Investigation of Nutrient Effect on Microalgae Growth for Biofuel in a Photobioreactor

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Abstract: - Fuel is a major regulator in the current global instability. It is safe to say that energy is the silent hero of the fourth industrial revolution. Because of its environmentally favorable function and cost-effective sustainability, biofuel can be an ideal alternative to fossil fuels. Microalgae-based biofuel is gaining popularity among scientists and entrepreneurs due to its high biomass yield. There are some growth factors like strain properties, light, temperature CO_2, P^H, nutrients (N, P, Mg, Mn, etc.), culture systems, etc. to increase biomass growth. In this present research, a growth model based on nitrogen intake is considered to investigate the effect on optimal biomass growth. The other kinematic parameters are taken from an experiment for our simulation. The local light intensity is taken into account for a geographical location. Microalgae culture shows a very significant growth in biomass concentration while nitrogen intake gradually decreases. The simulated results were also compared with a reference model and the experimental one and found a good agreement. The rate of biomass concentration within the first 100 hours in our present research work, using 1.575 gL^{-1} acetate and 0.0735gL^{-1}N, is revealing upper than the compared experimental results. The nitrogen consumption by the culture shows a similar pattern to the reference study.

Key-Words: - Biofuel, Biomass, Microalgae, Two-phase Flow, Nutrients, Photobioreactor, CFD, Simulation

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1 Introduction

Formulation of fossil fuels takes millions of years, and they are not a reliable, renewable source of energy to be used across the world. Moreover, the effects of the burning of fossil fuels, especially carbon dioxide, are having far-reaching effects on our climate and ecosystems. The two global burning questions in the present world are climate change and global warming. Due to fossil fuel burning, a huge amount of CO_2 is emitted to the atmosphere and the negative impacts are the rise in the surface temperature of the world which is directly related to climate change. Also, fossil fuel burning causes global warming for which the ice is melting. We see that present threats that are shaking our world are mainly deforestation, overfishing, energy crisis, shortage of water conservation etc. Present research shows that the impact of all these problems is that our resource preservation as well as fossil fuels is depleting because of the primary extraction of crude oil, hard coal, and natural gas due to the reduction of the stack for present and future generations, [1].

So, finding alternative renewable environment-friendly resources other than fossil fuels become a great help in saving humanity. There are a lot of renewable resources, [2], [3], [4] like soya, rapeseed, palm oil, jatropha, microalgae etc., to produce biofuels. Compared with all, biofuel research shows that microalgae are the best option, [4], [5], [6]. Microalgae are unicellular organisms; that exist individually or in chains or groups. They do not have

roots, stems, or leaves. They have fast growth rate and high photosynthetic efficiency. Microalgae convert CO_2 to O_2. There are two major conventional systems for microalgae cultivation process – Open ponds and closed photobioreactor. Photobioreactors have different geometric shapes. Considering the factors like risk of contamination, biomass quality, production flexibility, we observed that a closed photobioreactor is better than an open pond system. Research is going on to reduce the higher investment cost for using the closed one. From previous research we find that among different structures of closed photobioreactors, tubular photobioreactor is the best because of low contamination risk and high sunlight trap for its large illumination area to capture sunlight.

In our present work, we consider a single Horizontal Loop Tubular Photobioreactor (HLTP) for biomass production from microalgae cultivation. Production of biofuel from algae is dependent on the microalgal biomass production rate or concentration. Biomass production is limited by several factors like strain properties, light, temperature, CO_2/pH, nutrient control, culture systems, [7] etc. Present research shows that inorganic nitrogen plays a key role in maximizing biomass production.

We use the Galerkin finite element approximation method for our model and simulate the model to analyze the effect of nutrients, substrate concentration and light intensity on the rate of biomass growth. This study illustrates the usefulness not only of computer-based optimization studies for the improvement of microalgal-based production, but also of carefully constructed predictive models for the accurate simulation of these systems. Results of this research can be applied in the practical setup for large-scale culture.

