# Green microalgae in intermittent light: a meta-analysis assisted by machine learning Supplementary materials

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**Microalgae** | **Light** | **Intermittent** | **Frequency** | **Machine learning**
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## Presentation

Please find the tables agglomerating the literature survey results when dissolved gas was used as monitoring protocol.

## References

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**Table 1.** All data collected from studies conducted in medium frequency with the photosynthesis rate ($P_{O_2}$) as the output variable. The table lists the study microorganism, the experimental device used to adapt the culture and measure the $P_{O_2}$, the parameters of the L/D cycles as well as the experimental results with their coefficient of variation if known (N.A. if not available). The photosynthesis rate presented is weighted by the quantity of light. The reference to continuous light appears as CL. (a) Oxygen evolution rate in $gO_2/g/h$ ; (b) Oxygen evolution rate in $\mu molO_2/g/s$ ; (c) Oxygen evolution rate in $mgO_2/g/h$ ; (d) Oxygen evolution rate in $molO_2/g/s$ and (e) Normalized oxygen evolution rate: fraction of the oxygen evolution rate in flashing light on the continuous one.

| Studied microalga | Subculturing | Monitoring device | $I_{avg}$ (µmolE/m²/s) | $\tau_c$ (ms) | $\varepsilon$ (-) | Weighted $P_{O_2}$ | Experimental CV (%) | $\eta$ (%) | References |
|---|---|---|---|---|---|---|---|---|---|
| *Chlamydomonas reinhardtii CC 1690 wild type 21 gr mt +* | PBR design: rectangular PBR (70 mL working volume) | Oxygen monitor set-up: small cylindrical stirred vial | 650 | CL | 1 | 0.943 | <10 % | - | (1) [a] |
| | Optical light path: 3 cm | Light source: halogen lamp | 325 | 6.1 | 0.5 | 1.284 | <10 % | 36 | |
| | Light source: halogen lamp | Protocol: 10 min of dark adaptation, then the sample is exposed for 20 min to increasing light intensities | 325 | 14.5 | 0.5 | 1.270 | <10 % | 35 | |
| | Illumination protocol: culture illuminated with a 16/8 h day-night cycle. During the 16 h period, the cells are exposed to different L/D cycles | | 325 | 24.3 | 0.5 | 1.322 | <10 % | 40 | |
| | Cultivation mode: turbidostat (0.17 <OD680nm <0.25) | | 520 | 15.2 | 0.8 | 1.078 | <10 % | 14 | |
| *Chlamydomonas reinhardtii CC-124 wild type mt-137c* | PBR design: flat PBR (375 mL working volume) | Oxygen monitor set-up: consists of 3 chambers (2 water jackets and 1 measurement chamber at the middle) | 58 | CL | 1 | 0.31 | 10 % | - | (2) [b] |
| | Optical light path: 25 mm | Optical light path: 15 mm | 58 | 0.2 | 0.05 | 0.22 | <10 % | -29 | |
| | Light source: red LEDs (630 nm) | Light source: red LEDs (620 nm) | 113 | CL | 1 | 0.67 | <10 % | - | |
| | Cultivation mode: turbidostat (set point: 60% of the maximal flux without algae) | Protocol: sample taken from the flat PBR during steady-state operation | 113 | 0.2 | 0.1 | 0.46 | <10 % | -31 | |
