Vol. 14, Issue 11, November 2026
ISSN(P) 2347-5404 ISSN(O)2320 771X

Effect of Light Intensity on Growth of Common Algae

Aarthi B Pradhan

Assistant Professor

Naran Lala College of Professional And Applied Sciences- 396450

ORCID ID: https://orcid.org/0009-0007-4925-9813

Abstract — Light intensity impacts algal growth by regulating the availability of energy for photosynthesis. But increased light does not automatically result in proportional growth due to limitations like photosynthetic saturation, self-shading, and over-lighting. This study will explore the effects of light intensity on the growth of Chlorella vulgaris, a freshwater microalga, through controlled experiments and relevant literature. The data used here is simulated and needs to be replaced with actual experimental data prior to publication as empirical research. Five levels of photosynthetic photon flux density of 25, 50, 100, 200, and 400 µmol photons m^{-2} s^{-1} will be compared for 12 days with four independent culture flasks for each treatment. The initial biomass concentration of 0.100 g L^{-1} is kept constant. In the simulated dataset, biomass at the end of experiment will be found to grow from 0.290 ± 0.026 g L^{-1} in 25 µmol photons m^{-2} s^{-1} light intensity to 1.010 ± 0.052 g L^{-1} in 200 µmol photons m^{-2} s^{-1} light intensity, and then reduced to 0.710 ± 0.052 g L^{-1} in 400 µmol photons m^{-2} s^{-1} light intensity. One way ANOVA will give $F(4,15) = 167.47$, $p < 0.001$. The highest biomass productivity will be 0.0758 g L^{-1} day^{-1} at 200 µmol photons m^{-2} s^{-1}.

This will provide a consistent approach in the evaluation of non-linear growth while distinguishing a treatment-specific reduction in growth from direct evidence of photoinhibition.

Keywords — Chlorella vulgaris, light intensity, algal growth, photosynthesis, biomass productivity, photoinhibition

Introduction

Algae participate in aquatic primary production by producing organic matter using light energy and inorganic carbon. Algal growth affects the cycle of nutrients, oxygen production, and food web functions. They are also useful in various commercial applications like ingredients for food, feed for aquaculture, and other biological products. Spolaore et al. (2006) discuss the different commercial aspects of microalgal production and the need for matching production conditions with desired output.

Light is one of the main cultivation variables as it is the source of the energy required for carbon assimilation in photosynthesis. In case of low light, there is a restriction of biomass production by energy availability. With increased light, the rate of photosynthesis may increase until other limiting processes come into play. Exceeding this range of light might result in no effect or even stress to the organism. Carvalho et al. (2011) point out that light intensity should always be taken into account together with wavelength, light duration, and distribution of radiation in the culture.

Chlorella vulgaris is an ideal organism to examine these relationships. It is a unicellular green microalga with well-known cultivation methods and much scientific interest. Nevertheless, the response depends on the strain properties and cultivation conditions. The results obtained for one strain do not necessarily apply to all organisms called algae. Reviews by Safi et al. (2014) and Krienitz et al. (2015) provide the biological and practical significance of Chlorella along with its diversity.

This paper considers how a specific range of light intensities might affect biomass production under controlled conditions. It will also address a common problem with presenting growth statistics: precision without clear experimental details.

Literature Review

Light Availability and Photosynthetic Growth

According to Carvalho et al., 2011, light availability should be considered in the operation of photobioreactors. It is important to understand that appropriate light availability depends on the organisms grown as well as on the cultivation system. Despite the high intensity of light in a reactor, there may be poorly illuminated areas due to absorption and scattering of light in the cells. Therefore, the output of the lamps will not be sufficient to determine the lighting of the entire culture.

Photosynthetic Acclimation to Irradiance Changes

Photoacclimation occurs according to changes in photosynthesis-irradiance curves and photosynthetic pigments. Cells grown in different irradiances can change

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

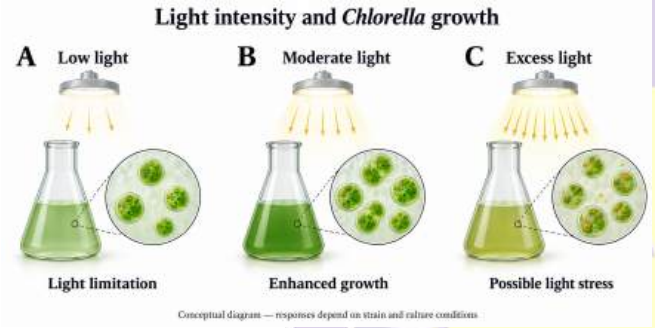
their ability to harvest light. In other words, cells may show a result of their short-term energy acquisition and long-term physiological adaptation. Identical illuminations may, thus, lead to different results in cultures grown in different conditions.