2 Outline of Methodology

2.1 Mathematical Modeling

Algae suspension, CO_2 and Nutrient (N) mixture is considered as an incompressible viscous multiphase Newtonian fluid flow. The flow is turbulent, and the governing equations are the continuity equation and the Navier-Stokes equations as:

$$\nabla.\mathbf{u} = 0 \tag{1}$$

And

$$\rho\frac{\partial \mathbf{u}}{\partial t} + \rho(\mathbf{u}.\nabla)\mathbf{u} = \nabla.[-PI + \mu(\nabla\mathbf{u} + (\nabla\mathbf{u})^T)] + \rho g \tag{2}$$

Here we use COMSOL Multiphysics to assess the tubular PBR fluid dynamics. The κ-ε model is used to evaluate turbulence behavior. This model, which is well-known in the industry, uses the average Navier-Stokes equations and two additional equations to evaluate the turbulence behavior. Average Navier-Stokes equations solve the average velocity and pressure profile, [8].

$$\rho\frac{\partial \mathrm{u}}{\partial t} + \rho(\mathbf{u}.\nabla)\mathbf{u} = \nabla.[-P\mathrm{I} + (\mu + \mu_T)(\nabla\mathbf{u} + (\nabla\mathbf{u})^T) - \frac{2}{3}(\mu + \mu_T)(\nabla.\mathbf{u})\mathrm{I} - \frac{2}{3}\rho k\mathrm{I}] + \rho\mathrm{g} + F \tag{3}$$

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho\mathbf{u}) = 0, \tag{4}$$

where $\mathbf{u}$ is the average velocity of suspension, t is the time, μ is the dynamic viscosity, P is the pressure, k is the turbulent kinetic energy, F is a volumetric force and I is the turbulence intensity, which is defined as I = u'/u, where u' is the quadratic average fluctuations of the average velocity, [9].

Here

$$\mu_T = \rho C_\mu \frac{k^2}{\varepsilon}, \tag{5}$$

where ε is the turbulence kinetic energy dissipation and C_μ is model parameter.

and

$$p_k = \mu_T[\nabla\mathbf{u}.(\nabla\mathbf{u} + (\nabla\mathbf{u})^T) - \frac{2}{3}(\nabla.\mathbf{u})^2] - \frac{2}{3}\rho k\nabla.\mathbf{u} \tag{6}$$

The turbulent kinetic energy and kinetic energy dissipation are obtained from:

$$\rho\frac{\partial k}{\partial t} + \rho(\mathbf{u}.\nabla)k = \nabla.[(\mu + \frac{\mu_T}{\sigma_k})\nabla k] + p_k - \rho \tag{7}$$

and

$$\rho\frac{\partial \varepsilon}{\partial t} + \rho(\mathbf{u}.\nabla)\varepsilon = \nabla.[(\mu + \frac{\mu_T}{\sigma_k})\nabla\varepsilon] + C_{e1}\frac{\varepsilon}{k}p_k - C_{e2}\rho\frac{\varepsilon^2}{k} \tag{8}$$

respectively.

Here σ_k is model parameter. The stress tensor σ_g is given by

$$\sigma_g = -PI + 2\mu D(v), \tag{9}$$

where D is the rate of deformations. The rate of deformations D, of equation (9) can be written as

$$D(v) = \frac{1}{2}[\nabla\mathbf{u} + (\nabla\mathbf{u})^T] \tag{10}$$

Putting equations (9) and (10) in equation (2), we get

$$\rho\frac{\partial \mathbf{u}}{\partial t}+\rho(\mathbf{u}.\boldsymbol{\nabla})\mathbf{u}=\boldsymbol{\nabla}.[-PI+\mu(\boldsymbol{\nabla}\mathbf{u}+(\boldsymbol{\nabla}\mathbf{u})^{T})]+\rho g \quad (11)$$

The Dynamic viscosity of the fluid μ is given by:

$$\mu(t)=\mu_0\mu_r(t), \quad (12)$$

here μ_0 is the initial viscosity and $\mu_r(t)$ is the Einstein's relative viscosity.

