2019). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Table 5 and Table 6 show the business analysis.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, the business is profitable, ROI = 0, then the farm breaks even, and ROI is negative, so it is not efficient.

Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. Treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5
R/C and ROI in *A. platensis* culture integrated with *Clarias* catfish rearing systems

Components	Value (IDR)	Value (IDR) per cycle								
		TC			T24			T12		
		G1	G2	G3	G1	G2	G3	G1	G2	G3
Production cost										
Investment cost										
Dynamo	18000	0.00	0.00	0.00	173.08	173.08	173.08	173.08	173.08	173.08
Pinwheel	30000	0.00	0.00	0.00	288.46	288.46	288.46	288.46	288.46	288.46
Aerator	37000	474.36	474.36	474.36	0.00	0.00	0.00	0.00	0.00	0.00
Container	80000	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82
Tube lamp	47000	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92
Asahi cloth	18000	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08
Variable cost										
Fish feed	11000	2546.17	3942.40	2079.00	3627.91	4400.00	3069.00	3092.21	4400.00	2882.00
Electricity	1444.7	13695.76	13695.76	11892.77	10921.93	11615.39	11615.39	10921.93	10921.93	10921.93
Fish	19000	6000.20	8763.37	15038.30	6093.30	10352.72	18483.20	6591.10	11762.14	19986.10
Coarse salt	5000	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
Total production cost		24654.31	28813.71	31422.45	23042.50	28767.47	35566.95	23004.60	29483.43	36189.39
Income										
Catfish	22000	10147.06	17413.00	20086.00	11987.36	21401.60	25539.80	13619.32	23141.80	27121.60
Product <i>A. platensis</i> flour	500	10500.00	9675.00	7800.00	11250.00	10200.00	10050.00	10500.00	9900.00	9150.00
Total Income		20647.06	27088.00	27886.00	23237.36	31601.60	35589.80	24119.32	33041.80	36271.60
Profit		-4007.25	-1725.71	-3536.45	194.86	2834.13	22.85	1114.72	3558.37	82.21
R/C		0.84	0.94	0.89	1.01	1.10	1.00	1.05	1.12	1.00
ROI		-16.25	-5.76	-11.25	0.85	9.82	0.06	4.85	12.01	0.23

Table 6

R/C and ROI in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	R/C value (HSD _{α0.05} = 0.069)	ROI value (HSD _{α0.05} = 6.882)	Feed Conversion Ratio (FCR) in catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Sriwijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [in Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Acien F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Moraes E. G., de Moraes M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresour Technol*, 256:86-94.
- de Moraes L. B. S., Mota G. C. P., da Silva Farias R., Marinho Y. F., Silva L. O. B., Gálvez A. O., 2021 Growth and nitrogen uptake by *Arthrospira platensis* cultured in

- aquaculture wastewater from Nile tilapia reared in biofloc system. *Acta Scientiarum. Biological Sciences*, 43:e57549-e57549.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. *Bioma*. 10(1):19-22 [in Indonesian].
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Espiñeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? *Reviews in Aquaculture*, 12(3):1579-1594.
- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. *Jurnal Teknologi Kimia dan Industri*, 2(2):192-197 [in Indonesian].
- Naidoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16):6218-6230.
- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C., Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3):14-20.
- Oktafiani M., Hermana J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. *Jurnal Teknik POMITS*, 2(2):D57-D62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. *Jurnal Akuakultur Rawa Indonesia*, 5(1):83-96 [in Indonesian].
- Tabarzad M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. *Molecular biology reports*, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1):44-57.

- Vonshak A., 2002 *Spirulina platensis* (*Arthrospira*): Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.
- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [In Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.
- *** Antara, 2021 [<https://www.antaraneews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, Accessed on 18 January 2021 19:41 WIB] [In Indonesian].
- *** The Ministry of Maritime Affairs and Fisheries (KKP), 2021 <https://kkp.go.id/djpb/artikel/26634-kkp-gerakkan-perikanan-budidaya-jadi-penopang-ketahanan-pangan-dan-pembangunan-ekonomi-daerah-di-tengah-pandemi>. Accessed in December 2022.

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX December 2022.

Authors:

Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id
 Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: yohanesst256@gmail.com
 Tanbiyaskur Tanbiyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: tanbiyaskur@unsri.ac.id
 Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: dadejubaedah@fp.unsri.ac.id
 Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mohamadamin@fp.unsri.ac.id
 Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: fitranimirna@gmail.com
 Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: gofarnuni@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanbiyaskur T., Jubaedah D., Amin M., Fitriani M., Gofar N., 2022 Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period. *AAAL Bioflux* 15(6):XXXX-XXXX.

(21 Desember 2022)

Dear Dr. Murni Widyanti, I'm sorry but in the "off" you sent, I do not see the modification you are about. Please create the modification in the next time.

Dear Dr. Dharma Munir,

We have the modification in the next document and I hope you like it. Thank you for being so helpful.

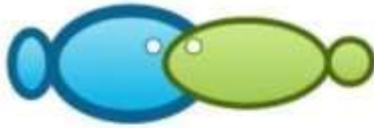
Best regards,
Murni Widyanti

Dear Dr. Dharma Munir,

Components	Value (Rp)	Value Rp/lot per cycle			T14			T12			Pemeriksaan (Rp/lot/lot)
		T1	T2	T3	T1	T2	T3	T1	T2	T3	
Production cost (involvement cost)											
Crystals	10000	0.09	0.08	0.06	173.08	173.08	173.08	173.08	173.08	173.08	173.08
Protein	50000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Amoxicillin	50000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Carbomer	60000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Tube lamp	40000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Water cost	10000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Washing cost	10000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Fun tool	10000	0.09	0.08	0.09	260.45	260.45	260.45	260.45	260.45	260.45	260.45
Electricity	1448.7	13883.78	13883.78	13883.78	3027.81	4490.00	3688.00	3882.21	4490.00	3882.00	3882.00

Subtotal: Rp 13883.78

Dear Murni Widyanti,



Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period

¹Marini Wijayanti, ¹Yohanes Setiawan, ¹Tanbiyaskur Tanbiyaskur, ¹Dade Jubaedah, ¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia. Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: *A. platensis*, *Clarias* catfish rearing, r/c ratio, raceway.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's tagline "Mobilizing aquaculture, it is believed that it can support food security and regional economic development amid the Covid-19 Pandemic" (KKP 2021), which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the

ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2019; Widyantoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density was of 0.90 ± 0.02 gL⁻¹, biomass productivity of 0.009 ± 0.001 gL⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faalj (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of *Spirulina* in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method. This study was conducted from April to November 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias* catfish- *Arthrospira* culture.



Figure 1. Design of integrated *Clarias* catfish - *Arthrospira* culture in this study.

Preparation of *Arthrospira* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am – 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

Arthrospira platensis daily growth rate. The daily growth rate (μ) of *A. platensis* can be calculated using the Vonshak formula $\mu = ((\ln N_t - \ln N_0)/t) \times 100\%$, where N_t is the biomass concentration at t days culture and N_0 is the initial biomass at 0 day culture (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken at 0.04 g after passing through the exponential phase (harvest) for preparing phycocyanin extraction. The method of phycocyanin extraction followed previous studies (Wijayanti et al 2020). The absorbance of the extracted supernatant was measured using a spectrophotometer at a wavelength of 615 nm and 652 nm for determining phycocyanin yield with Bennett and Bogorard formulas : C-phycocyanin (mg mL⁻¹) = $((OD_{615}) - 0.474 (OD_{652}))/5.34$; and Phycocyanin yield (mg g⁻¹) = (C-phycocyanin x Solvent volume)/Dried Biomass (Bennett & Bogorad 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

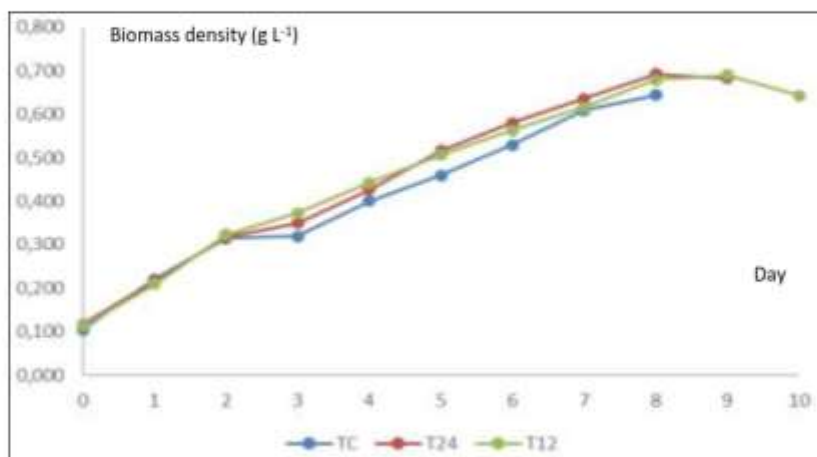


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment, 0.645 g L⁻¹.

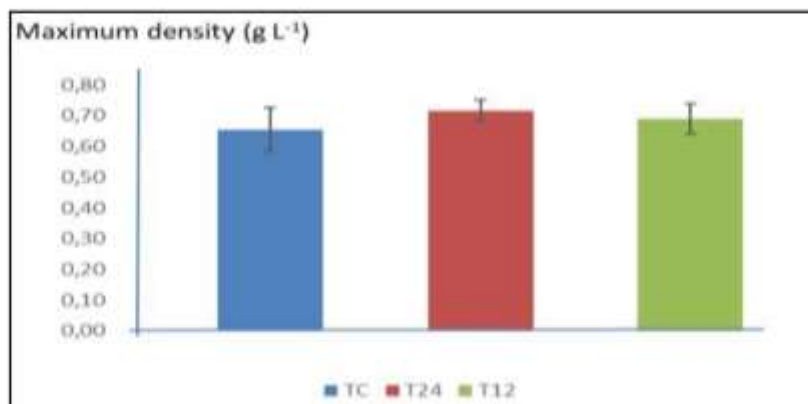


Figure 2. Maximum density of *A. platensis* biomass.