Cultivation Experiments for Chlorella

Metsoviti et al. studied growth of C. vulgaris in greenhouse and laboratory illuminations. It was shown that illuminations influence the growth rate as well as the biomass composition in experiments. The growth rate increased with the increase in artificial illuminations. This result is especially important since it prevents one from considering a decrease at particular illumination as the inherent characteristic of C. vulgaris.

General Information about C. vulgaris

Safi et al. discuss the cultivation, composition, processing, and applications of C. vulgaris. This source can serve as a broad base for selection of this organism for biomass studies. However, the productivity depends on the conditions of cultivation, which makes comparisons in different laboratories problematic due to different nutrient availability, temperature, and culture geometry.



Krienitz et al. (2015) position Chlorella in the context of biology and taxonomy. The discussion highlights the importance of strain identification. A green coloration of a freshwater culture does not guarantee that the culture contains C. vulgaris in the case of mixed communities.

Culture Geometry and Physiological Assessment

Ugwu et al. (2008) provide information on photobioreactor geometries and implications for cultivation. Dimensions of the reactor, mixing, and gas transfer affect the association between external lighting and biomass production. Thus, alteration of reactor geometry during light treatments becomes another variable.

Masojídek et al. (2021) investigate parameters that affect photosynthesis and growth in mass cultures. This work emphasizes the interplay between culture conditions and photosynthesis. Therefore, results from laboratory studies should be carefully interpreted prior to transfer to outdoor cultivation where the intensity of light varies during the day and interacts with culture depth and mixing.

Maxwell and Johnson (2000) give a detailed description of chlorophyll fluorescence and its role in evaluation of photosynthetic functioning. Baker (2008) elaborates on applications and interpretive considerations of chlorophyll fluorescence. These publications suggest the inclusion of physiological assessments in the study of excessive-light effect. Biomass will reveal the difference in growth between light regimes, but it cannot reveal the photosynthetic mechanism behind that difference.

These ten publications justify the experimental procedure that involves controlling culture conditions, direct photon flux measurement, replicating experiments independently, and distinguishing the assessment of growth from that of mechanism.

Research Objectives and Hypothesis

The main goal is the comparison of dry biomass at the end of the experiment between five light intensities. The goals of secondary nature are the calculation of average net specific growth rate, biomass productivity, and doubling time.

Null hypothesis: The means of day-12 biomass are identical between all five treatments. Alternative hypothesis: At least one treatment mean is different.

One secondary expectation is the nonlinearity of the response curve, where the increase in illumination has diminishing effect or causes negative growth at high levels.

Materials and Methods

Study Design and Data Status

Experimental design incorporates a completely randomized design with five light treatments and four independent culture vessels per treatment, which results in twenty experimental units. Numerical data below are simulated, not real. They serve to demonstrate the calculation procedure, but do not reveal any biological effects in the chosen strain.

Each culture vessel is an experimental unit. Technical replicates in one culture vessel should not be counted as new independent cultures.

Organism and Culture Preparation

Experimental design prescribes use of an authenticated C. vulgaris strain available from a recognized culture collection. Strain accession, source, and acquisition information should be recorded for the experiment.

Culture media is Bold's Basal Medium without an organic carbon source. Inoculation is done from a common, actively growing stock in equal portions to each culture vessel. Initial

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

dry biomass is standardized to 0.100 g L^{-1}. Culture identity and contamination are assessed microscopically before treatment assignment.

Light Treatments and Environmental Control

Illumination by white LEDs is regulated to achieve five target photon flux densities. Quantum sensor measures photosynthetic photon flux density in the range of photosynthetically active radiation at the fixed location on the illuminated vessel surface.