The Einstein's relative viscosity is given by:

$$\mu_r(t)=1+\in C(t) \quad (13)$$

where $\in$ is the Einstein's coefficient and *C(t)* is the concentration of the fluid.

$$C(t)=C_0+\frac{1}{\mathrm{a}+\mathrm{b}e^{-\mu_X t}} \quad (14)$$

where C_0 is the initial concentration, a and b are the constants, and μ_X is the specific growth rate of microalgae cells.

2.2 Experimental Design

In this system represented by the Figure 1, plexiglass tubes and coils act as solar collectors, increasing temperature and extending the growing season. Algae are pumped continuously through rows of connected flexible transparent tubes or coils to collect solar energy. Much greater density can be maintained than in open ponds.

The schematic representation of algal biomass production in a tubular photobioreactor is depicted in the following Figure 1.

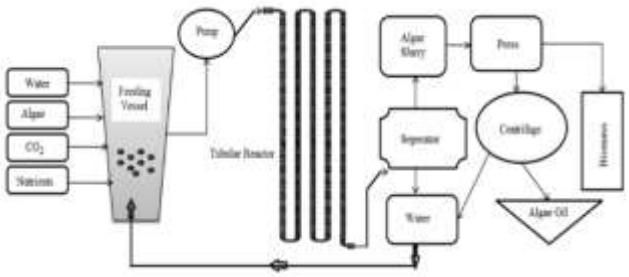

Fig. 1: Schematic diagram of working procedure for biomass production in Horizontal Loop Tubular Reactor (HLTP)

On the downside, algae may stick to the inside of the tubes and block sunlight, and tubes may get too hot. So, we need to use turbulence to mix the light and dark zones. Excessive oxygen produced by the algae while growing can reduce growth. A vertical plate system has been designed that has a flexible orientation to the sun and allows oxygen to be released at the bottom.

Several experiments were conducted in laboratories which proved that a strongly dense concentration of substrate is treat as a system inhibitor, and also can effectively decrease biomass growth rates, [10]. For determining substrate inhibition on the non-steady behavior of the cell, a transformed Monod or Haldane equation is extensively applied, [11], [12], [13]:

$$\mu=\mu_{max}\frac{S}{S+K_S+\frac{S^2}{K_{is}}} \quad (15)$$

Here, μ, μ_{max}, S, K_S and K_{iS} indicate specific growth rate, maximum specific growth rate, concentration of substrate, substrate saturation constant, and substrate inhibition constant respectively t. Though the exhaustion of nutrients inhibits biomass growth, it is very common to raise the oil accumulation, [14], [15]. Moreover, the microalgae growth is vitally dependent on light intensity, [16], [17]. For this reason, the Haldane equation (Eq. 15) is necessarily upgraded to measure the excessive effects of nutrient concentration and light intensity. Because of the variable consequence of N on biomass concentration, two extra terms for the nutrient (N) effect as a substrate [12] were added here to depict the specific biomass growth rate. In addition, the Aiba model [18], [19] was kept in account to simulate the effect of light intensity as pseudo-substrate. Different approximate kinetic parameters and their measured values in the reference are given in the Table 1.

Table 1. The kinetic parameters and their values obtained in the reference, [20]

Parameter	Value (units)
μ_{Xmax}	0.227h^{-1}
K_{XS}	0.050gSL^{-1}
K_{iXS}	9.923 gSL^{-1}
K_{XN}	0.065gNL^{-1}
K_{iXN}	0.500gNL^{-1}
K_{XI}	19.519$\mu Em^{-2}s^{-1}$
K_{iXI}	2053.924$\mu Em^{-2}s^{-1}$
σ_X	34.104$gX^{-1}Lm^{-1}$
$Y_{\frac{X}{N}}$	6.833$gXgN^{-1}$
I_0	125$\mu Em^{-2}s^{-1}$