Table 1
Maximum density (g L⁻¹) of *A. platensis* in treatment stirring on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66±0.14
T24	0.80	0.68	0.67	0.72±0.07
T12	0.80	0.66	0.61	0.69±0.10
Mean	0.80±0.00	0.66±0.02	0.60±0.08	

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 (first culture cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.66 g L⁻¹, 0.60 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture

medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

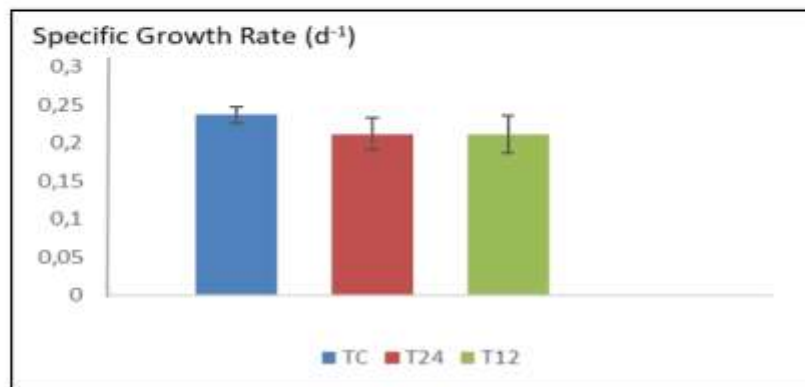


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate (% per day) of *A. platensis* in treatment stirring and on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	22.69	22.19	23.63±2.07
T24	25.99	19.27	18.22	21.16±4.22
T12	25.99	20.97	16.35	21.11±4.82
Mean	25.99±0.00	20.98±1.71	18.92±2.98	

Based on the results in Table 2, the control treatment gave the best specific growth rate value of 23.63% per day. The 12 hours stirring gave the lowest growth rate value of 21.11% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for

increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content (%) in *A. platensis* culture media

Treatment of stirring media	Group of cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in biofloc system media can remove the nitrogen, such as nitrate nitrogen uptake of 99%, 80% of total ammonia nitrogen (TAN) and 90% of nitrite nitrogen for 10 days (de Moraes et al 2021). Ammonia can remove 87.77 ± 1.01% by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2019). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Table 5 and Table 6 show the business analysis.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, the business is profitable, ROI = 0, then the farm breaks even, and ROI is negative, so it is not efficient.

Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. Treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5
R/C and ROI in *A. platensis* culture integrated with *Clarias* catfish rearing systems

Components	Value (IDR)	Value (IDR) per cycle								
		TC			T24			T12		
		G1	G2	G3	G1	G2	G3	G1	G2	G3
Production cost										
Investment cost										
Dynamo	18000	0.00	0.00	0.00	173.08	173.08	173.08	173.08	173.08	173.08
Pinwheel	30000	0.00	0.00	0.00	288.46	288.46	288.46	288.46	288.46	288.46
Aerator	37000	474.36	474.36	474.36	0.00	0.00	0.00	0.00	0.00	0.00
Container	80000	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82	512.82
Tube lamp	47000	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92	451.92
Asahi cloth	18000	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08	173.08
Variable cost										
Fish feed	11000	2546.17	3942.40	2079.00	3627.91	4400.00	3069.00	3092.21	4400.00	2882.00
Electricity	1444.7	13695.76	13695.76	11892.77	10921.93	11615.39	11615.39	10921.93	10921.93	10921.93
Fish	19000	6000.20	8763.37	15038.50	6093.30	10352.72	18483.20	6591.10	11762.14	19986.10
Coarse salt	5000	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
Total production cost		24654.31	28813.71	31422.45	23042.50	28767.47	35566.95	23004.60	29483.43	36189.39
Income										
Catfish	22000	10147.06	17413.00	20086.00	11987.36	21401.60	25539.80	13619.32	23141.80	27121.60
Product <i>A. platensis</i> flour	500	10500.00	9675.00	7800.00	11250.00	10200.00	10050.00	10500.00	9900.00	9150.00
Total income		20647.06	27088.00	27886.00	23237.36	31601.60	35589.80	24119.32	33041.80	36271.60
Profit		-4007.25	-1725.71	-3536.45	194.86	2834.13	22.85	1114.72	3558.37	82.21
R/C		0.84	0.94	0.89	1.01	1.10	1.00	1.05	1.12	1.00
ROI		-16.25	-5.76	-11.25	0.85	9.82	0.06	4.85	12.01	0.23

Table 6

R/C and ROI in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{0.05= 0.069})	Mean of ROI value (HSD _{0.05= 6.882})	Feed Conversion Ratio (FCR) in catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Sriwijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [in Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Acién F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Moraes E. G., de Moraes M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresour Technol*, 256:86-94.
- de Moraes L. B. S., Mota G. C. P., da Silva Farias R., Marinho Y. F., Silva L. O. B., Gálvez A. O., 2021 Growth and nitrogen uptake by *Arthrospira platensis* cultured in aquaculture wastewater from Nile tilapia reared in biofloc system. *Acta Scientiarum*.

- Biological Sciences, 43:e57549-e57549.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. Archives of microbiology, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. Renewable and Sustainable Energy Reviews, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. Bioma. 10(1):19-22 [in Indonesian].
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. Applied Energy, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. Journal of Cellular Biotechnology, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Españeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? Reviews in Aquaculture, 12(3):1579-1594.
- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. Science, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. Jurnal Teknologi Kimia dan Industri, 2(2):192-197 [in Indonesian].
- Naldoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. Journal of Biomolecular Structure and Dynamics, 39(16):6218-6230.
- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C., Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. Int. J. Res. Biosciences, 4(3):14-20.
- Oktafiani M., Hermana J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. Jurnal Teknik POMITS, 2(2):D57-D62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. Reviews in Aquaculture, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. Frontiers in bioengineering and biotechnology, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. Journal of Applied Phycology, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. Jurnal Akuakultur Rawa Indonesia, 5(1):83-96 [in Indonesian].
- Tabarzad M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. Molecular biology reports, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. Bioresource technology, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. Applied Phycology, 1(1):44-57.
- Vonshak A., 2002 *Spirulina platensis* (*Arthrospira*): Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.

- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [In Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.
- *** Antara, 2021 [<https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, Accessed on 18 January 2021 19:41 WIB] [In Indonesian].
- *** The Ministry of Maritime Affairs and Fisheries (KKP), 2021 <https://kkp.go.id/djpb/artikel/26634-kkp-gerakkan-perikanan-budidaya-jadi-penopang-ketahanan-pangan-dan-pembangunan-ekonomi-daerah-di-tengah-pandemi>. Accessed in December 2022.

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX December 2022.

Authors:

Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id

Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: yohanesst256@gmail.com

Tanblyaskur Tanblyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: tanblyaskur@unsri.ac.id

Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: dadejubaedah@fp.unsri.ac.id

Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mohamadamin@fp.unsri.ac.id

Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: fitranimirna@gmail.com

Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: gofarnuni@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanblyaskur, Jubaedah D., Amin M., Fitriani M., Gofar N., 2022 Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period. *AAFL Bioflux* 15(6):XXXX-XXXX.

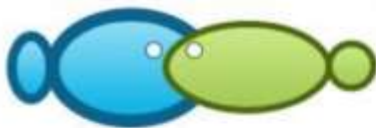
**Bukti konfirmasi submit revisi kedua, respon kepada reviewer, dan artikel yang di resubmit
(22 Desember 2022)**

Martini Wijayanti m.wijayanti@unsw.edu.au
Indonesia martini.wijayanti@gmail.com
Dear Dr. George Warten,
We are sorry if we ask for a revision again. We make highlight our revision in the text or symbols.
We remove Table 5 (a big table), and we change Table 6 become Table 5.
We hope it's not a problem to publish in only this table.
Thank you for your attention and correction. Thank you very much.
Best regards,
Martini Wijayanti
Agribisnis Program
Department of Fisheries
Faculty of Agriculture
Universitas Sebelas Maret

martini.wijayanti@gmail.com
Indonesia martini.wijayanti@gmail.com
Inggris martini.wijayanti@gmail.com Indonesia Inggris Indonesia Inggris
Dear Dr. Martini Wijayanti,

martini.wijayanti@gmail.com
Indonesia martini.wijayanti@gmail.com
Inggris martini.wijayanti@gmail.com Indonesia Inggris Indonesia Inggris
Dear Dr. Martini Wijayanti,
I needed the required modifications. Please check the manuscript. There are still an issue.
1. **Terdapat Terbalik** The author name should be written like this if so, in the How to cite sections, the name should be written Terbalik. Please clarify.
After your amend and final approval, I will publish the manuscript.
Best regards,
George Warten

Martini Wijayanti m.wijayanti@unsw.edu.au
Indonesia martini.wijayanti@gmail.com
Dear Dr. George Warten,
We hope that the author's name could be written like this "Terbalik Terbalik".
How to cite this article: Wijayanti M., Terbalik T., Terbalik T., Adawati D., Anis M., Fikri M., Gula N., 2022 The economic analysis of integrated multi-trophic Clarias variegatus and Arthropoda with different aquaculture period. [DOI: 10.24127/ajae.v1i1.11111](#)



Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period

¹Marini Wijayanti, ¹Yohanes Setiawan, ¹Tanbiyaskur Tanbiyaskur, ¹Dade Jubaedah, ¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia. Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias*-*Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: *A. platensis*, b/c ratio, *Clarias* catfish rearing, raceway.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's tagline "Mobilizing aquaculture, it is believed that it can support food security and regional economic development amid the Covid-19 Pandemic" (KKP 2021), which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the

ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabar zad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* (*Arthrospira*) production as well as fish farming wastewater (Wijayanti et al 2019; Widiantoro et al 2018; Ragaza et al 2020). *Arthrospira* (*Spirulina*) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density was of 0.90 ± 0.02 gL⁻¹, biomass productivity of 0.009 ± 0.001 gL⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira* culture media to make electricity use efficient and maximize the growth of *Spirulina* in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira*.