Table 1. Experimental conditions

Parameter	Protocol specification
Focal organism	Authenticated Chlorella vulgaris strain
Light intensities	25, 50, 100, 200, 400 µmol photons m^{-2} s^{-1}
Independent vessels	Four per treatment; 20 total
Vessel capacity	1 L
Initial working volume	500 mL
Initial biomass	0.100 g L^{-1}
Culture medium	Bold's Basal Medium
Temperature	Target 25 ± 1°C
Photoperiod	16 hours light and 8 hours dark
Initial pH	7.0 ± 0.2
Aeration	Equal flow of filtered air enriched to 1% CO_2
Duration	12 days
Primary endpoint	Day-12 dry biomass concentration

Independent illumination control or neutral-density screening allows randomized assignment of vessels without the need to associate each treatment with a fixed position on the shelves. Light barriers minimize light spill-over. Irradiance is measured after positioning and temperature is measured at the vessel level to determine lamp-induced heating effects.

Equal mixing and gas delivery are provided to the vessels. Evaporation is corrected with sterile water prior to measurements. Daily measurements include temperature, pH and any contamination or malfunction of equipment.

Measurement of Biomass

Optical density at 750 nm could be recorded daily as additional indicator of biomass accumulation. However, in this study the endpoint is measured gravimetrically and not indirectly by untested optical density conversion factor.

On day 12 a known volume of mixed culture is filtered on pre-weighed filters. The filtered biomass is washed to decrease the presence of residual medium salts and dried to a constant weight. Medium blank is treated in the same way. Concentration of dry biomass is measured as the difference between retained biomass mass and medium blank mass divided by filtered volume.

Sampling must be minimal and equal for all vessels. Sampled culture is not replenished with nutrient medium since replenishment will change nutrient concentrations and thus dynamics of the culture.

Growth calculations

Specific growth rate over the entire experimental period is:

$$\mu avg = [ln(X_{12}) - ln(X_0)]/12$$

where X_0 and X_{12} are the initial and final biomass concentrations in g L^{-1}. It is calculated over the full period including lag phase, exponential growth and deceleration phase and thus cannot be called exponential growth rate maximum.

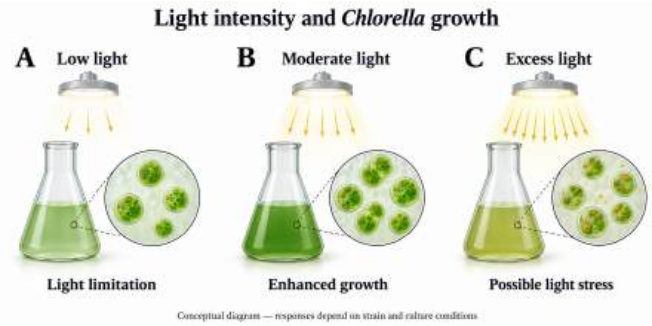
Productivity of biomass:

$$P = (X_{12} - X_0)/12$$

Doubling time:

$$td = ln(2)/\mu avg$$

Derived values at treatment level are calculated using the biomass means. For empirical submission, derived values at the vessel level also have to be preserved.



Analysis

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

A one-way analysis of variance is used to determine differences in the biomass on day 12. The Tukey honestly significant difference test analyzes the pairwise comparisons, where the familywise significance level is 0.05. Eta squared measures the proportion of the variation attributable to the treatment.

A proper empirical analysis needs to analyze residual plots, variance structure, and influential data points. As there are only four replicates for each treatment, assumptions tests are not diagnostic in this case. If required, an appropriate alternative can be used instead of the standard ANOVA.

Results

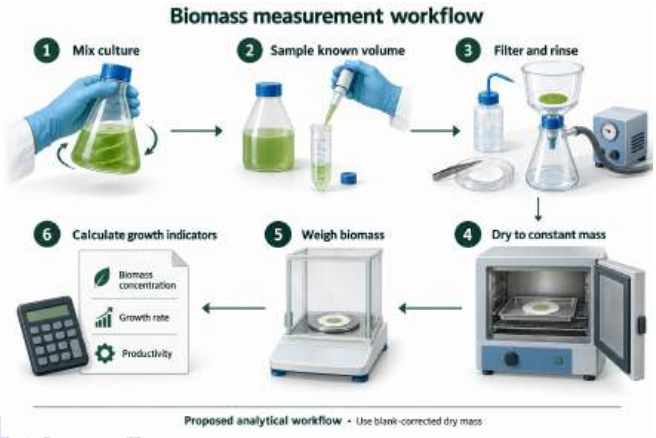
Biomass Concentration in the End

The biomass in the end increases until treatment four and decreases at the highest intensity. All treatments are above the initial biomass concentration.