Thus, the specific oil-free biomass growth rate, μ_X, is described by a pseudo-triple substrate expression as:

$$\mu_X = \mu_{Xmax} \frac{S}{S + K_{XS} + \frac{S^2}{K_{iXS}}} \frac{N}{N + K_{XN} + \frac{N^2}{K_{iXN}}} \frac{I(l)}{I(l) + K_{XI} + \frac{I(l)}{K_{iXI}}}, \quad (16)$$

where $\mu_{X\,max}$ denotes the maximum specific growth rate of oil-free biomass on substrate that relay upon the nitrogen concentration and local light intensity, $I(l)$. Here, the saturation constants are K_{XS}, K_{XN} and the inhibition constants for oil-free biomass growth based on substrate, nitrogen concentration and light intensity are K_{XI} and K_{iXS}, K_{iXN} and K_{iXI}, respectively. The local light intensity $I(l)$ is defined by [21]:

$$I(l) = I_0\, exp(-\sigma_X X l), \quad (17)$$

where l is the distance between the local position and the external surface of the system, I_0 is the incident light intensity, σ_x is the molar extinction coefficient and X is the oil-free biomass concentration [21]. The microalgal growth rate can be determined as:

$$\frac{dX}{dx} = \mu_X X \quad (18)$$

The N uptake rate is can be determined by [22]:

$$\frac{dN}{dx} = -\frac{1}{Y_{\frac{X}{N}}} \cdot \frac{dX}{dt}. \quad (19)$$

3 Results and Discussion

To observe the biomass growth condition, a simulation has been done with a two-phase turbulent flow of microalgae and CO_2 in a horizontal single loop tubular photobioreactor considering nitrogen as a nutrient for the growth of microalgae cells. The present result is then compared with the reference work [20] and the related experimental work, [10]. In this present result, the initial concentration of biomass is considered as 0gL^{-1} while the inlet velocity is taken as 0.5ms^{-1}. For mesh design, an extremely coarse design is considered in this work with 1370342 of degrees of freedom. The normal stress is 0; whereas the volume friction is taken 0.05. The simulation is conducted for 200h to observe the effect of nitrogen on growth.

On the day 7, in a week, the maximum rate of biomass production was determined by the rate of growth in culture density. The mass flow pattern through the whole computational domain shown in Figure 2 reflects the behavior of the flow in times at different cross sections of the tube.

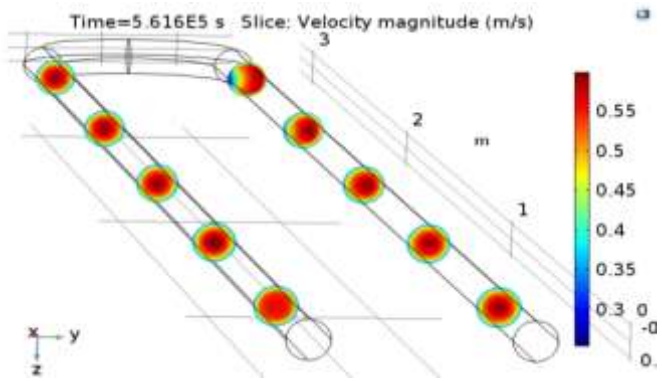

Fig. 2: Velocity profile of the flow through the tubular photobioreactor

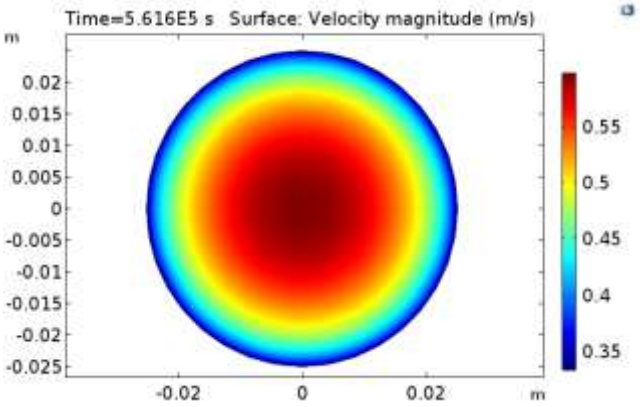

Fig. 3: Velocity profile of the flow in vertical cross section at x=0.8m.

The highest velocity is observed on the vertical cross-section of the tube at x=0.8m on the inlet side of the reactor. The highest velocity at the center of the tube and lowest velocity at the wall of the tube mean that the no slip condition is appropriately applied. The velocity profile, depicted in Figure 3, in the vertical cross section at x=0.8m at the inlet side of the reactor at the time 561600s also shows that the velocity has its maximum value at the center of the tube and gradually decreases to zero towards the tube wall.