Material and Method. This study was conducted from April to November 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias* catfish- *Arthrospira* culture.

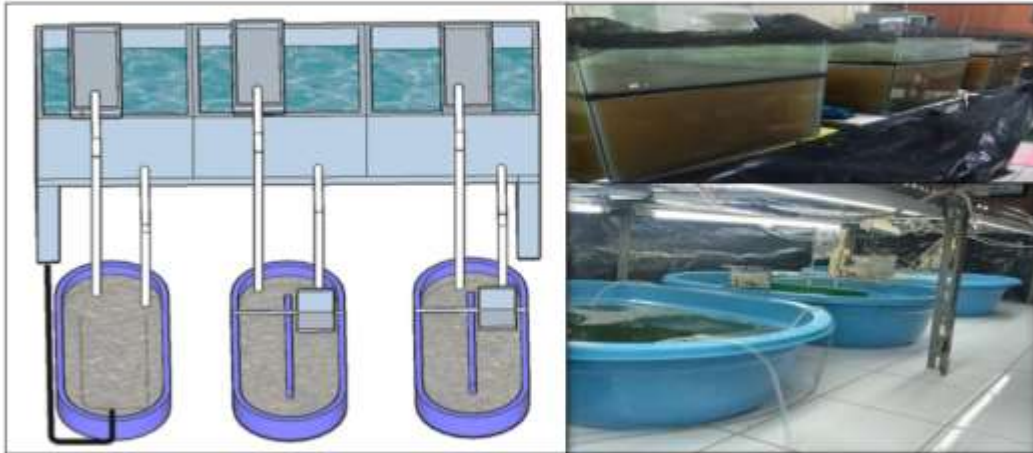


Figure 1. Design of integrated *Clarias* catfish - *Arthrospira* culture in this study.

Preparation of *Arthrospira* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am – 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

Arthrospira platensis daily growth rate. The daily growth rate (μ) of *A. platensis* can be calculated using the Vonshak formula $\mu = ((\ln N_t - \ln N_0)/t) \times 100\%$, where N_t is the biomass concentration at t days culture and N_0 is the initial biomass at 0 day culture (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken at 0.04 g after passing through the exponential phase (harvest) for preparing phycocyanin extraction. The method of phycocyanin extraction followed previous studies (Wijayanti et al 2020). The absorbance of the extracted supernatant was measured using a spectrophotometer at a wavelength of 615 nm and 652 nm for determining phycocyanin yield with Bennett and Bogorard formulas : C-phycocyanin (mg mL⁻¹) = $((OD\ 615) - 0.474 (OD\ 652))/5.34$; and Phycocyanin yield (mg g⁻¹) = (C-phycocyanin x Solvent volume)/Dried Biomass (Bennett & Bogorad 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

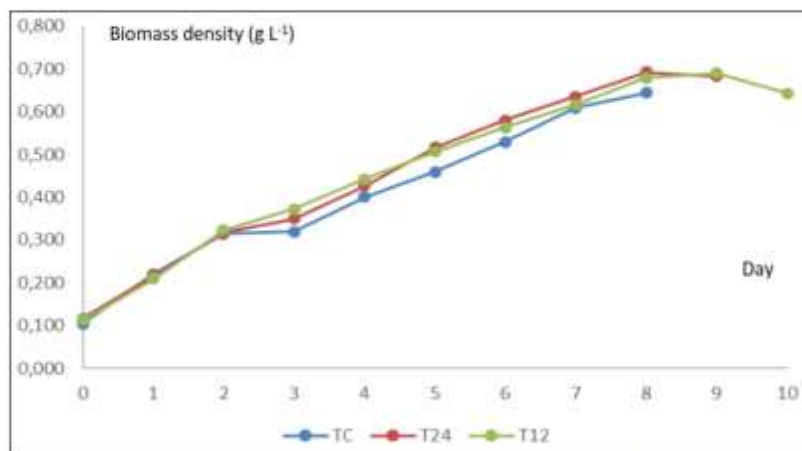


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment, 0.645 g L⁻¹.

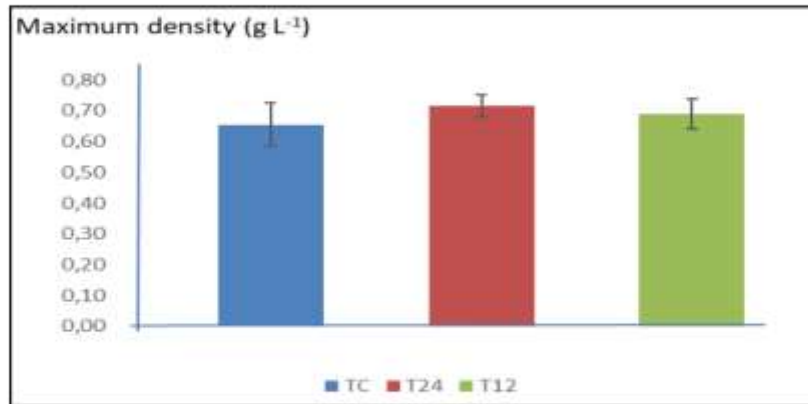


Figure 2. Maximum density of *A. platensis* biomass.

Table 1
Maximum density (g L⁻¹) of *A. platensis* in treatment stirring on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66 ± 0.14
T24	0.80	0.68	0.67	0.72 ± 0.07
T12	0.80	0.66	0.61	0.69 ± 0.10
Mean	0.80 ± 0.00	0.66 ± 0.02	0.60 ± 0.08	

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 (first culture cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.66 g L⁻¹, 0.60 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture

medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

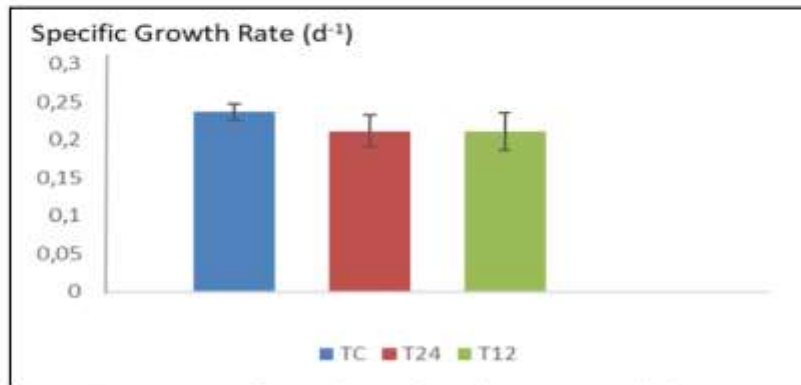


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate (% per day) of *A. platensis* in treatment stirring and on *A. platensis* culture media from *Clarias* waste water

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	22.69	22.19	23.63 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82
Mean	25.99 ± 0.00	20.98 ± 1.71	18.92 ± 2.98	

Based on the results in Table 2, the control treatment gave the best specific growth rate value of 23.63% per day. The 12 hours stirring gave the lowest growth rate value of 21.11% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for

increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content (%) in *A. platensis* culture media

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in biofloc system media can remove the nitrogen, such as nitrate nitrogen uptake of 99%, 80% of total ammonia nitrogen (TAN) and 90% of nitrite nitrogen for 10 days (de Moraes et al 2021). Ammonia can remove 87.77 ± 1.01% by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2019). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Table 5 shows the business analysis.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, the business is profitable, ROI = 0, then the farm breaks even, and ROI is negative, so it is not efficient.

Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. Treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5
R/C and ROI in *A. platensis* culture integrated with *Clarias* catfish rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{0.05} = 0.069)	Mean of ROI value (HSD _{0.05} = 6.882)	Feed Conversion Ratio (FCR) in catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Sriwijaya for funding the research under Competitive Grant II in 2021; 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [In Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Ación F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Moraes E. G., de Moraes M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresour technology*, 256:86-94.
- de Moraes L. B. S., Mota G. C. P., da Silva Farias R., Marinho Y. F., Silva L. O. B., Gálvez A. O., 2021 Growth and nitrogen uptake by *Arthrospira platensis* cultured in aquaculture wastewater from Nile tilapia reared in biofloc system. *Acta Scientiarum. Biological Sciences*, 43:e57549-e57549.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. *Bioma*. 10(1):19-22 [In Indonesian].
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Espifeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? *Reviews in Aquaculture*, 12(3):1579-1594.

- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. *Jurnal Teknologi Kimia dan Industri*, 2(2):192-197 [in Indonesian].
- Naidoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16):6218-6230.
- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C., Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3):14-20.
- Oktafiani M., Hermana J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. *Jurnal Teknik POMITS*, 2(2):D57-D62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. *Jurnal Akuakultur Rawa Indonesia*, 5(1):83-96 [in Indonesian].
- Tabarzdad M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. *Molecular biology reports*, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1):44-57.
- Vonshak A., 2002 *Spirulina platensis (Arthrospira)*: Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.
- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [in Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.

