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# Purified Water: A CLoser Look at Bottled Waters and Their Claims

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Henry Piñango

Southern Adventist University
Southern Scholars
Senior Project
Advisor: Dr. Bruce Schilling

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## Abstract

The claims made by three bottled water manufacturers were checked through a series of tests. CHA™ (by Abundant Life CHA™ Water Company in Chattanooga, TN), Penta® (by Bio-hydration Research Lab, Inc.), and Mountain Fresh superoxygenated water (Collegedale, TN) were the subject of this study. Three tests were done on these samples: pH level, dissolved oxygen, and osmosis rate test. The pH level test confirmed the claim that CHA™ water is alkaline (pH = 9.6); the other samples tested had pH levels ranging from 6.5 to 7.6. The dissolved oxygen test compared the oxygen concentration of several water samples to that of Mountain Fresh superoxygenated water. Mountain Fresh superoxygenated water did not always give higher oxygen levels than other water samples such as tap water. On two different days the Mountain Fresh superoxygenated water purchased had levels that were less that 5% higher than tap water. On the occasions in which samples of Mountain Fresh superoxygenated water showed higher levels of oxygen, the levels of oxygen were only two times greater than tap water. The osmosis test showed that Penta® and RO water were the fastest at diffusing through the membrane of an egg. But Penta® and RO water were merely faster than CHA™ and tap water. While Penta® diffused an average of 4.03 grams of water in the first 30 minutes of the test, tap water diffused 3.6 grams of water. These tests show that perhaps the claims, with the exception of the alkalinity of CHA™ water, made by the manufacturers have been exaggerated.

## Introduction

The world of science is constantly making new of breakthroughs. Every year researchers from all over the world are able to find new and interesting inquiries which may improve life for humans. Among such investigations is the study of water: the colorless, tasteless, and odorless chemical which is most essential for living things on this planet. In pursuit of better understanding, researchers have spent countless hours trying to figure out how water behaves at the molecular level. This increase of attention towards the subject is driven by the benefits that water already brings to living things, especially humans. The natural benefits of water include, but are not limited to, on aid in loss of weight, revamping the immune system, getting rid of bodily wastes, and others.

In this experiment, some of the claims made by different water brands are tested. The claims of the three following bottled water brands were the main focus: CHA™ water (by

Abundant Life CHA™ Water Company in Chattanooga, TN), Penta® water (by Bio-hydration Research Lab, Inc.), and Mountain Fresh superoxygenated water (Collegedale, TN).

*CHA™ water*:

The name of this bottled water brand is an acronym for the properties the manufacturer claims it possesses. The letters C, H, and A in the name of the water stand for charge, hydration, and alkaline respectively.

CHA™ water, according to the manufacturer's website (1), goes through a process which makes it negatively charged. Once charged, CHA™ water emulates the negative charge found in the water from high altitude mountain springs. The product website goes on to explain that the negative charge of CHA™ water works as an antioxidant in the body.

Along with the property of negative charge, CHA™ water has optimal hydration. Once it arrives in the body, CHA™ water is supposed to hydrate the cells at a higher rate than any other type of water. This property is given to CHA™ water through, as the manufacturer states, a "proprietary process." The manufacturer also goes on to explain that tap water has large clusters of around 25 molecules of $H_2O$; this causes it to be inefficient at penetrating the cell wall in order to hydrate the cell. CHA™ water forms smaller clusters which easily penetrate the cell (1).

The third property found in CHA™ water, as described by the manufacturer, is alkalinity. CHA™ water is supposed to have a pH range of 8.5 to 10. The website claims that the alkalinity of CHA™ water gets rid of toxins and acids, which are products of cellular metabolism, from the body (1).

*Penta® water*:

Penta® water, according to the manufacturer, is the cleanest water in the world (2). It goes through an 11-hour, 13-step process, to remove all types of impurities. The 13-step process includes the following procedures: double UV light treatment, multimedia filtration, granular activated carbon filtration, 5-micron filtration, double reverse osmosis, deionization, 1-micron filtration, ozonation, double .2-micron filtration, and the patented "Penta Process." The main claim made by the manufacturer is that Penta® water will hydrate cells faster due to its purity (2).

*Superoxygenated water*:

Mountain Fresh Water company does not ship bottled water like the previous two manufacturers. Instead, Mountain Fresh Water installs water filtering stations in several supermarkets. At these stations, the public can buy purified, superoxygenated water. The machine used to obtain the water for this experiment is located at the Village Market in Collegedale, TN.

The purification of Mountain Fresh Water involves a seven stage process: sediment filtration, 2 activated charcoal filters, reverse osmosis, pH balancing filtration, UV sterilization, and superoxygenation. According to the manufacturer, Mountain Fresh superoxygenated water has up to five times the oxygen of tap water. This superoxygenation is believed to provide more oxygen to the bloodstream once absorbed by the capillaries that line the stomach (3).

In this research, three different types of tests were formulated in order to verify some of the claims of the bottled water manufacturers: pH level, amount of dissolved oxygen, and rate of osmosis through a membrane. The pH test checks the alkalinity of CHA™ water versus other types of water. The dissolved oxygen test examines and compares the amount of oxygen in superoxygenated water and other water samples. The osmosis rate test determines how much faster, if any different, Penta® and CHA™ water flow through a membrane (simulating cell hydration) compared to other samples. Each test was repeated two to three times and then averaged. CHA™, Penta®, and superoxygenated water samples are compared to: deionized, Aquafina (PepsiCo, Inc.), Dasani (Coca-Cola, Co.), reverse osmosis (RO), and tap water samples.