The microalgae cell growth is represented by means of biomass concentration which is illustrated in Figure 4 using 2.1 gL^{-1} acetate and 0.098gL^{-1}N for total time at a point at x=3m at the inlet side of the tube. The present result seems to be the same pattern as the reference work and the experimental work but exhibits higher biomass concentration throughout the time which is very indicative. Figure 5 is also showing

same behavior for nitrogen consumption, i.e., nitrogen consumption is lower than the compared and the experimental one.

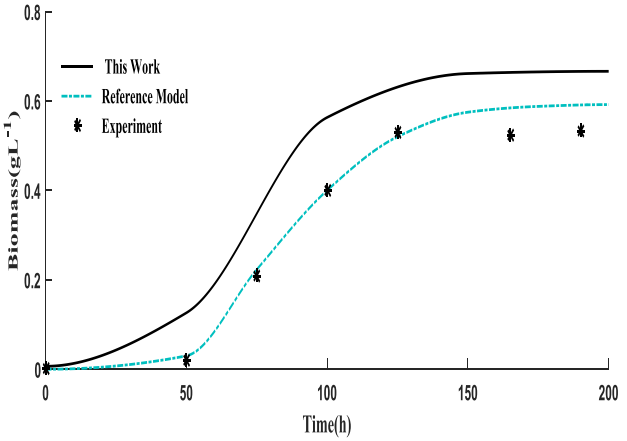

Fig. 4: Biomass concentration at a point in the domain using 2.1 gL^{-1} acetate and 0.098gL^{-1}N

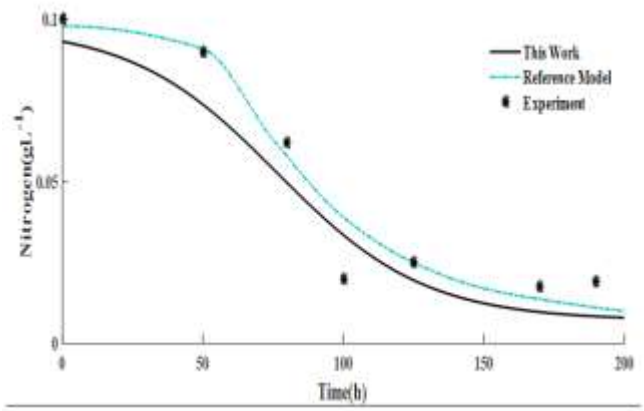

Fig. 5: Nitrogen consumption at a point in the domain using 2.1 gL^{-1} acetate and 0.098gL^{-1}N

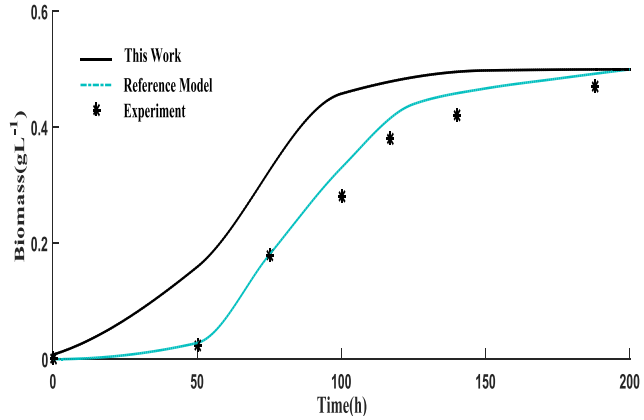

Fig. 6: Biomass concentration at a point in the domain using 1.575 gL^{-1} acetate and 0.0735gL^{-1}N