- *** Antara, 2021 [<https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming>, Senin, Accessed on 18 January 2021 19:41 WIB] [in Indonesian].
- *** The Ministry of Maritime Affairs and Fisheries (KKP), 2021 <https://kkp.go.id/djpb/artikel/26634-kkp-gerakkan-perikanan-budidaya-jadi-penopang-ketahanan-pangan-dan-pembangunan-ekonomi-daerah-di-tengah-pandemi>. Accessed in December 2022.

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX December 2022.

Authors:

Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id
Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: yohanesst256@gmail.com
Tanbiyaskur Tanbiyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: tanbiyaskur@unsri.ac.id
Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: dadejubaedah@fp.unsri.ac.id
Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mohamadamin@fp.unsri.ac.id
Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: fitranimirna@gmail.com
Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: gofarnuni@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanbiyaskur, Jubaedah D., Amin M., Fitriani M., Gofar N., 2022 Techno-economic analysis of integrated multitrophic *Clarias* catfish and *Arthrospira* with different agitation period. *AAFL Bioflux* 15(6):xxxx-xxxx.



Re: Status of Manuscript

Dear Dr. George Ntuenyi
Ntuenyi, George Ntuenyi (gntuenyi@uconn.edu)

23 December 2022, 10:59 AM

Hi George,
We have received your article entitled "The Role of 'Stereotype' in the 'Stereotype'".
We are pleased to inform you that your article has been accepted for publication in the Journal of Applied Psychology. The article will appear in the December 2023 issue of the journal. The article will be published online ahead of the print edition. The article will be published in the print edition in the December 2023 issue of the journal. The article will be published in the print edition in the December 2023 issue of the journal. The article will be published in the print edition in the December 2023 issue of the journal.

Best regards,
Dr. George Ntuenyi
Ntuenyi, George Ntuenyi
Department of Psychology
University of Connecticut
Storrs, CT 06269-3043

More info: gntuenyi@uconn.edu

Dr. George Ntuenyi

Department of Psychology

University of Connecticut

Storrs, CT 06269-3043

Phone: 860/405-3400

Fax: 860/405-3401

Web: www.uconn.edu

Journal of Applied Psychology

Volume 103, Number 4, December 2023

Pages 1-10

ISSN: 0021-9010

DOI: 10.1037/a0054444

Copyright © 2023 by the American Psychological Association

0021-9010/23/\$12.00 DOI: 10.1037/a0054444

Published online first on December 23, 2022

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org

For more information, contact the publisher at subscriptions@apa.org




For more information, contact the publisher at subscriptions@apa.org



For more information, contact the publisher at subscriptions@apa.org

Bukti konfirmasi artikel accepted (13 Januari 2023)






Bukti konfirmasi artikel published online (13 Januari 2023)

 **muntean.go@gmail.com** kepada saya 13 Jan 2023, 21:10  

 Inggris  Indonesia Terjemahkan pesan Notifikasi untuk Inggris



Dear Dr. Marini Wijayanti,
I am pleased to announce that the necessary changes have been made and your article has been published and it is now available on our website.
Thank you for publishing with us.

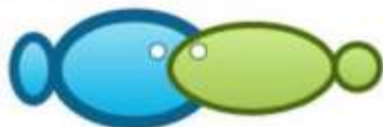
[Pesan dipotong] [Lihat seluruh email](#)

 **Marini Wijayanti** mariniwijayanti@foanet.ac.id 13 Jan 2023, 21:18  

Dear Dr. Muntean,
Thank you for publishing our manuscript.

[Pesan dipotong] [Lihat seluruh email](#)

 Balas  Teruskan



Techno-economic analysis of integrated multitrophic *Clarias gariepinus* and *Arthrospira platensis* with different agitation period

¹Marini Wijayanti, ¹Yohanes Setiawan, ¹Tanbiyaskur Tanbiyaskur, ¹Dade Jubaedah, ¹Mohamad Amin, ¹Mirna Fitriani, ²Nuni Gofar

¹ Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia; ² Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia. Corresponding author: M. Wijayanti, mariniwijayanti@fp.unsri.ac.id

Abstract. *Arthrospira platensis* is a cyanobacteria that contains high levels of protein, fatty acids, minerals, vitamins, amino acids, and phycocyanins. The cultivation of *Arthrospira platensis* is constrained by fertilizers that have relatively high prices, so alternative fertilizers are used, one of which is catfish waste which has sufficient nutrient content for the growth of *A. platensis* which can be integrated as IMTA (Integrated Multi-trophic Aquaculture) *Clarias-Arthrospira*. Cultures of *A. platensis* on a mass scale often use open culture ponds in the form of raceways because they are easy to handle. Raceway pond agitation uses pedals that rotate for 24 hours leading to high electricity usage costs which account for 23% of total production costs. This study aims to determine the efficient stirring time on the growth of microalgae *A. platensis*. This study used 3 treatments with different stirring frequencies, namely treatment 1 stirring for 24 hours (T24), treatment 2 stirring for 12 hours (T12), and control using aeration for 24 hours (TC). After harvesting the biomass, the water from filtration has flowed into the catfish rearing container. Parameters observed were daily density of *A. platensis*, specific growth rate of *A. platensis*, revenue-cost (R/C) ratio, return of investment (ROI) and feed conversion ratio of catfish rearing that was used for *A. platensis* production. The results of the specific growth rate of *A. platensis* in this study were TC 23.625%, T24 21.162%, T12 21.105% per day. The maximum density at TC and T12 was 0.8 g.L⁻¹ on day 10 while at T24 0.8 g.L⁻¹ on day 9. Revenue Cost (R/C) ratio can be reached at TC 0.94, T24 1.09, T12 1.12. The result of catfish rearing used TC, T24, and T12 waste water treatments with *A. platensis* showed that the feed conversion ratio of catfish rearing was 1.38, 1.20, and 1.04 respectively. The stirring using a raceway container for 12 hours produced the best results compared to other treatments.

Key Words: b/c ratio, catfish, raceway, *Spirulina* sp.

Introduction. Aquaculture techno-economics is a complete study to scale up aquaculture business from pilot plant scale to mass scale or industrial scale, to ensure environmental-system stability and economic analysis of the feasibility of aquaculture. The development of fish farming is being intensified as an effort to meet the food needs of the community, especially protein. The Ministry of Maritime Affairs and Fisheries (KKP) launched the 2021 KKP's tagline "Mobilizing aquaculture, it is believed that it can support food security and regional economic development amid the Covid-19 Pandemic" (KKP 2021), which is to drive aquaculture by paying attention to environmental sustainability and encouraging community economic turnover (Antara 2021). The increasingly limited land and water for fish cultivation make the need for zero waste aquaculture technology that is approached with a recirculation system (Ramli et al 2020). The productivity of fish farming pond recirculation systems can be increased by using the IMTA (Integrated Multi-trophic Aquaculture) system. Integrated multi-trophic aquaculture (IMTA) is a production system of aquatic biota in which various species, of different trophic levels, are raised near each other and the by-products (organic and inorganic waste) of one cultured species are recycled to be used as nutrients for other biotas. IMTA can reduce the

ecological impact around aquaculture operations, increase social perceptions of aquaculture, and provide financial benefits to aquaculture actors through product diversification, faster production cycles, and better income on IMTA products (Knowler et al 2020). The concept of fish production and remediation aquaculture commodities such as microalgae and cyanobacteria with high economic value can be an alternative for zero waste swamp aquaculture systems.

Cyanobacteria have been shown to be a rich source of biologically active secondary metabolites including antiviral, anti-inflammatory, immunostimulant agents, and their medicinal and nutraceutical properties (Deyab et al 2019; Tabarzad et al 2020). Tiwari and Tiwari (2020) have summarized and updated therapeutic applications. Cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics", after many studies have shown that these cyanobacteria have immunomodulatory, antitumor-anticancer, antiviral-antiHIV, antibacterial, antimalarial, antidiabetic activities which are specific characters for drug candidates (Naidoo et al 2020). *Arthrospira platensis* which is the only cyanobacteria that is safe for consumption free of toxins can be used to treat wastewater, including waste from fish farming because biomass can metabolize nutrients and remove pollutants from aquaculture waste efficiently (Zhang et al 2019). Treatment of industrial waste and by-products can be used for alternative culture media for *Spirulina* sp. (*Arthrospira platensis*) production as well as fish farming wastewater (Wijayanti et al 2019; Widyanoro et al 2018; Ragaza et al 2020). *Arthrospira platensis* (*Spirulina* sp.) cultivation in fish pond wastewater can have certain characteristics. Their adaptation growing in organic wastewater makes changes in the bioactive and production of important compounds. Phycocyanin is blue pigment in microalgae or cyanobacteria that have functions as antioxidant, source of food coloring, cosmetics, nutraceuticals, pharmaceuticals, and anticancer (Liu et al 2013; Tang et al 2020; Tiwari & Tiwari 2020). *Arthrospira platensis* cultured in catfish culture waste media 100% laboratory-scale bulk system can produce a maximum density of 0.867 grams dry weight per liter, the growth rate of 22.026% day⁻¹ and 11.347 mg g⁻¹ phycocyanin yield and able to reduce nitrogen waste by more than 80% and phosphate by more than 70% (Wijayanti et al 2020).