| | | | 227 | CL | 1 | 1.24 | <10 % | - | |
| | | | 227 | 0.2 | 0.2 | 0.82 | <10 % | -34 | |
| | | | 559 | CL | 1 | 1.80 | <10 % | - | |
| | | | 559 | 0.2 | 0.5 | 1.55 | <10 % | -14 | |
| *Chlamydomonas reinhardtii wild type strain coded 21 gr* | PBR design: glass air-lift loop PBR (0.6 L working volume) | Oxygen monitor set-up: small reaction vessel in a closed cabinet | 240 | CL | 1 | 248 | N.A. | - | (3) [c] |
| | Light source: fluorescent light tubes | | 158 | 12.9 | 0.66 | 322 | N.A. | 30 | |
| | Illumination protocol: PBR placed in a closed cabinet. The dark period obtained with a part of the PBR covered with aluminum foil | Light source: halogen lamp | 158.4 | CL | 1 | 196 | N.A. | - | |
| | | | 158.4 | 12.9 | 0.66 | 321 | N.A. | 8 | |
| | Cultivation mode: turbidostat (set point: 70% of the maximal flux without algae) | | 198 | CL | 1 | 225 | N.A. | - | |
| | | | 198 | 12.9 | 0.66 | 355 | N.A. | 4 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 396 | CL | 1 | 286 | N.A. | - | |
| | | | 396 | 12.9 | 0.66 | 405 | N.A. | -7 | |
| | | | 594 | CL | 1 | 295 | N.A. | - | |
| | | | 594 | 12.9 | 0.66 | 409 | N.A. | -9 | |
| *Scenedesmus almeriensis* CCAP 276/24 | PBR design: bubble column PBR (1.8 L working volume)<br>Optical light path: 8 cm<br>Light source: fluorescent light tubes<br>Cultivation mode: semi-continuous (C=1.8 g/L) | Oxygen monitor set-up: transparent glass tank<br>Optical light path: 1 cm<br>Light source: white LEDs<br>Protocol: cell concentration of 0.1 g/L | 63 | CL | 1 | 4.617E-07 | N.A. | - | (4) [d] |
| | | | 63 | 10 | 0.05 | 2.142E-06 | N.A. | -77 | |
| | | | 63 | 1 | 0.05 | 6.290E-06 | N.A. | -32 | |
| | | | 67.8 | CL | 1 | 4.963E-07 | N.A. | - | |
| | | | 67.8 | 10 | 0.1 | 2.052E-06 | N.A. | -59 | |
| | | | 101.05 | CL | 1 | 7.324E-07 | N.A. | - | |
| | | | 101.05 | 1 | 0.05 | 7.150E-06 | N.A. | -51 | |
| | | | 101.05 | 1 | 0.05 | 6.242E-06 | N.A. | -57 | |
| | | | 126 | CL | 1 | 9.048E-07 | N.A. | - | |
| | | | 126 | 10 | 0.1 | 1.782E-06 | N.A. | -80 | |
| | | | 126 | 1 | 0.1 | 3.082E-06 | N.A. | -66 | |
| | | | 135.6 | CL | 1 | 9.697E-07 | N.A. | - | |
| | | | 135.6 | 10 | 0.2 | 1.723E-06 | N.A. | -65 | |
| | | | 135.6 | 1 | 0.2 | 3.435E-06 | N.A. | -29 | |
| | | | 202.1 | CL | 1 | 1.386E-06 | N.A. | - | |
| | | | 202.1 | 10 | 0.1 | 2.262E-06 | N.A. | -84 | |
| | | | 202.1 | 1 | 0.1 | 4.675E-06 | N.A. | -66 | |
| | | | 252 | CL | 1 | 1.640E-06 | N.A. | - | |
| | | | 252 | 10 | 0.2 | 1.801E-06 | N.A. | -78 | |
| | | | 252 | 1 | 0.2 | 4.014E-06 | N.A. | -51 | |
| | | | 339 | CL | 1 | 1.911E-06 | N.A. | - | |
| | | | 339 | 10 | 0.5 | 1.996E-06 | N.A. | -48 | |
| | | | 339 | 1 | 0.5 | 2.560E-06 | N.A. | -33 | |
| | | | 404.2 | CL | 1 | 2.007E-06 | N.A. | - | |
| | | | 404.2 | 10 | 0.2 | 2.154E-06 | N.A. | -79 | |
| | | | 404.2 | 10 | 0.2 | 1.455E-06 | N.A. | -86 | |
| | | | 404.2 | 1 | 0.2 | 3.590E-06 | N.A. | -64 | |
| | | | 630 | CL | 1 | 2.119E-06 | N.A. | - | |
| | | | 630 | 10 | 0.5 | 1.721E-06 | N.A. | -59 | |
| | | | 630 | 1 | 0.5 | 2.640E-06 | N.A. | -38 | |