Table 2. Simulated day-12 biomass concentrations

Light intensity, µmol photons m^{-2} s^{-1}	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Mean ± SD, g L^{-1}
25	0.260	0.280	0.300	0.320	0.290 ± 0.026
50	0.480	0.510	0.530	0.560	0.520 ± 0.034
100	0.760	0.790	0.830	0.860	0.810 ± 0.044
200	0.950	0.990	1.030	1.070	1.010 ± 0.052
400	0.650	0.690	0.730	0.770	0.710 ± 0.052

The 200 µmol photons m^{-2} s^{-1} treatment has 3.48 times the final biomass of the lowest-light treatment. Increasing intensity from 100 to 200 µmol photons m^{-2} s^{-1} corresponds to a 24.7% increase in final biomass. Increasing intensity from 200 to 400 µmol photons m^{-2} s^{-1} corresponds to a 29.7% decrease.



Growth Rate and Productivity

Growth calculations follow the same ranking as final biomass because initial concentration and duration are identical across treatments.

Table 3. Calculated growth indicators from simulated treatment means

Light intensity, µmol photons m^{-2} s^{-1}	Average net specific growth rate, day^{-1}	Equivalent doubling time, days	Biomass productivity, g L^{-1} day^{-1}
25	0.089	7.81	0.0158
50	0.137	5.05	0.0350
100	0.174	3.98	0.0592
200	0.193	3.60	0.0758
400	0.163	4.24	0.0508

Maximum calculated productivity is reached at 200 µmol photons m^{-2} s^{-1}. Positive growth rate at 400 µmol photons m^{-2} s^{-1} implies net biomass accumulation despite its lower endpoint compared to the 200 treatment.

Comparison of Treatment Groups

ANOVA with the 20 simulated endpoints results in $F(4,15) = 167.47$, $p < 0.001$, with $\eta^2 = 0.978$. The null hypothesis is thus rejected for the simulated dataset. This is a feature of the provided numbers and not the proof of a finding from a performed experiment.

Tukey-corrected comparisons differentiate all treatment groups at the 0.05 level. The closest pair is 100 and 400 µmol photons m^{-2} s^{-1}, with adjusted $p = 0.032$. The 200 versus 400 comparison has corrected $p < 0.001$.

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Discussion

Interpretation of the Growth Pattern

It matches a shift from insufficient illumination towards increasing biomass production and a subsequent deterioration at the highest exposure level. However, assignment of a biological meaning to the data does not mean an experimental validation of the pattern.

Low-light treatment corresponds to the light supply which could be the limiting factor of accumulation. Increase in the biomass through intermediate intensities would match the increased energy supply, as long as carbon, nutrients, and temperature are appropriate. Photoacclimation could affect this relation during the cultivation, as explained by MacIntyre et al. (2002).

The lower endpoint at 400 µmol photons m^{-2} s^{-1} allows for the conclusion about lower performance of this treatment in the given data set. It does not prove photoinhibition. Difference in temperature, pH value, depletion of nutrients, carbon, or ununiform illumination could also affect the results in an experiment.

Comparison with Literature

Metsoviti et al. observed increased growth with higher artificial irradiance in the cultivation system. This means that the decrease in growth with the increase in the artificial irradiance demonstrated in the present simulation is not the reproduction of the given result. It rather demonstrates the necessity to include the strain, light spectrum, reactor construction and other environmental factors in the description of the optimal irradiance intensity.

Geometry of the culture plays an important role in interpretation. Dense culture prevents the cells from being exposed to light, while mixing causes them to move between dark and bright zones. Ugwu et al. and Masojídek et al. explain the physical and physiological background of this process. Intensity which seems excessive in a shallow and diluted culture might behave differently in a deeper or denser one.

Practical Implications

Among the simulated intensities, 200 µmol photons m^{-2} s^{-1} generates the largest biomass. It should be described as the best tested intensity, but not as the exact optimum. The treatments at different intensities between 100 and 400 should be additionally introduced for precise determination of the point of maximal response.