The design of the cyanobacterial bioreactor influences the important phyto-biochemical content contained in the post-harvest biomass. Determination of the design and culture system that is better and low-cost, will increase the practical and economic feasibility of integrating cyanobacteria in aquaculture recirculation systems, thereby increasing the potential for mass algae cultivation when scaling up this aquaculture recirculating system (Ramli et al 2020). Increasing the scale of production from a closed system to an open system is an important step for the stability of product quality and quantity, the technological and economic feasibility of the IMTA system. The pilot-scale is used for commercial-scale preparation. Open pond bioreactors are often used because they are easy and inexpensive to maintain (Mutiah & Khoirunisa 2013). There are two types of open pond bioreactors, raceway, and circular/central pivot ponds. Circular ponds where mixing is done by agitators or raceway ponds are equipped with a paddle wheel agitation system (Fazal et al 2018). De Jesus et al (2018) showed that 24-hour stirring resulted in a biomass concentration of 1.60 ± 0.04 g L⁻¹, biomass productivity of 0.054 ± 0.003 g L⁻¹ h⁻¹, and a specific growth rate of 0.05 ± 0.002 h⁻¹ on the coast of Bahia in the city of Salvador, Brazil, and in the city of Camaquã, Brazil its yield density was of 0.90 ± 0.02 gL⁻¹, biomass productivity of 0.009 ± 0.001 gL⁻¹ h⁻¹ and specific growth of 0.02 ± 0.001 h⁻¹. However, stirring for 24 hours resulted in the use of high electrical energy.

Jonker and Faaij (2013) concluded the electric energy consumption of stirring is 23% of the total energy demand. The difference in the stirring time of *A. platensis* culture with catfish culture wastewater has never been studied before. Therefore, it is important to study differences in the length of time for stirring *Arthrospira platensis* culture media to make electricity use efficient and maximize the growth of *Spirulina* sp. in catfish culture wastewater media by knowing the highest maximum population density of *Arthrospira platensis*.

Material and Method. This study was conducted from April to November 2021 at the Laboratory of Aquaculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatra, Indonesia. The experimental design used in this study was a Randomized Block Design using 3 treatments of agitation methods: control using 24-hour aeration day⁻¹ (TC), stirring for 24 hours day⁻¹ (T24) and stirring for 12 hours day⁻¹ (T12). The replications of culture time cycling were first culture cycle, second culture cycle, and third culture cycle of integrated *Clarias gariepinus* - *Arthrospira platensis*.

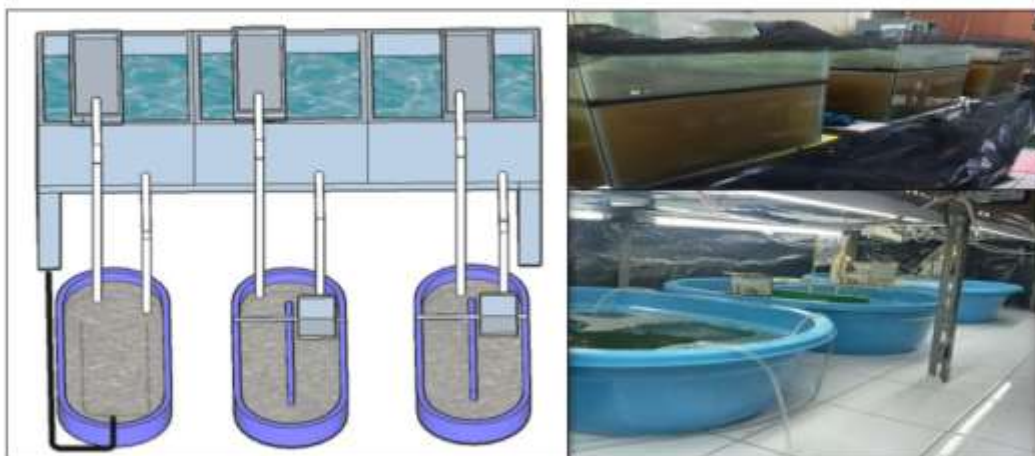


Figure 1. Design of integrated *Clarias gariepinus* - *Arthrospira platensis* culture in this study.

Preparation of *Arthrospira platensis* growing media. Wastewater comes from catfish rearing ponds which are kept for 14 days using a 40 x 40 x 40 cm aquarium. The density of catfish reared is 500 fish/m³ with a size of 12±1 cm with a salinity of 4 ppt (Sitio et al 2017) and a pH of 7.5-8 (Ndubuisi et al 2015). During the maintenance catfish were fed floating pellets with a protein content of 31-33%. Feed is given 2 times a day (morning and evening) at satiation. No water changes are made during fish rearing. After rearing the catfish, the wastewater from catfish farming is taken and filtered using a 30-40 micron cloth to clean the wastewater from dirt and insoluble feed residue.

Culturing and harvesting *Arthrospira platensis*. *A. platensis* used was first cultured as initial stock inoculum (Aquaculture Laboratory culture collection at Sriwijaya University) with a minimum density of ± 1.0 g L⁻¹. Then the *A. platensis* seeds were put into the catfish culture wastewater media, with an initial density of ± 0.1 g L⁻¹. The lighting time with the help of fluorescent lamps is 12 hours (Oktafiani & Hermana 2013; Budiardi et al 2010). Agitation was carried out using a mill with a speed of 5-6 rpm. The control had aeration using an aerator for 24 hours, treatment 1 was stirred for 24 hours, while in treatment 2 the stirring was for 12 hours (06:00 am – 6:00 pm).

When *A. platensis* has passed the peak phase of maximum density or exponential phase, harvesting of *A. platensis* is carried out using a cloth filter measuring 30-40 microns (Wijayanti et al 2020). *A. platensis* was filtered with a cloth then weighed for the wet weight and then put into a porcelain crucible, then dried in an oven at 40°C for 18 hours (Afriani et al 2018 modification), then mashed in a mortar.

Daily density measurement. In this study, the initial density of *A. platensis* was measured using 1 milliliter of *A. platensis* culture samples in each treatment with 3 replications. The 1 milliliter water sample was put into a pre-weighed aluminum foil bowl. The wet samples were then dried in an oven at 40°C for 18 hours. The dried water sample after the oven treatment was reweighed to obtain dry weight biomass. The dry weight of *A. platensis* biomass was then converted to g L⁻¹. Measurement of the density of *A. platensis* was carried out in each treatment every day at the same hour.

Arthrospira platensis daily growth rate. The daily growth rate (μ) of *A. platensis* can be calculated using the Vonshak formula $\mu = ((\ln N_t - \ln N_0)/t) \times 100\%$, where N_t is the biomass concentration at t days culture and N_0 is the initial biomass at 0 day culture (Vonshak 2002).

Extraction and measurement of phycocyanin yield. The dry biomass of *A. platensis* was taken at 0.04 g after passing through the exponential phase (harvest) for preparing phycocyanin extraction. The method of phycocyanin extraction followed previous studies (Wijayanti et al 2020). The absorbance of the extracted supernatant was measured using a spectrophotometer at a wavelength of 615 nm and 652 nm for determining phycocyanin yield with Bennett and Bogorard formulas : C-phycocyanin (mg mL⁻¹) = $((OD\ 615) - 0.474 (OD\ 652))/5.34$; and Phycocyanin yield (mg g⁻¹) = (C-phycocyanin x Solvent volume)/Dried Biomass (Bennett & Bogorad 1973).

Reduction of total nitrogen content. Reduction of total nitrogen content in the media was carried out at the beginning and end of the study (1 day after the peak phase in each treatment).

Business analysis. Profit calculation is done by R/C Ratio and ROI, which is calculating the selling price of catfish and *A. platensis* dry biomass divided by production costs including feed costs, electricity usage for biomass production, and drying time for one production cycle in each treatment.

$$RCR = \frac{\text{Total Revenue}}{\text{Total Production Costs}}$$

$$ROI = \frac{\text{Total Profit} \times 100\%}{\text{Total Production Costs}}$$

Statistical analysis. The values of maximum density, growth rate, phycocyanin yield, benefit-cost ratio, reduction in total nitrogen content of each treatment medium were analyzed for variance (ANOVA). If it was significantly different, then the analysis was continued using the Honest Significant Difference test. The density of *A. platensis* is presented in graphical form. Specific growth rate data, phycocyanin yield, reduction of total nitrogen, R/C ratio, ROI, and FCR are presented in tabular form.

Results and Discussion

Density of *A. platensis*. The daily density of *A. platensis* for each culture treatment have been shown in Figure 1. The time of achieving the highest density of *A. platensis* in each treatment was eight days after cultivation start.

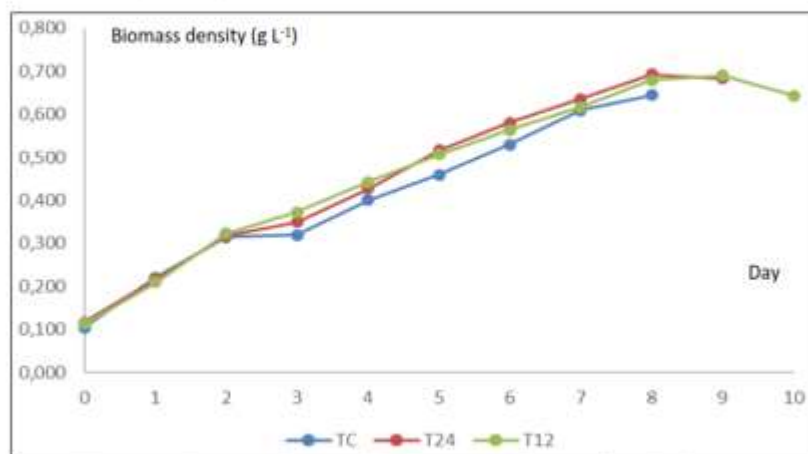


Figure 1. Biomass density of *Arthrospira platensis* for 10 days.

