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# Oxygen Production During Photosynthesis in Aquatic Plant *Myriophyllum hippuroides*

**Abstract**

In this experiment western milfoil, a common fresh water plant, was used to determine the rate of oxygen production during photosynthesis. The rate was determined based on the amount of gaseous oxygen produced by a given number of plants over a period of time. The combined results of ten trials yielded an average oxygen production rate of 0.57μmol/m$^2$/s ± 0.016μmol/ m$^2$/s. This rate is comparable to those of various other aquatic plants, which vary from 0.1μmol/m$^2$/s to upwards of 5μmol/m$^2$/s [2].

**Introduction**

Photosynthesis is one of life's most important processes. It is necessary for transforming the sun's energy into the usable chemical form of carbohydrates and for the production of oxygen gas. Photosynthesis in aquatic environments differs slightly from photosynthesis in land plants [2]. This is due to the forms of carbon available for aquatic plants. In aqueous solutions, carbon is not only present in the form of $CO_2$, but also as $CO_3^{2-}$ ,$HCO_3^-$ and to a lesser extent $H_2CO_3$[2]. Aquatic plants use one or more of the available carbon sources along with water molecules and energy from the sun (or in the case of this experiment, an artificial light source) to create carbohydrates, water molecules and oxygen gas [4][2].

Laing W.A. And Browse J. A [2] discuss how the rate at which this reaction progresses depends on the concentrations of necessary reactants (in part determined by the pH of the water), the availability of various wavelengths of light and the temperature. Smith F.A. and Walker N.A. [4] discuss the additional factor of water currents, and show that this too has a massive impact on the rate of photosynthesis. During the course of these measurements, the availability of light and water currents were kept constant (each container sat on a surface that was slightly above ambient temperature, creating a convection current). Available light was also constant, provided by a fluorescent bulb. The other factors were however uncontrolled, and resulted in some variation in the rates of photosynthesis throughout the experiment.

**Methods**

Two identical 2L containers were filled with water and allowed to sit for a day. This allowed for at least some of the dissolved chlorine in the water to dissipate. This step was necessary to better mimic the natural habitat of the aquatic plant, and to minimize any potential negative side effects of high chlorine concentrations in the water, as chlorine is known to have negative effects on the growth rates and by extension rates of photosynthesis of some aquatic plants [1].

The milfoil plants were then placed in the two containers and given a day to adjust. The collecting apparatuses were then placed over each group of plants. They consisted of inverted funnels attached to graduated cylinders that had been filled with water. One graduated cylinder had a 10ml volume, with marked 0.1ml increments while the other had a 25ml volume with marked 0.5ml increments. This allowed for the oxygen gas that was produced by the plant to be collected in the cylinders so that the volume of oxygen produced could be measured. The containers were isolated from sunlight, as it was too variable a light source, and instead placed in front of a 15 Watt compact fluorescent light which was kept on for 14 hours a day.

Throughout the day, the amount of oxygen gas that had accumulated in the cylinder was recorded. Each morning the cylinders were refilled with water so that a new trial could be preformed. The experimental set up is shown in figure 1.

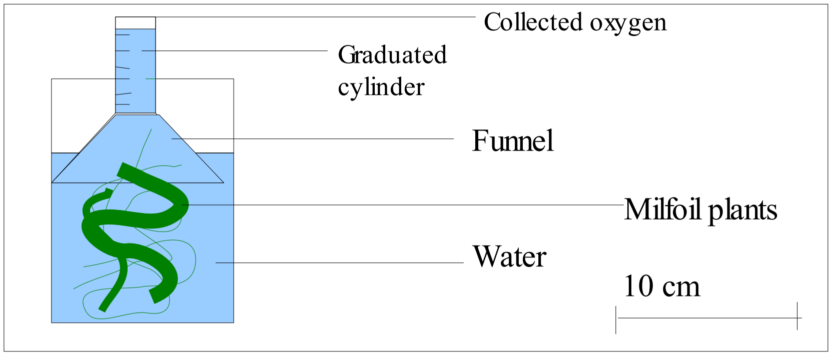


Fig. 1 Apparatus used for collecting oxygen during photosynthesis.

A total of 10 trials were preformed, always with two preformed in unison to maximize efficiency. No more than two trials were possible at a time because of limited available supplies. Of the 10 trials, three used four milfoil plants, three used nine plants and four used six plants. The water temperature varied with the ambient temperature of the room, which ranged from 23°C to 30°C.

**Results & Discussion**

Data was collected in the form of the volume of gas present in the graduated cylinder at a given time after the start of the trial. This raw data, displayed in figure 2, showed useful information about the system but had to be refined before it could be used to determine the rate of oxygen production.