This comparison also illustrates the difference between biomass production and energy efficiency. The higher biomass does not mean the most economical regime of illumination. Consumption of electricity, illuminated area, operating time and harvesting costs are necessary for the economic analysis.

Limitations and Recommendations for Future Research

The major limitation of the analysis is that the provided dataset is simulated. No physiological conclusions regarding the specific strain could be made without direct measurements. The other limitations of the suggested research design include only one strain, the short batch cultivation, and only four independent cultures per each treatment.

Endpoint data do not show when differences in growth appear. The future research should collect daily measurements for each vessel and calculate the exponential phase growth during a justified time period. Residual nitrate, phosphate, dissolved oxygen and pH values will help to identify limiting factors of growth.

Dark-adapted chlorophyll fluorescence, oxygen evolution and recovery from the lower-light exposure will allow for better study of the stress due to excessive light. Measurement of chlorophyll fluorescence needs standardization and careful interpretation as emphasized by Maxwell and Johnson and Baker. Oxford Academic



Conclusion

Light intensity is a key factor in algal growth, but it is affected by biological and operational factors. In the fabricated data, C. vulgaris achieves maximum final biomass at light intensity of 200 µmol photons m^{-2} s^{-1}, with average productivity equal to 0.0758 g L^{-1} day^{-1}. The most intensive light intensity results in low biomass, although this cannot prove photoinhibition alone. The experimental approach allows for standardized endpoints, calculations, and analysis for subsequent replacement with real data.

References

- *Baker, N. R. (2008). Chlorophyll fluorescence: A probe of photosynthesis in vivo. Annual Review of Plant Biology, 59, 89–113. DOI: 10.1146/annurev.arplant.59.032607.092759.*

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

- *Carvalho, A. P., Silva, S. O., Baptista, J. M., & Malcata, F. X. (2011). Light requirements in microalgal photobioreactors: An overview of biophotonic aspects. Applied Microbiology and Biotechnology, 89, 1275–1288. DOI: 10.1007/s00253-010-3047-8.*
- *Krienitz, L., Huss, V. A. R., & Bock, C. (2015). Chlorella: 125 years of the green survivalist. Trends in Plant Science, 20(2), 67–69. DOI: 10.1016/j.tplants.2014.11.005.*
- *MacIntyre, H. L., Kana, T. M., Anning, T., & Geider, R. J. (2002). Photoacclimation of photosynthesis irradiance response curves and photosynthetic pigments in microalgae and cyanobacteria. Journal of Phycology, 38(1), 17–38. DOI: 10.1046/j.1529-8817.2002.00094.x.*
- *Masojídek, J., Ranglová, K., Lakatos, G. E., Silva Benavides, A. M., & Torzillo, G. (2021). Variables governing photosynthesis and growth in microalgae mass cultures. Processes, 9(5), 820. DOI: 10.3390/pr9050820.*
- *Maxwell, K., & Johnson, G. N. (2000). Chlorophyll fluorescence—A practical guide. Journal of Experimental Botany, 51(345), 659–668. DOI: 10.1093/jexbot/51.345.659.*
- *Metsoviti, M. N., Papapolymerou, G., Karapanagiotidis, I. T., & Katsoulas, N. (2020). Effect of light intensity and quality on growth rate and composition of Chlorella vulgaris. Plants, 9(1), 31. DOI: 10.3390/plants9010031.*
- *Safi, C., Zebib, B., Merah, O., Pontalier, P. Y., & Vaca-Garcia, C. (2014). Morphology, composition, production, processing and applications of Chlorella vulgaris: A review. Renewable and Sustainable Energy Reviews, 35, 265–278. DOI: 10.1016/j.rser.2014.04.007.*
- *Spolaore, P., Joannis-Cassan, C., Duran, E., & Isambert, A. (2006). Commercial applications of microalgae. Journal of Bioscience and Bioengineering, 101(2), 87–96. DOI: 10.1263/jbb.101.87.*
- *Ugwu, C. U., Aoyagi, H., & Uchiyama, H. (2008). Photobioreactors for mass cultivation of algae. Bioresource Technology, 99(10), 4021–4028. DOI: 10.1016/j.biortech.2007.01.046.*

2347-5404
IJRHS
ESTD.2013

© 2026. This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0).