The maximum density in treatment TC was 0.645 g L⁻¹ on day 8, in treatment T24 it reached 0.693 g L⁻¹ on day 8, in treatment T12 it reached 0.690 g L⁻¹ on day 9. The maximum density of *A. platensis* on treatments have been shown in Figure 2. It can be seen that the highest density of *A. platensis* was in the T24 treatment with a biomass of 0.693 g L⁻¹ and T12 with an average biomass of 0.690 g L⁻¹, while the lowest density was in the TC treatment, 0.645 g L⁻¹.

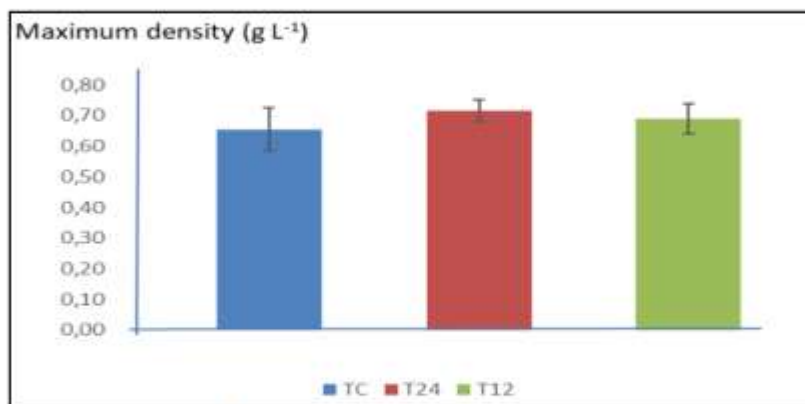


Figure 2. Maximum density of *A. platensis* biomass.

Table 1

Maximum density (g L⁻¹) of *A. platensis* in treatment stirring on *A. platensis* culture media from *Clarias gariepinus* waste water

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	0.80	0.65	0.52	0.66 ± 0.14
T24	0.80	0.68	0.67	0.72 ± 0.07
T12	0.80	0.66	0.61	0.69 ± 0.10
Mean	0.80 ± 0.00	0.66 ± 0.02	0.60 ± 0.08	

Based on Table 1, the highest density of *A. platensis* was seen in replicate 1 (first culture cycle) with a biomass of 0.80 g L⁻¹ and after that, it decreased gradually to 0.66 g L⁻¹, 0.60 g L⁻¹. The high and low density of *A. platensis* was determined by the nutrients that were still present in the cultivation medium. The N ratio affects the growth of microalgae and the level of light intensity that enters the media. The maintenance of *A. platensis* describes the growth phase from the first day to the 10th day slowly, because of cells adapting to the new environmental conditions. All treatments had an average increase on day 8. This explains that the growth of *A. platensis* cells undergo division. The existence of cell division causes the growth of *A. platensis* to run quickly because the growth medium of *A. platensis* is rich in nutrients that are needed for its growth. On day 8 the maximum density of *A. platensis* culture was reached. After the 8th day, all treatments experienced a decline (death) phase on average. This is caused the number of nutrients in the media had decreased. However, *A. platensis* cells were still able to divide but the number was not as large as in the growth phase.

According to Budiardi et al (2010), the death phase is due to limited nutrition and light supply, old cell age, environmental factors that are no longer supportive, and contamination by other microorganisms. According to Haryati (2008), the decrease in growth of *A. platensis* occurs due to reduced nutrients caused by the increase in *A. platensis* biomass, as a result, biomass needs to compete for nutrients in the culture

medium. In addition, the denser the biomass results in the reduced intensity of light entering the culture media so that it can interfere with the biomass to carry out photosynthesis. The pinwheel and aeration aid in the agitation of the medium containing nutrients and algae so that all cells are thoroughly exposed to the nutrients and light supplied. In addition, the agitation caused by the velocity of the bubbles produced was not good because not all parts of the cells were exposed to the nutrients from the medium. High bubbles aeration can also give less than optimal results on biomass density in the *Arthrospira platensis* culture (Jung et al 2019)

Specific growth rate. The specific growth rate describes the rate of growth of algal cells per unit time which can be used as a benchmark to determine the carrying capacity of the media on algae growth (Santosa 2010). The value of the specific growth rate of *A. platensis* for each treatment is shown in Table 2 and Figure 3.

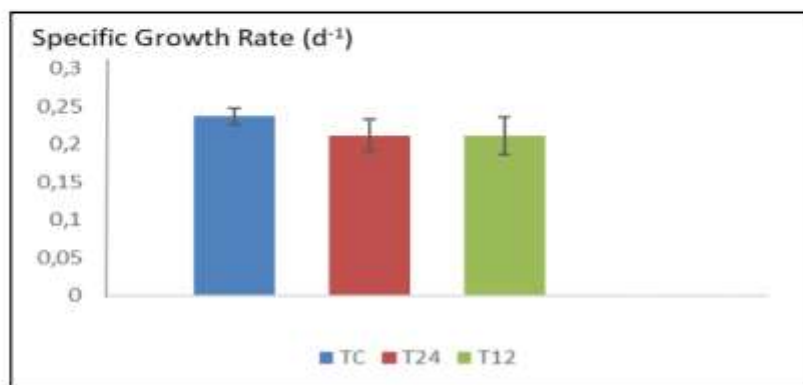


Figure 3. Specific growth rate of *A. platensis* in growth phase.

Table 2
Specific growth rate (% per day) of *A. platensis* in treatment stirring and on *A. platensis* culture media from *Clarias gariepinus* waste water

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	25.99	22.69	22.19	23.63 ± 2.07
T24	25.99	19.27	18.22	21.16 ± 4.22
T12	25.99	20.97	16.35	21.11 ± 4.82
Mean	25.99 ± 0.00	20.98 ± 1.71	18.92 ± 2.98	

Based on the results in Table 2, the control treatment gave the best specific growth rate value of 23.63% per day. The 12 hours stirring gave the lowest growth rate value of 21.11% per day. Although, the specific growth rate of *A. platensis* biomass in all of the results of the treatment is not different significantly. The high growth rate is caused by sufficient carbon dioxide which is diffused with aeration bubbles. According to de Godos et al (2014), the growth rate is influenced by the limitations of carbon dioxide in the media. Under phototrophic growth conditions in raceway pond cultures, the carbon dioxide becomes very limited. It can be at least 5% of the carbon required by algal cultures is released directly into the atmosphere from culture media.

In contrast, the first cycle gave different specific growth rates with the third cycle of culture. In the first cycles of culture, the biomass had better conditions than in the third cycle. The biomass of *A. platensis* needs the micronutrient for growth. The wastewater medium is less micronutrient for enhancing growth. It can be suggested for adding the micronutrient such as vitamins and trace minerals in the culture media for

increasing the performance of *A. platensis* cells, especially for enhancing the growth. According to Borowitzka and Vonshak (2017), potential problems with media recovery are selective enrichment of cultured contaminating organisms or unwanted cell morphologies; build-up of specific ions that negatively impact algal growth; establishment of auto-inhibition; cell disruption during harvest resulting in increased dissolved organic matter; flocculants residues lead to flocculation of cells in the culture. For the medium to be recovered may require some pretreatment or conditioning before being returned to the culture tank. Most large commercial algae producers have successfully implemented moderate recovery.

Reduction of total nitrogen content. Ammonia in the form of ammonium is used by *A. platensis* as a nitrogen source to stimulate its growth. Nitrogen needed for microalgae growth is generally absorbed in the form of nitrate (NO_3^-). Nitrate is further reduced by nitrite reductase to nitrite and then reduced to ammonium (NH_4^+) so that it can be synthesized through various amino compounds in *Spirulina* sp. (Widyantoro et al 2018). The percentage of nitrogen reduction have been shown in Table 3.

Table 3
Reduction of total nitrogen content (%) in *A. platensis* culture media

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	97.54	98.82	98.76	98.38 ± 0.73
T24	99.28	99.19	99.01	99.16 ± 0.14
T12	92.75	95.71	98.07	95.51 ± 2.66

Based on the results in Table 3, the percentage reduction of nitrogen content in treatment T24 (99.161%) is higher than in treatment TC (98.373%), and T12 (95.507%). However, based on analysis of variance between treatments and groups, the percentage reduction of nitrogen content had no significant effect. *A. platensis* in T24 treatment was able to utilize more nitrogen content. In this study *A. platensis* in wastewater of *Clarias gariepinus* catfish can reduce total nitrogen media by more than 95%. The study of *A. platensis* in wastewater of Nile tilapia (*Oreochromis niloticus*) reared in biofloc system media can remove the nitrogen, such as nitrate nitrogen uptake of 99%, 80% of total ammonia nitrogen (TAN) and 90% of nitrite nitrogen for 10 days (de Moraes et al 2021). Ammonia can remove 87.77 ± 1.01% by *Spirulina platensis* cultured in wastewater of *Pangasius* catfish reared for 10 days (Wijayanti et al 2019). Thus, given the results obtained, besides being able to grow in wastewater, *A. platensis* can also be used in bioremediation processes of aquaculture wastewater.

Phycocyanin yield. The results of the phycocyanin analysis included C-phycocyanin and phycocyanin extract yields. Based on the research, the highest concentration of phycocyanin was obtained from TC which was an average of 0.464 mg mL⁻¹. While the lowest levels of C-phycocyanin were in treatment 1 with an average of 0.39 mg mL⁻¹. The yield value of phycocyanin *A. platensis* for each treatment is presented in Table 4.