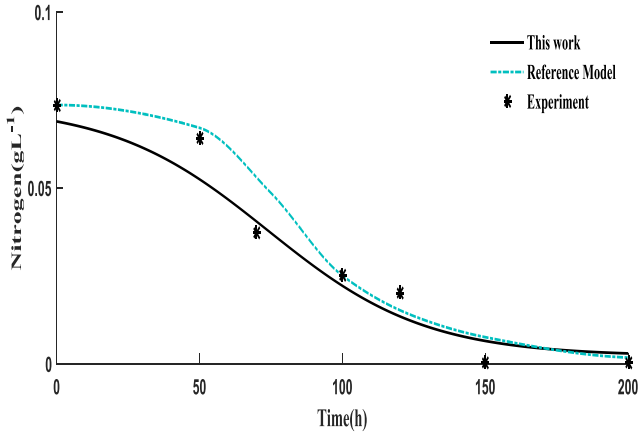

Fig. 7: Nitrogen consumption at a point in the domain using1.575 gL^{-1} acetate and 0.0735gL^{-1}N

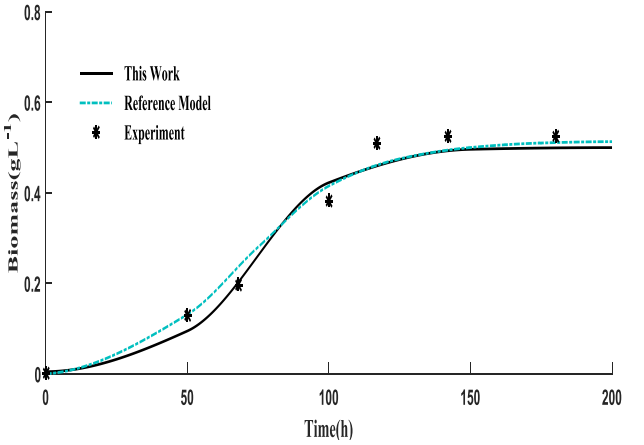

Fig. 8: Biomass concentration at a point in the domain using 2.196 gL^{-1} acetate and 0.0742gL^{-1}N

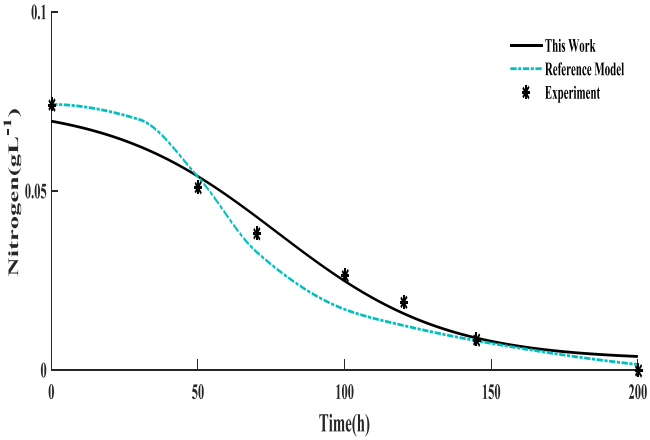

Fig. 9: Nitrogen consumption at a point in the domain using 2.196 gL^{-1} acetate and 0.0742gL^{-1}N

In the Figure 6, the rate of biomass concentration within first 100 hours in our present research work,

using 1.575 gL^{-1} acetate and 0.0735gL^{-1}N, is revealing upper values than the compared and experimental one as in Figure 4. Very significant identical behavior of the present study, compared study, and experimental results are observed for the nitrogen consumption and biomass concentration in Figure 7 and Figure 8 respectively. Finally, nitrogen consumption in the present research work with respect to time exhibits a good agreement with that of experimental results which is better than the compared one in Figure 9 using 2.196 gL^{-1} acetate and 0.0742gL^{-1}N. From the last figure (Figure 9.), we regard that our present research of nutrient (N) uptake fit better than that of the compared model which is very meaningful.

Considering all the numerical and computational analysis of the present study, we can come to the point that the present research almost fits better with experimental research than compared reference model for oil-free biomass growth from microalgae culture in the presence of nutrient (N).