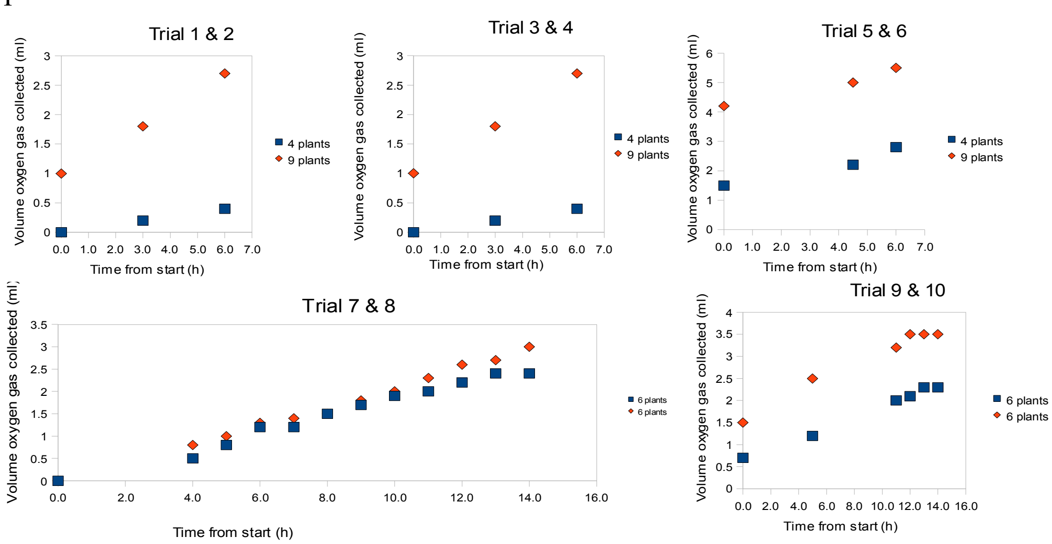


Fig 2 The amount of oxygen gas recorded in a graduated cylinder as photosynthesis occurred. The initial volumes are not pure oxygen, but a mixture of atmospheric gases that were trapped in the cylinder during set up of the trial. The points in red have an uncertainty of 0.2ml, while the points in green have an uncertainty of 0.05ml.

The vertical shift in the graphs in figure 2 are artifacts of the experimental method, since some gas was trapped in the graduated cylinders before photosynthesis began. The trends are linear for the shorter trials, but appear to have a negative concavity toward the end of the longer trials. It appears that the rate of photosynthesis decreases after around 12 consecutive hours of light (evident in trials 7 through 10). This may relate to changes in the plants physiology due to its circadian rhythm, and is beyond the scope of this paper.

To create a more meaningful representation of the data, the initial volume present in the cylinder was subtracted, giving the total volume of oxygen gas produced by the plants in the container over the course of the trial. This value was then divided by the number of plants present, to give a the oxygen produced over the course of each trial by each individual plant. All of the trials were plotted on the same axis allowing for a determination of the average rate of oxygen production per plant, as shown in figure 4.