Table 4
Phycocyanin (%) of *A. platensis* dry biomass at 10 days after cultivation

Treatment of stirring media	Group cycle			The effect of treatment (T)
	1	2	3	
TC	5.098	1.192	5.315	3.87 ± 2.32
T24	5.043	2.391	2.318	3.25 ± 1.55
T12	3.300	2.697	4.350	3.45 ± 0.84

The analysis of variances at the treatment effects of phycocyanin yield (Table 4) showed that the stirring time and the different groups were not significantly different from the phycocyanin yield. The highest phycocyanin yield was obtained in the treatment using an aerator for 24 hours day⁻¹ (3.87%) and the lowest was in the stirring treatment using a propeller for 24 hours day⁻¹ (3.25%). According to Zhou et al (2017), pH value and salinity of culture media conditions can affect protein levels in *A. platensis* cells, differences in salinity affect the external osmotic pressure of *A. platensis* cells causing changes in cell composition, especially phycocyanin. Sharma & Tiwari (2011) stated that the environment includes nutrient availability, pH, salinity, light, and temperature can influence the growth and bio pigments accumulation of cyanobacteria biomass.

Business analysis. The results of the feasibility analysis for semi-mass production are obtained from production costs with the assumption that the purchase price of catfish is IDR 19,000 kg⁻¹, the price of feed is IDR 11,000 kg⁻¹, the price of electricity is IDR 1,445 kWh⁻¹, the price of salt is IDR 5,000 kg⁻¹ and the selling price of catfish IDR 22,000 kg⁻¹, selling price of *A. platensis* IDR 500 g⁻¹, with investment in tools such as a dynamo (4 watts) IDR 18,000 with a service life of 4 years, a mill of IDR 30,000 with a service life of 4 years, two aerators (10 watts) IDR 37,000 with a service life of 3 years, containers IDR 80,000 with a service life of 6 years, Tube lamp (32 watts) IDR 47,000 with a service life of 4 years and Asahi cloth IDR 18,000 with a service life of 4 years, analysis of R/C Ratio and ROI in each treatment and group. Table 5 shows the business analysis.

R/C Ratio (Return Cost Ratio) is a comparison between total revenue and production costs. There are three criteria in the R/C ratio, namely: R/C ratio > 1, then the business is profitable, R/C ratio = 1, then the farm is breaking even, and R/C ratio < 1, then it is not efficient. ROI (Return On Investment) is a comparison between the total profit and production costs in percent. There are three criteria in ROI: ROI is positive, the business is profitable, ROI = 0, then the farm breaks even, and ROI is negative, so it is not efficient.

Honestly Significant Difference test showed that the R/C ratio and ROI in treatment TC (aeration for 24 hours day⁻¹) were significantly lower than treatments T24 and T12. Treatments T24 and T12 were not different significantly, although the highest value was in the T12 treatment. In the T12 treatment, the R/C Ratio and ROI were the highest, while in the control treatment the R/C Ratio and ROI were the lowest compared to other treatments, the low profit in the aeration treatment was due to the use of electricity up to 46% of the total production cost, so it was less economical if done in cultivation.

Table 5
R/C and ROI in *A. platensis* culture integrated with *Clarias gariepinus* rearing systems, and the feed conversion ratio of the catfish rearing

Treatment of stirring media	Mean of R/C value (HSD _{0.05= 0.069})	Mean of ROI value (HSD _{0.05= 6.882})	Feed Conversion Ratio (FCR) in catfish rearing
TC	0.942 ± 0.050 ^a	-5.756 ± 5.025 ^a	1.38 ± 0.33
T24	1.098 ± 0.059 ^b	9.821 ± 5.907 ^b	1.30 ± 0.30
T12	1.120 ± 0.068 ^b	12.013 ± 6.842 ^b	1.04 ± 0.40

In T12's first production cycle, the average cost of feed was IDR 3,458, catfish was IDR 12,780 and catfish earn was IDR 21,294, product *A. platensis* flour was IDR 9,850 with a total income of IDR 31,144 with a profit of IDR 1,585 from production costs of IDR 29,559 (*A. platensis* in 30 liters of media and 20 fish). *A. platensis* in 12,000 liters of media and 8,000 fish will get an income of IDR 12,457,696 and a profit of IDR 5,527,788 with a production cost of IDR 6,929,908 in 1 cycle, if in 1 year of production there are 26 cycles then the profit obtained will reach IDR 143,722,495.

Conclusions. The utilization of catfish culture wastewater for the culture of *A. platensis* with different treatments and stirring time gave a significant effect on business analysis, but no effect on the maximum density and the growth rate of *A. platensis*, the reduction of total nitrogen content in the media, and the yield of phycocyanin. The best growth rate and total nitrogen reduction were obtained in treatment T24 (stirring using a mill for 24 hours per day). The result of the business analysis was better using a raceway system with wheel rotation than using an aeration system. The treatment stirring wheels 12 hours per day is the best result for scaling up *Arthrospira platensis* production at an outdoor integrated pond system.

Acknowledgements. We are grateful to the University of Sriwijaya for funding the research under Competitive Grant II in 2021: 0022/UN9/SK.LT12M.PT/2021.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Afriani S., Uju, Setyaningsih I., 2018 [Chemical composition of *Spirulina platensis* cultivated in a photobioreactor with different photoperiods]. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(3):471-479 [in Indonesian].
- Bennett A., Bogorad L., 1973 Complementary chromatic adaptation in a filamentous blue-green alga. *The Journal of Cell Biology*, 58:419-435.
- Borowitzka M. A., Vonshak A., 2017 Scaling up microalgal cultures to commercial scale. *European Journal of Phycology*, 52(4):407-418.
- Budiardi T., Utomo N. B. P., Santosa A., 2010 Growth performance and nutrition value of *Spirulina* sp. under different photoperiod. *Jurnal Akuakultur Indonesia*, 9(2):146-156.
- de Godos I., Mendoza J. L., Ación F. G., Molina E., Banks C. J., Heaven S., 2014 Evaluation of carbon dioxide mass transfer in raceway reactors for microalgae culture using flue gases. *Bioresour Technol*, 153:307-14.
- de Jesus C. S., da Silva Uebel L., Costa S. S., Miranda A. L., de Moraes E. G., de Moraes M. G., Costa J. A. V., Nunes I. L., de Souza Ferreira E., Druzian J. I., 2018 Outdoor pilot-scale cultivation of *Spirulina* sp. LEB-18 in different geographic locations for evaluating its growth and chemical composition. *Bioresource technology*, 256:86-94.
- de Moraes L. B. S., Mota G. C. P., da Silva Farias R., Marinho Y. F., Silva L. O. B., Gálvez A. O., 2021 Growth and nitrogen uptake by *Arthrospira platensis* cultured in aquaculture wastewater from Nile tilapia reared in biofloc system. *Acta Scientiarum. Biological Sciences*, 43:e57549-e57549.
- Deyab M., Mofeed J., El-Bilawy E., Ward F., 2020 Antiviral activity of five filamentous cyanobacteria against coxsackievirus B3 and rotavirus. *Archives of microbiology*, 202(2):213-223.
- Fazal T., Mushtaq A., Rehman F., Khan A. U., Rashid N., Farooq W., Rehman M. S. U., Xu J., 2018 Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renewable and Sustainable Energy Reviews*, 82:3107-3126.
- Hariyati R., 2008 [Growth and biomass of *Spirulina* sp. in laboratory scale]. *Bioma*. 10(1):19-22 [in Indonesian].
- Jonker J. G. G., Faaij A. P. C., 2013 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production. *Applied Energy*, 102:461-475.
- Jung F., Jung C. G., Krüger-Genge A., Waldeck P., Küpper J. H., 2019 Factors influencing the growth of *Spirulina platensis* in closed photobioreactors under CO₂-O₂ conversion. *Journal of Cellular Biotechnology*, 5(2):125-134.
- Knowler D., Chopin T., Martínez-Espiñeira R., Neori A., Nobre A., Noce A., Reid, G., 2020 The economics of Integrated Multi-Trophic Aquaculture: where are we now and where do we need to go? *Reviews in Aquaculture*, 12(3):1579-1594.