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|---|---|---|---|---|---|---|---|---|
| | | | 1010.5 | CL | 1 | 2.161E-06 | N.A. | - | |
| | | | 1010.5 | 10 | 0.5 | 2.184E-06 | N.A. | -50 | |
| | PBR design: bubble column PBR (2 L working volume) | Oxygen monitor set-up: flat panel PBR | 1000 | 1.000 | 0.10 | -0.0162 | N.A. | -102 | |
| | Light source: LEDs | Optical light path: 2 cm | 1000 | 0.500 | 0.10 | -0.0708 | N.A. | -107 | |
| | Illumination protocol: PBR placed in a climate chamber | Light source: LEDs | 1000 | 0.333 | 0.10 | 0.0343 | N.A. | -97 | |
| | | | 1000 | 0.250 | 0.10 | 0.0721 | N.A. | -93 | |
| | | | 1000 | 0.200 | 0.10 | 0.1088 | N.A. | -89 | |
| | | | 1000 | 0.167 | 0.10 | 0.1112 | N.A. | -89 | |
| | | | 1000 | 0.143 | 0.10 | 0.1237 | N.A. | -88 | |
| | | | 1000 | 0.125 | 0.10 | 0.1832 | N.A. | -82 | |
| | | | 1000 | 0.111 | 0.10 | 0.1729 | N.A. | -83 | |
| | | | 500 | 0.250 | 0.03 | 0.0009 | N.A. | -100 | |
| | | | 500 | 0.200 | 0.03 | -0.0800 | N.A. | -108 | |
| *Tetraselmis chui* SAG 19.52 | | | 500 | 0.167 | 0.03 | -0.0683 | N.A. | -107 | (5) [e] |
| | | | 500 | 0.143 | 0.03 | -0.0658 | N.A. | -107 | |
| | | Protocol: after one day of acclimation in the bubble column PBR, measurement for 10 to 20 min | 500 | 0.125 | 0.03 | -0.0462 | N.A. | -105 | |
| | Cultivation mode: continuous (C =0.13 g/L) | | 500 | 0.111 | 0.03 | -0.0785 | N.A. | -108 | |
| | | | 500 | 1.000 | 0.10 | -0.0676 | N.A. | -107 | |
| | | | 500 | 0.500 | 0.10 | 0.0000 | N.A. | -100 | |
| | | | 500 | 0.333 | 0.10 | 0.0374 | N.A. | -96 | |
| | | | 500 | 0.250 | 0.10 | 0.0588 | N.A. | -94 | |
| | | | 500 | 0.200 | 0.10 | 0.0959 | N.A. | -90 | |
| | | | 500 | 0.167 | 0.10 | 0.1105 | N.A. | -89 | |
| | | | 500 | 0.143 | 0.10 | 0.1412 | N.A. | -86 | |
| | | | 500 | 0.125 | 0.10 | 0.2081 | N.A. | -79 | |
| | | | 500 | 0.111 | 0.10 | 0.2098 | N.A. | -79 | |
| | | | 1000 | 1.000 | 0.100 | -0.01622 | N.A. | -102 | |
| | | | 1000 | 0.500 | 0.100 | -0.07083 | N.A. | -107 | |
| | | | 1000 | 0.333 | 0.100 | 0.03433 | N.A. | -97 | |
| | | | 1000 | 0.250 | 0.100 | 0.07215 | N.A. | -93 | |
| | | | 1000 | 0.200 | 0.100 | 0.10883 | N.A. | -89 | |
| | | | 1000 | 0.167 | 0.100 | 0.11122 | N.A. | -89 | |
| | | | 1000 | 0.143 | 0.100 | 0.12367 | N.A. | -88 | |
| | | | 1000 | 0.125 | 0.100 | 0.18320 | N.A. | -82 | |

| | | | | | |
|---|---|---|---|---|---|
| 1000 | 0.111 | 0.100 | 0.17290 | N.A. | -83 |
| 500 | 0.250 | 0.030 | 0.00090 | N.A. | -100 |
| 500 | 0.200 | 0.030 | -0.08004 | N.A. | -108 |
| 500 | 0.167 | 0.030 | -0.06830 | N.A. | -107 |
| 500 | 0.143 | 0.030 | -0.06577 | N.A. | -107 |
| 500 | 0.125 | 0.030 | -0.04620 | N.A. | -105 |
| 500 | 0.111 | 0.030 | -0.07853 | N.A. | -108 |

