The Effect of Initial Carbon Dioxide Concentration on the Rate of Photosynthesis in the Aquatic Plant *Elodea*

Introduction:

In the field of plant biology, one of the fundamental processes of life is photosynthesis. This process occurs through the fixation of carbon dioxide in the presence of water and may or may not require light (photosynthetic dark reactions can occur in the absence of light). The end result of photosynthesis is the production of organic materials, such as sugars and oxygen, which are necessary for the life processes of many organisms. Although the majority of plants carry out photosynthesis, they do so at different rates. The rate of photosynthesis is dependent upon several environmental factors, including temperature, amount of light present, amount of carbon dioxide present, and the color of the light. In this lab, the purpose was to manipulate one environmental factor to determine the effect on the process of photosynthesis. It was decided that the environmental factor to be tested would be the concentration of carbon dioxide initially present. Then a hypothesis was generated: An increase in the concentration of carbon dioxide initially present will lead to an increase in the rate of photosynthesis, and as a result, an increase in the amount of oxygen generated. Throughout the experiments, the aquatic plant *Elodea* was used to carry out photosynthesis. This particular plant is especially conducive to scientific experiments involving photosynthesis because of its ability to produce oxygen bubbles as it carries out photosynthesis, making it simple to monitor the rate of photosynthesis in an experiment.

Materials & Methods:

In this experiment, all other possible environmental factors, such as temperature, were kept constant, while the environmental factor to be tested was varied. To test the original hypothesis, different concentrations of sodium bicarbonate ($NaHCO_3$), a source of carbon dioxide, were used. Approximately three one inch sections of *Elodea* were cut with a razor blade. As the method of examining the rate of photosynthesis was counting the number of oxygen bubbles produced by the plants, special attention was paid to cutting the stem of the *Elodea* at an angle so that carbon dioxide bubbles could escape properly. Three graduated cylinders were each filled with 10 mL of solutions of 0.2% sodium bicarbonate, 0.1% sodium bicarbonate, and 0.0% sodium bicarbonate (pure water). These concentrations were accomplished by diluting a stock solution of 0.2% sodium bicarbonate with distilled water. All solutions used room temperature distilled water; therefore temperature was not a factor that was tested in this experiment. The three pieces were placed in the individual graduated cylinders. The number of bubbles that broke the surface of the water for each cylinder was counted during a five minute time period, and the results were recorded in a data chart. This was repeated for a total of five trials, with new pieces of *Elodea* being cut for each trial. During each of the trials, a bright lamp stationed approximately one foot away was aimed at the three cylinders to help stimulate the process of photosynthesis.

Results:

For each of the five trials, the rate of photosynthesis was measured by counting the number of oxygen bubbles that was produced by the *Elodea* plant. Bubbles were counted as they traveled up the cylinder and broke the surface. Table 1 shows the data chart for the number of bubbles observed at each particular concentration of sodium bicarbonate in the five trials.

	Trial Number				
Concentration of $NaHCO_3$	**1**	**2**	**3**	**4**	**5**
0.0 %	0	0	0	0	3
0.1 %	1	0	3	4	5
0.2 %	12	3	13	8	18

Table 1. Number of Bubbles Observed for Increasing Concentrations of $NaHCO_3$, a Source of Carbon Dioxide

Afterwards, the average number of oxygen bubbles observed for each concentration of sodium bicarbonate was calculated. This data can be seen below in Table 2. It was observed that the rate of photosynthesis steadily increased as the initial concentration of sodium bicarbonate increased.

Concentration of $NaHCO_3$	**Average Number of Oxygen Bubbles**
0.0%	0.6
0.1%	2.6
0.2%	10.8

Table 2. Average Number of O_2 Bubbles Observed for Each Concentration of $NaHCO_3$

Discussion:

As shown by the data in Tables 1 and 2 in the Results section, the number of oxygen bubbles generally increased as the initial concentration of sodium bicarbonate increased. Thus, one can conclude that the rate of photosynthesis is directly related to the concentration of sodium bicarbonate. The results seen in this experiment are therefore supportive of the original hypothesis presented in the introduction of the paper. Since

sodium bicarbonate acts as a source of carbon dioxide, one of the required starting materials for the process of photosynthesis, it was expected that solution with more sodium bicarbonate, and this more starting carbon dioxide, would lead to the production of more oxygen compared to a solution that had no sodium bicarbonate in it. Comparing the results seen with 0.0% and 0.2% sodium bicarbonate solutions (Table 1 and 2), it is apparent that there is a much greater amount of oxygen produced with the addition of more carbon dioxide at the start of the experiment. The average number of bubbles for pure water is less than 1, while the average for 0.2% sodium bicarbonate is 10.8 bubbles.

Based on the data shown in Table 1, it is evident that not every trial yielded ideal results. For instance, the results of Trial 2 show that the 0.2% sodium bicarbonate yielded 3 oxygen bubbles, an atypically low number for that particular concentration. Neither the 0.1% of the pure water solutions yielded any oxygen bubbles. There are several possible explanations for these results. As the rate of photosynthesis is measured by the amount of oxygen escaping in the form of bubbles from the stem of the *Elodea* plant, it is possible that there were problems with the stems of the plants. They may not have been cut at a sharp enough angle to allow the bubbles to escape, of they may have been blocked by some particles that were present in the plant. As the number of bubbles depends on the eyesight of individuals, it is also possible that human error is involved. Tiny bubbles of oxygen may have escaped the notice of the individuals performing the bubble counts.

In relation to the question of how photosynthesis is affected by the initial amount of carbon dioxide present, it would be interesting to further explore how different concentrations of sodium bicarbonate can increase the rate of oxygen produced. In the

experiments described in this paper, a stock solution of 0.2% sodium bicarbonate was used, so higher percentages of sodium bicarbonate could not be tested. Therefore, it would be useful to try percentages of sodium bicarbonate such as 0.5%, 0.75%, and 1.0%. Based on the results seen in this experiment, one would expect that increasing the percentage of sodium bicarbonate present would lead to an even greater increase in the rate of photosynthesis, and correspondingly, more oxygen bubbles produced. However, one would also expect that once the maximal rate of photosynthesis is reached, adding a higher concentration of sodium bicarbonate would not affect that rate of photosynthesis.

Literature Cited:

Qiu, Yin-Long. Bio 230 Lab Manual – Plant Biology, Fall 2006.