- Liu H., Zhang H., Niedzwiedzki D. M., Prado M., He G., Gross M. L., Blankenship R. E., 2013 Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria. *Science*, 342(6162):1104-1107.
- Mutiah E., Khoirunisa E., 2013 [Cultivation process of *Spirulina platensis* using pome (Palm Oil Mill Effluent) as culture medium in raceway open pond bioreactor]. *Jurnal Teknologi Kimia dan Industri*, 2(2):192-197 [in Indonesian].
- Naidoo D., Roy A., Kar P., Mutanda T., Anandraj A., 2021 Cyanobacterial metabolites as promising drug leads against the Mpro and PLpro of SARS-CoV-2: An in silico analysis. *Journal of Biomolecular Structure and Dynamics*, 39(16):6218-6230.
- Ndubuisi U. C., Chimezie A. J., Chinedu U. C., Chikwem I. C., Alexander U., 2015 Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. *Int. J. Res. Biosciences*, 4(3):14-20.
- Oktafiani M., Hermana J., 2013 [Effect of substrate concentration and bacterial concentration on algae production in a batch process bioreactor system]. *Jurnal Teknik POMITS*, 2(2):D57-D62 [in Indonesian].
- Ragaza J. A., Hossain M. S., Meiler K. A., Velasquez S. F., Kumar V., 2020 A review on *Spirulina*: alternative media for cultivation and nutritive value as an aquafeed. *Reviews in Aquaculture*, 12(4):2371-2395.
- Ramli N. M., Verreth J. A. J., Yusoff F. M., Nurulhuda K., Nagao N., Verdegem M. C., 2020 Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in bioengineering and biotechnology*, 8:1004.
- Santosa A., 2010 [Production of *Spirulina* sp. cultured by photoperiodic manipulation]. Undergraduate Thesis. IPB University [in Indonesian].
- Sharma N. K., Tiwari S. P., Tripathi K., Rai A. K., 2011 Sustainability and cyanobacteria (blue-green algae): facts and challenges. *Journal of Applied Phycology*, 23(6):1059-1081.
- Sitio M. H. F., Jubaedah D., Syaifudin M., 2017 [Survival and growth of catfish fry (*Clarias* sp.) in different media salinity]. *Jurnal Akuakultur Rawa Indonesia*, 5(1):83-96 [in Indonesian].
- Tabarзад M., Atabaki V., Hosseinabadi T., 2020 Anti-inflammatory activity of bioactive compounds from microalgae and cyanobacteria by focusing on the mechanisms of action. *Molecular biology reports*, 47(8):6193-6205.
- Tang D. Y. Y., Khoo K. S., Chew K. W., Tao Y., Ho S. H., Show P. L., 2020 Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. *Bioresource technology*, 304:122997.
- Tiwari A. K., Tiwari B. S., 2020 Cyanotherapeutics: an emerging field for future drug discovery. *Applied Phycology*, 1(1):44-57.
- Vonshak A., 2002 *Spirulina platensis* (*Arthrospira*): Physiology, cell-biology and biotechnology. Taylor & Francis. 252 pp.
- Widyantoro H., Wijayanti M., Dwinanti S. H., 2018 [Modification of *Spirulina platensis* media as an effort to utilize catfish farming wastewater]. *Jurnal Akuakultur Rawa Indonesia*, 6(2):153-164 [in Indonesian].
- Wijayanti M., Jubaedah D., Gofar N., Anjastari D., 2019 Optimization of *Spirulina platensis* culture media as an effort for utilization of *Pangasius* farming waste water. *Sriwijaya Journal of Environment*, 3(3):108-112.
- Wijayanti M., Syaifudin M., Yulisman, Nurianti Y., Hidayani A., Gofar N., 2020 Characterization of *Arthrospira platensis* cultured in wastewater of *Clarias* catfish farming media: DNA barcode, helical form, growth, and phycocyanin. *Biodiversitas*, 21(12):5872-5883.
- Zhang F., Man Y. B., Mo W. Y., Wong M. H., 2020 Application of *Spirulina* in aquaculture: a review on wastewater treatment and fish growth. *Reviews in Aquaculture*, 12(2):582-599.
- Zhou W., Li Y., Gao Y., Zhao H., 2017 Nutrients removal and recovery from saline wastewater by *Spirulina platensis*. *Bioresource technology*, 245:10-17.

- *** Antara, 2021 [[https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish farming](https://www.antaranews.com/berita/1953848/minister-kkp-call-priority-2021-moving-fish-farming), Senin, Accessed on 18 January 2021 19:41 WIB] [in Indonesian].
- *** The Ministry of Maritime Affairs and Fisheries (KKP), 2021 <https://kkp.go.id/djpb/artikel/26634-kkp-gerakkan-perikanan-budidaya-jadi-penopang-ketahanan-pangan-dan-pembangunan-ekonomi-daerah-di-tengah-pandemi>. Accessed in December 2022.

Received: 9 December 2021. Accepted: 20 June 2022. Published online: XXXX January 2023.

Authors:

Marini Wijayanti, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mariniwijayanti@fp.unsri.ac.id
Yohanes Setiawan, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: yohanesst256@gmail.com
Tanbiyaskur Tanbiyaskur, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: tanbiyaskur@unsri.ac.id
Dade Jubaedah, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: dadejubaedah@fp.unsri.ac.id
Mohamad Amin, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: mohamadamin@fp.unsri.ac.id
Mirna Fitriani, Aquaculture Program, Department of Fisheries, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: fitranimirna@gmail.com
Nuni Gofar, Soil Science Program, Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya, Ogan Ilir, South Sumatera, Indonesia, e-mail: gofarnuni@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Wijayanti M., Setiawan Y., Tanbiyaskur T., Jubaedah D., Amin M., Fitriani M., Gofar N., 2023 Techno-economic analysis of integrated multitrophic *Clarias gariepinus* and *Arthrospira platensis* with different agitation period. AACL Bioflux 16(1):xxxx-xxxx.

Home Journal AACL News Human Resources Other Journals

You are here > Home > Volume 16(1)/2023

AACL Bioflux	Volume 16(1)/2023
Instructions to authors	First pages, 2023 AACL Bioflux 16(1):I-VIII.
Submission letter	Pelacuda D. D., Patria M. P., Wouthuyzen S., Syahallatus A., 2023 Key success factors and problems in coral transplantation: A review. AACL Bioflux 16(1):1-24.
Model of paper	Yuniarti M., Syamsuddin M. L., Saicabilla A., Ihsan Y. N., Yulledi L. P., 2023 Hydrodynamic and cohesive sediment transport modelling in Cilifuh Bay, West Java, Indonesia. AACL Bioflux 16(1):26-38.
Reviewer information pack	Wijayanto D., Nugroho R. A., Kurohman F., Nurcanto D. B., 2023 The effect of salinity on the growth, survival and profitability of TGGG hybrid grouper culture (♀ tiger grouper × ♂ giant grouper). AACL Bioflux 16(1):39-47.
Editorial Board expanded	Tupamahu A., Haruna, Bilooy F. D., 2023 The effect of material type and mesh size of the drift gillnet selectivity on Abe's flyingfish, <i>Challopogon abei</i>, in Seram Sea, Indonesia. AACL Bioflux 16(1):49-64.
Coverage / databases	Rostika R., Pratiwy F. M., Andhikawati A., Pacaribu B., Dewanti L. P., 2023 The addition of fish oil to commercial feed as omega-3 fatty acid source in biofloc <i>Clarias</i> sp. culture system. AACL Bioflux 16(1):66-86.
Volume 16(6)/2023 (December, 30)	Robin, Valen F. S., Nomeni A., Turnip G., Luhullima M. Y., Insani L., 2023 Presence of non-native freshwater fish in Indonesia: A review - Risk and ecological impacts. AACL Bioflux 16(1):86-78.
Volume 16(5)/2023 (October, 30)	Latuconsina H., Purbiantoro W., Padang A., 2023 Different marine macroalgae feeding preferences of adult white-spotted rabbitfish (<i>Siganus canaliculatus</i>). AACL Bioflux 16(1):80-88.
Volume 16(4)/2023 (August, 30)	Effendi I., Rifal M., Nadra M. R., Syawal H., Burlani D. T., Yocwaty D., Riza S., 2023 Bioactivity of <i>Brugulera gymnorrhiza</i> leaf extract on fish pathogenic bacteria <i>Staphylococcus aureus</i>, <i>Aeromonas hydrophila</i>, and <i>Pseudomonas aeruginosa</i>. AACL Bioflux 16(1):89-98.
Volume 16(3)/2023 (June, 30)	Tahapary J., Simbolon D., Zulkarnain, Wiryawan B., 2023 Design and physical performance of fish apartments by utilizing pearl oyster shell waste. AACL Bioflux 16(1):99-109.
Volume 16(2)/2023 (April, 30)	Dewi P., Sutarjo, Hermawan M., Yucrizal, Maulita M., Nuriaela E., Kusmedy B., Danapraja S., Nugraha E., 2023 Study of sea surface temperature and chlorophyll-a influence on the quantity of fish caught in the waters of Sadeng, Yogyakarta, Indonesia. AACL Bioflux 16(1):110-127.
Volume 16(1)/2023 (February, 28)	Supono, Nurdianti L., Fidyandini H. P., 2023 Effect of different ratios of sodium and potassium on the growth and survival rate of Pacific white shrimp (<i>Litopenaeus vannamei</i>) cultured in freshwater. AACL Bioflux 16(1):128-134.
Volume 15(6)/2022 (December, 30)	Nugroho E. D., Ardiansyah R., Kurniawan N., Wildodo, Rahayu D. A., 2023 Species identification of echinoderms from Gilli Ketapang Island by combining morphology and molecular data. AACL Bioflux 16(1):136-160.
Volume 15(5)/2022 (October, 30)	Prayudha B., Ulumuddin Y. I., Siregar V., Suyerso, Agus S. B., Pracetyo L. B., Anggraini K., Saizalohi A., 2023 Geomorphological and hydrological changes play a critical role in mangrove forest degradation in a rapidly shrinking lagoon in Indonesia. AACL Bioflux 16(1):161-187.
Volume 15(4)/2022 (August, 30)	Bahtiar R., Afriana W., Kurniawan T., 2023 Potential impact of Covid-19 pandemic on fisheries export sector in Indonesia: literature review and pointer of future research agenda. AACL Bioflux 16(1):188-179.
Volume 15(3)/2022 (June, 30)	Wijayanti M., Setiawan Y., Tanblyaskur T., Jubaidah D., Amin M., Fitriani M., Gofar N., 2023 Techno-economic analysis of integrated multitrophic <i>Clarias gariepinus</i> and <i>Arthrospira platensis</i> with different agitation period. AACL Bioflux 16(1):179-189.
Volume 15(2)/2022 (April, 30)	Latupe J. P., Baskoro M. S., Wiryawan B., Muctaruddin, 2023 Small scale handline tuna fishery in Buru Island, Maluku Province, Indonesia, during the Covid-19 pandemic. AACL Bioflux 16(1):190-198.
Volume 15(1)/2022 (February, 28)	Syamsuddin M. L., Fatz H. U., Ismail M. R., Zailica S., 2023 Spatial distributions of the thermal front and of catches of mackerel (<i>Scomberomorus commerson</i>) in the Java Sea, Indonesia. AACL Bioflux 16(1):199-208.
Volume 10(6)/2017 (December, 30)	
Volume 10(5)/2017 (October, 30)	
Volume 10(4)/2017 (August, 30)	