4 Conclusion

For biofuel production from microalgae, nutrients play a vital role in the rapid growth of the algal cell. A computational model for nutrient-like nitrogen (N) uptake together with microalgae suspension flow has been improved in our present work. Other growth parameters such as light, temperature, CO_2, P^H, and culture systems are also taken into account to forecast the influence of altering substrate and nitrogen (N) on biomass growth rates and nitrogen consumption rates. Following that, the results are applied in collaboration with the established model and experimental investigations to evaluate kinetic boundaries that are vital for accurate simulation processes. According to the simulation, the flow creates a perfect parabolic shape inside the reactor. In addition, the present culture shows very consistent growth of microalgae biomass and a logistic nitrogen (N) uptake which is very noteworthy. From the simulation, it is also found that the nitrogen intake follows a gradual down logistic curve while biomass shows a gradual upward logistic curve. In all cases, a significant amount of similarity is found for N uptake compared to the reference and the experimental work. However, higher biomass concentration is observed throughout the time compared to experimental work considering nutrient consumption using different amounts of acetate and nitrogen. Thus, we are expecting that such prognostic findings may contribute a lot in economic and commercial industries like food, agriculture, medicines, microalgae-based biofuel technologies, etc.

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References:

[1] A. J. Huijbregts, J. N. Steinmann, M. F. Elshout, G. Stam, F. Verones, M. Vieira, M. Ziip, A. Hollander and R. V. Zelm, "A harmonised life cycle impact assessment method at midpoint and endpoint level", *The International Journal of Life Cycle Assessment*, vol. *22*(2), pp. 138-147, 2016. https://doi.org/10.1007/s11367-016-1246-y.

[2] X. Dalai, N. N. Bakhshi, M. J. Reaney, P. B. Hertz, "Experimental Investigation on Transesterification Efficiency of Calophyllum Inophyllum Biodiesel" *Bioresour. Technol.*, 80, 53-62, 2002. https://doi.org/10.26634/jfet.7.2.1759.

[3] P. Spolaore, C. Joannis-Cassan, E. Duran, and A. Isambert, "Commercial applications of microalgae", *J. Biosci. Bioeng*, vol. 101, pp. 87-96, 2006. https://doi.org/10.1263/jbb.101.87.

[4] A. B. M. H. Sharif, A.B. Nasrulhaq, H. A. M. Majid, S. Chandran and R. Zuliana, *"Biodiesel production from waste cooking oil as environmental benefits and recycling process",* A Review. Asia Biofuel Conference Book, Dec. 11-13, Singapore, 2007.

[5] J. C. Quinn, K. Cattdon, N. Wagner and T. H. Bradley, "Current large-scale us biofuel potential from microalgae cultivated in photobioreactors", *Bioenergy Res.,* vol. 5 (1), pp. 49-60, 2012. doi: 10.1007/s12155-011-9165-z.

[6] X. P. Zhou, S. Yuan, C. Wu, B. Song and S. L. Peng, "Potential production and distribution of microalgae in China", *Renewable Sustainable Energy,* vol. 5, 053101, 2013. https://doi.org/10.1063/1.4817757.

[7] H. C. Kamrul, N. Nahar and K. D. Ujjwal "The Growth Factors Involved in Microalgae Cultivation for Biofuel Production: A Review", *Computational Water, Energy, and Environmental Engineering,* vol. 9(04), 185-215, 2020. doi: 10.4236/cweee.2020.94012.

[8] X. Wu and J. C. Merchuk, "Simulation of Algae Growth in a Bench Scale Internal Loop Airlift Reactor", *Chemical Engineering Science,* vol. vol. 59, pp. 2899-2912, 2004. doi: doi.org/10.1016/j.ces.2004.02.019.

[9] S. G. Arnol, A. A. Daniel, P. A. Juan, C. A. Gόmez-Pérez and E. Jairo, Helical Tubular Photobioreactor Design Using Computational Fluid Dynamics (*Helical Tubular Photobioreactor Design Using Computational Fluid Dynamics*), CT&F - Ciencia, Tecnología y Futuro, vol. 10(1), pp. 123-130, 2020. https://doi.org/10.29047/01225383.117.

[10] M. Bekirogullari, j. Pitman, C. Theodoropoulos"Integrated computational and experimental studies of microalgal production of fuels and chemicals", In: K.V. Gernaey, K. H. J., G. Rafiqul (Eds), *Computer Aided Chemical Engineering,* Elsevier, 2015. https://doi.org/10.1016/B978-0-444-63576-1.50093-5.