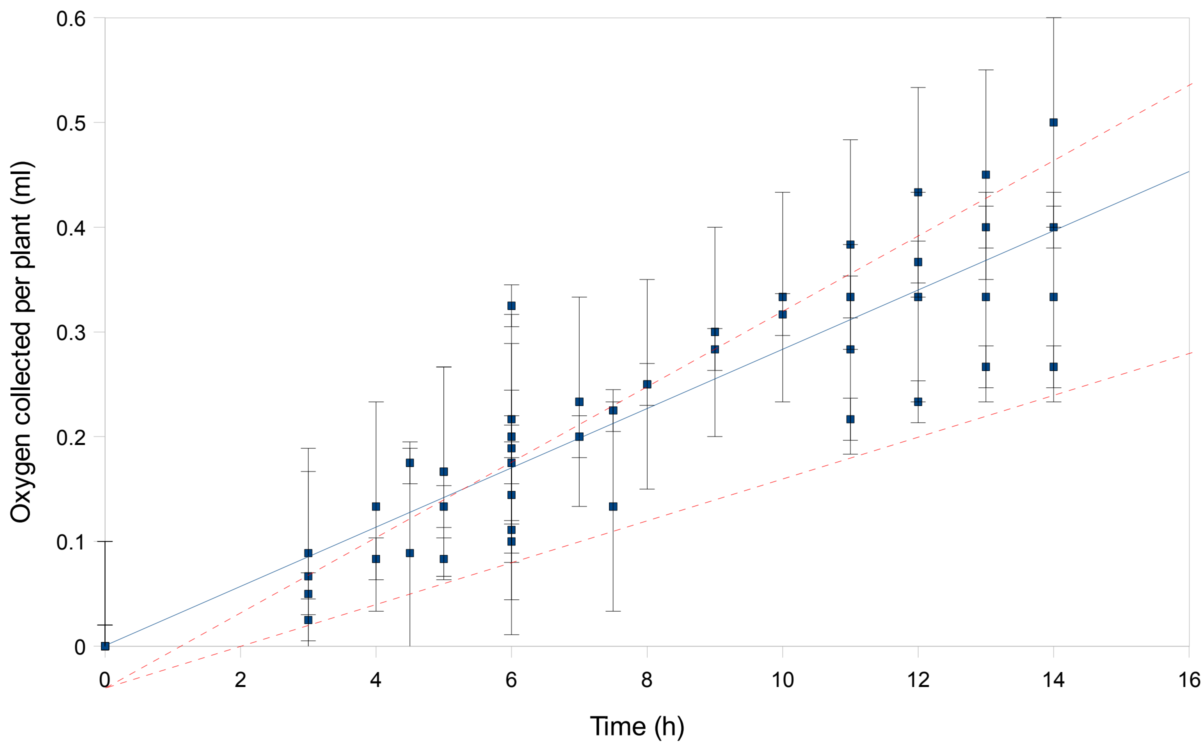


Fig 4 The volume of $O_2$ collected per plant over the course of each trial. Results for all ten trials shown with average(solid blue), min and max feasible (red dashed) trend lines.

To determine the likely range of values for the rate of oxygen production per plant, a minimum and a maximum feasible slope were determined. The average of these two slopes gave the best approximation of the rate, while the difference between the two gave a good approximation of the uncertainty. The minimum slope was determined to be 0.020ml/hour/plant while the maximum slope was determined to be 0.0357ml/hour/plant. The combined data showed an average trend of 0.028ml oxygen produced by each plant each hour plus or minus 0.0077ml/hour/plant.

Laing W.A. and Browse J. A [2] report photosynthesis rates (rate of $O_2$ production) of 0.71μmol/m$^2$/s to 2.01μmol/m$^2$/s, depending on the surrounding carbonate ion concentration, for the aquatic plant *Egeria densa*. Sand-Jensen [4] reports rates between 100nmol/m$^2$/s (0.1μmol/m$^2$/s) and 1200nmol/m$^2$/s (1.2μmol/m$^2$/s) for *Chara corallina*, depending on the pH of the plant's surroundings. A third report shows data on rates of $CO_2$ consumption by a wide variety of aquatic plants, which can be directly compared to $O_2$ production, since the two molecules appear in the stoichiometric photosynthesis equation in a one to one ratio [3]. Although the results vary from plant to plant and depending on the surrounding conditions, 67% of photosynthetic aquatic communities had photosynthesis rates below 5μmol/m$^2$/s [3]. This figure is not limited to aquatic plants, it includes algal and phytoplankton communities which can have photosynthetic rates upwards of 20μmol/m$^2$/s. The cells in aquatic plants have more diverse functions than those in other photosynthetic aquatic communities, with only a small portion of the cells being devoted specifically to carrying out photosynthesis. It is likely that the oxygen production rates for aquatic plants will be significantly lower than 5μmol/m$^2$/s[3].

To make a meaningful comparison between established rates of photosynthesis and the results obtained through this measurement, the results must first be converted into units of μmol/m$^2$/s. To do this, the volume of oxygen must be converted into an amount, using the ideal gas equation and assuming approximately standard pressure (P=100kPa) and a temperature of roughly 25°C (T=298K).

$$N=PV/RT \quad (1)$$

Using equation (1) the rate of 0.028ml/h/plant translates roughly to 0.113μmol/h/plant. The conversion to seconds is one of simply dividing this rate by 3600s/h, giving a rate of $3.14\times10^{-5}$μmol/s/plant. Finally, the rate must also be put in terms of the area of plant cover instead of the number of plants involved. To do this the approximate area covered by one plant was calculated. The funnel placed over the plants had a diameter of 0.065m, and therefor an area of 0.0033m$^2$. This area enclosed roughly six plants, meaning that one plant covered an area of about $5.5\times10^{-4}$m$^2$. After the conversion, the final rate is given as $5.7\times10^{-7}$mol/ m$^2$/s ± $1.6\times10^{-8}$mol/ m$^2$/s or 0.57μmol/m$^2$/s ± 0.016μmol/ m$^2$/s.

**Conclusion**

The determined photosynthesis rate of 0.57μmol/m$^2$/s ± 0.016μmol/ m$^2$/s is at the lower end of the rates shown in the literature. This could be attributed to several factors, the most likely of which is the fact that water was stagnant, in that there was very little current around the plants. This means that the amount of carbon available to the plants was likely lower than in the average aquatic system [4], because no new dissolved carbon was cycled into the water surrounding the plants. Additionally, there would have been a thick unstirred layer in the water surrounding the plants, meaning that once the carbonate ions close to the plant had been used up, it was unlikely that carbonate ions elsewhere in the solution would have been moved close to the plant's membranes to be taken up [4]. Smith F.A. and Walker N.A. [4] Conducted a series of experiments that showed that the photosynthesis rate of plants increases with increased water circulation, with rates dropping to 0μmol/ m$^2$/s after an extended period of time with no circulation [4]. So while the determined value is low, it is not unreasonably so. This rate tells us that western milfoil is not going to play a major role in the cycling of carbon dioxide and oxygen in an ecosystem unless there are extremely large quantities of it present.

References

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