**Table 2.** All data collected from studies conducted in high frequency with the photosynthesis rate ($P_{O_2}$) as the output variable. For reasons of readability, the results obtained in the study of Schulze et al. (5) are not presented in this table. The table lists the study microorganism, the experimental device used to adapt the culture and measure the $P_{O_2}$, the parameters of the L/D cycles as well as the experimental results with their coefficient of variation if known (N.A. if not available). The photosynthesis rate presented is weighted by the quantity of light. The reference to continuous light appears as CL. (a) Oxygen evolution rate in $\mu molO_2/g/s$ ; (b) Oxygen evolution rate in $\mu MO_2/mM(Chl)/s$ and (c) Oxygen evolution rate in $molO_2/g/s$.

| Studied microalga | Subculturing | Monitoring device | $I_{avg}$ (µmolE/m²/s) | Frequency (Hz) | $\varepsilon$ (-) | Weighted $P_{O_2}$ | Experimental CV (%) | $\eta$ (%) | References |
|---|---|---|---|---|---|---|---|---|---|
| *Chlamydomonas reinhardtii CC-124 wild type mt-137c* | PBR design: flat PBR (375 mL working volume) | Oxygen monitor set-up: consists of 3 chambers (2 water jackets and 1 measurement chamber at the middle) | 58 | CL | 1 | 0.31 | 10 | - | (2) [a] |
| | Optical light path: 25 mm | Optical light path: 15 mm | 58 | 10 | 0.05 | 0.27 | <10 % | -13 | |
| | Light source: red LEDs (630 nm) | Light source: red LEDs (620 nm) | 67 | CL | 1 | 0.37 | <10 % | - | |
| | | | 67 | 50 | 0.05 | 0.37 | <10 % | 0 | |
| | | | 114 | CL | 1 | 0.68 | <10 % | - | |
| | | | 114 | 10 | 0.1 | 0.55 | <10 % | -19 | |
| | | | 118 | CL | 1 | 0.70 | <10 % | - | |
| | | | 118 | 50 | 0.1 | 0.70 | <10 % | 0 | |
| | Cultivation mode: turbidostat (set point: 60% of the maximal flux without algae) | Protocol: sample taken from the flat PBR during steady-state operation | 132 | CL | 1 | 0.78 | <10 % | - | |
| | | | 132 | 100 | 0.1 | 0.80 | <10 % | 3 | |
| | | | 227 | CL | 1 | 1.24 | <10 % | - | |
| | | | 227 | 10 | 0.2 | 0.87 | <10 % | -30 | |
| | | | 232 | CL | 1 | 1.26 | <10 % | - | |
| | | | 232 | 50 | 0.2 | 1.02 | <10 % | -19 | |
| | | | 238 | CL | 1 | 1.28 | <10 % | - | |
| | | | 238 | 100 | 0.2 | 1.36 | <10 % | 6 | |
| | | | 559 | CL | 1 | 1.80 | <10 % | - | |
| | | | 559 | 10 | 0.5 | 1.45 | <10 % | -19 | |
| | | | 557 | CL | 1 | 1.79 | <10 % | - | |
| | | | 557 | 50 | 0.5 | 1.59 | <10 % | -11 | |
| | | | 561 | CL | 1 | 1.80 | <10 % | - | |
| | | | 561 | 100 | 0.5 | 1.66 | <10 % | -8 | |
| *Chlorella vulgaris* | PBR design: column PBR (30 mL working volume) | Oxygen monitor set-up: 2 mL cuvette | 500 | CL | 1 | 49 | N.A. | - | (6) [b] |