[11] J. F. Andrews, "A mathematical model for the continuous culture of microorganisms utilizing inhibitory substates", *Biotechnology and Bioengineering,* vol. 10(6), pp. 707-723, 1968. https://doi.org/10.1002/bit.260100602.

[12] C. N. Economou, G. Aggelis, S. Pavlou and D. V. Vayenas, "Modeling of single-cell oil production under nitrogen-limited and substrate inhibition conditions", *Biotechnol Bioeng.,* vol. 108(5), pp. 1049-1055, 2011. doi: 10.1002/bit.23026.

[13] C. O. James, Y. Hirokazu, and T. Hideo, "Kinetic study on light-limited batch cultivation of photosynthetic cells", *Journal of Fermentation and Bioengineering,* vol. 80 (3), pp. 259-264, 1995. doi: https://doi.org/10.1016/0922-338X(95)90826-L.

[14] O. James, H. H. Charles, W. Hillier, H. Chen, F. Kordbacheh, G. D. Price and A. D. Michael, "Fatty acid profiling of Chlamydomonas reinhardtii under nitrogen deprivation" *Bioresource Technology,* vol. 102(3), pp. 3343-3351, 2011. https://doi.org/10.1016/j.biortech.2010.11.051.

[15] T. Rahul, D. Yaşar and B. Paul "Kinetic modeling of photoautotropic growth and neutral lipid accumulation in terms of ammonium concentration in Chlamydomonas Reinhardtii", Bioresource Technology, vol. 119, pp. 419-424, 2012. https://doi.org/10.1016/j.biortech.2012.05.124.

[16] E. M. Grima, F. G. Camacho, J. A. S. Pérez, J. M. F. Sevilla, F. G. A. Fernandez, and A. C. Gomez, "A mathematical model of microalgal growth in light-limited chemostat culture", *Journal of Chemical Technology and Biotechnology,* vol. 61(2), pp. 167-173, 1994. https://doi.org/10.1002/jctb.280610212.

[17] Y. C. Jeon, C. W. Cho, and Y. S. Yun, "Measurement of microalgal photosynthetic activity depending on light intensity and quality" *Biochemical Engineering Journal,* vol. 27(2), pp. 127-131, 2005. https://doi.org/10.1016/j.bej.2005.08.017.

[18] S. Aiba, *"Growth kinetics of photosynthetic microorganisms. Microbial reactions"* Advances in Biochemical Engineering (ABE,volume 23), 2005.

[19] D. Zhang, P. Dechatiwongse, E. A. D. RioChanona, G. C. Maitland, K. Hellgradt and V. S. Vassiliadis, "Modelling of light and temperature influences on cyanobacterial growth and biohydrogen production" *Algal Research,* vol. 9, pp. 263-274, 2015. https://doi.org/10.1016/j.algal.2015.03.015.

[20] M. Bekirogullari, I. S. Fragkopoulos and J. K. Pittman, Theodoropoulos, "Production of lipid-based fuels and chemicals from microalgae: An integrated experimental and model-based optimization study", *Algal Research,* vol. 23, pp. 78-87, 2017. https://doi.org/10.1016/j.algal.2016.12.015.

[21] Q. Behet, A. Shilton and B. Guieysse, "Modeling the effects of light and temperature on algae growth: State of the art and critical assessment for productivity prediction during outdoor cultivation" *Biotechnology Advances,* vol. 31(8), pp. 1648-1663, 2013. https://doi.org/10.1016/j.biotechadv.2013.08.014.

[22] X. W. Zhang, F. Chen and M. R. Johns, "Kinetic models for heterotrophic growth of Chlamydomonas reinhardtii in batch and fed-batch cultures" *Process Biochem.,* vol. 35, pp. 385-389, 1999. https://doi.org/10.1016/S0032-9592(99)00082-5.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Nurun Nahar, carried out the research and simulation, organized the manuscript.
- Mohammad Iftekhar Monir simulated the results and reviewed the manuscript.
- Ujjwal Kumar Deb conceptualized the idea, and edited the Sections.

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Conflict of Interest

The authors declare no competing or conflict of interests in conducting this original research. Neither of the authors stands to gain financially from this work.