| | Optical light path: 1.8 cm | | 500 | 5000 | 0.5 | 49 | N.A. | 0 | |
| | Light source: red LEDs (654 nm) | | 500 | 1000 | 0.5 | 49 | N.A. | 0 | |
| | | Light source: LEDs | 500 | 500 | 0.5 | 49 | N.A. | 0 | |
| | Cultivation mode: batch (culture diluted <20 µM chl a) | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | 500 | 100 | 0.5 | 48 | N.A. | -2 | |
| | | | 500 | 50 | 0.5 | 45 | N.A. | -8 | |
| | | | 500 | 10 | 0.5 | 38 | N.A. | -22 | |
| | | | 500 | 2000 | 0.2 | 49 | N.A. | 0 | |
| | | | 500 | 400 | 0.2 | 49 | N.A. | 0 | |
| | | | 500 | 200 | 0.2 | 45 | N.A. | -8 | |
| | | | 500 | 40 | 0.2 | 34 | N.A. | -31 | |
| | | | 500 | 20 | 0.2 | 19 | N.A. | -61 | |
| *Scenedesmus almeriensis CCAP 276/24* | PBR design: bubble column PBR (1.8 L working volume) | Oxygen monitor set-up: transparent glass tank | 63 | CL | 1 | 4.617E-07 | N.A. | - | (4) [c] |
| | Optical light path: 8 cm | Optical light path: 1 cm | 63 | 10 | 0.05 | 5.467E-07 | N.A. | 18 | |
| | Light source: fluorescent light tubes | Light source: white LEDs | 63 | 50 | 0.05 | 6.431E-07 | N.A. | 39 | |
| | | | 67.8 | CL | 1 | 4.963E-07 | N.A. | - | |
| | | | 67.8 | 10 | 0.1 | 6.227E-07 | N.A. | 26 | |
| | | | 67.8 | 20 | 0.1 | 6.788E-07 | N.A. | 37 | |
| | | | 67.8 | 50 | 0.1 | 7.197E-07 | N.A. | 45 | |
| | | | 101.05 | CL | 1 | 7.356E-07 | N.A. | - | |
| | | | 101.05 | 10 | 0.05 | 5.130E-07 | N.A. | -30 | |
| | | | 101.05 | 50 | 0.05 | 8.844E-07 | N.A. | 20 | |
| | Cultivation mode: semi-continuous (C=1.8 g/L) | Protocol: cell concentration of 0.1 g/L | 126 | CL | 1 | 9.048E-07 | N.A. | - | |
| | | | 126 | 20 | 0.1 | 9.572E-07 | N.A. | 6 | |
| | | | 135.6 | CL | 1 | 9.697E-07 | N.A. | - | |
| | | | 135.6 | 10 | 0.2 | 9.904E-07 | N.A. | 2 | |
| | | | 135.6 | 50 | 0.2 | 1.265E-06 | N.A. | 31 | |
| | | | 202.1 | CL | 1 | 1.386E-06 | N.A. | - | |
| | | | 202.1 | 10 | 0.1 | 2.220E-06 | N.A. | 60 | |
| | | | 202.1 | 50 | 0.1 | 1.487E-06 | N.A. | 7 | |
| | | | 252 | CL | 1 | 1.640E-06 | N.A. | - | |
| | | | 252 | 10 | 0.2 | 1.376E-06 | N.A. | -16 | |
| | | | 252 | 50 | 0.2 | 1.679E-06 | N.A. | 2 | |
| | | | 339 | CL | 1 | 1.911E-06 | N.A. | - | |
| | | | 339 | 10 | 0.5 | 1.422E-06 | N.A. | -26 | |
| | | | 339 | 50 | 0.5 | 1.796E-06 | N.A. | -6 | |
| | | | 404.2 | CL | 1 | 2.007E-06 | N.A. | - | |

| | | | | | |
|---|---|---|---|---|---|
| 404.2 | 10 | 0.2 | 1.263E-06 | N.A. | -37 |
| 404.2 | 20 | 0.2 | 1.355E-06 | N.A. | -33 |
| 630 | CL | 1 | 2.119E-06 | N.A. | - |
| 630 | 10 | 0.5 | 2.091E-06 | N.A. | -1 |