*pH level tests*:

The pH is a value taken to represent the acidity or alkalinity of a solution, usually aqueous. There are several ways of determining the pH level of a substance. Among the most popular tests to determine pH are indicator paper, titration, and use of a calibrated electronic pH meter. Indicator paper, by definition, is a small strip of compacted amorphous powder which changes color with acidity of solution (4). The use of this type of indicator in analytical chemistry is limited to where precision is not necessary. Titrations, on the other hand, are used in the laboratory as one of the most precise ways for determining the pH of a substance (4) and involve the use of acid/base chemical reactions to determine the acid content. A more sophisticated way of measuring pH in a substance is through the use of a calibrated electronic pH meter. The apparatus is calibrated by placing the electrode in a solution of known pH. The solution of known pH can be prepared by placing a pH buffer capsule in a predetermined amount of solution. Once calibrated, the pH meter is capable of accurately measuring the pH of a substance. The latter procedure was chosen to measure pH levels of substances in this experiment because it provides for a quicker and more accurate way of measuring pH levels.

*Dissolved Oxygen tests*:

Several methods for measuring oxygen levels in water have been developed. This research considered three different procedures: the Winkler titration, NMR relaxometry, and oxygen electrodes. The Winkler method consists of quantitatively oxidizing iodide ions to iodine – where oxygen is the main oxidizing agent (in the presence of an alkaline solution of manganese (II) ion). The iodine generated this way is determined by a titration with a standard thiosulfate solution. The end-point is determined by the visual aid of starch, a color indicator, which turns dark blue in the presence of iodine. The concentration of oxygen present in the sample can be determined from the titer (5). Another way of measuring oxygen levels in a water sample is through NMR (nuclear magnetic resonance) relaxometry. This method uses proton spin relaxation measurements for the determination of dissolved oxygen in water (6). A third way of conducting this test is through the use of an oxygen selective electrode. The electrode determines the amount of oxygen in the water sample by an electrochemical reaction which produces an electrical current proportional to the level of oxygen present. It is capable of measuring the oxygen concentration in the sample two ways: by concentration in units of mg/L and percent oxygen saturation. The oxygen concentration gives a numerical amount, or how many milligrams of oxygen there are per liter of solution. The percent oxygen saturation is the measured dissolved oxygen, in parts per million, divided by the equilibrium amount of oxygen that the water can hold at that particular temperature and atmospheric pressure, then multiplied by 100%. Because of its ease of use compared to the other methods, this research uses the oxygen electrode method to measure both the percent oxygen saturation and concentration.

Calibration of the oxygen electrode to determine oxygen concentration involves the use of a solution of known concentration. This involves equilibrating the oxygen in a water sample with the oxygen in the air. This equilibrium is described mathematically by Henry's law.

$$[O_2] = k \times P_{O2}$$

where $[O_2]$ is the oxygen concentration in the water in moles per liter; $P_{O2}$ is the atmospheric pressure of $O_2$ in the atmosphere; and k is known as Henry's law constant for water and has to be determined experimentally for any given temperature [1].

1. Schilling, B. Southern Adventist University, Collegedale, TN. Physical Chemistry I, 2005.

In order to figure out the oxygen concentration of the standard, both the Henry's law constant and the oxygen partial pressure are needed. The atmosphere is made up of several gases with the major ones being nitrogen, oxygen, argon, carbon dioxide, and water. There are a few more gases, but their levels represent a small fraction of the atmosphere. Through the use of Dalton's law of partial pressures the oxygen pressure can be related to the total atmospheric pressure by

$$P_{O2} = P_{air} \times X_{O2}$$

where $X_{O2}$ is known as the mole fraction of oxygen and has a value of .21 for dry air (8). The pressure of air can be acquired by subtracting the pressure of water from the total atmospheric pressure.

$$P_{air} = P_{tot} - P_{H2O}$$

The pressure of water vapor is given by

$$P_{H2O} = P_{H2O}^* \times RH$$

where $P_{H2O}^*$ is the water equilibrium vapor pressure and RH is the relative humidity found through the use of a sling cyclometer [1].

In order to calibrate the instrument, the measurements of the relative humidity, the atmospheric pressure (using a mercury barometer) and the room temperature are necessary. Once the temperature is known, tables are used to determine the water equilibrium vapor pressure (7) and the Henry's law constant for oxygen (9)

*Osmosis rate tests*:

There are several ways of testing the effectiveness of the diffusion of water samples through membranes. This research analyzed two methods of testing osmosis rates: diffusion of water through membranes on a thistle tube and diffusion of water through the membrane of a de-

1. Schilling, B. Southern Adventist University, Collegedale, TN. Physical Chemistry I, 2005.

shelled egg. The first involves the use of a thistle tube covered with either an animal or cellulose membrane. The thistle tube, once covered with the selected membrane, is filled with a sugar solution. The thistle tube is then placed in a beaker containing the water sample. Osmosis involves the flow of water across a membrane from low to high concentrations. Thus, the level of water in the thistle tube increases. The water sample with the best diffusion rate would be the one to flow in through the membrane of the thistle tube the quickest. Tim Wood of the Carolina Biological Supply Company suggests that this experiment is most effective for testing osmosis over a longer period of time – approx. two to three days [2]. Tests using this method produced no useable results and the method was abandoned. The other method for testing osmosis rate considered in this research involves the use of the membrane of an egg. Once the egg's shells are removed, the membrane of an egg is capable of simulating the properties of a human cell (12). Since the extent of this research is to compare the osmosis rates of the water samples under consideration in a short time interval of three hours, the egg experiment is the most fitting.

## Experimental

An IQ Scientific Instruments Dual pH Meter (model IQ150 with a solid state pH probe) was used to determine the pH of the different samples: deionized water – or $dH_2O$, tap water, Natural Springs water, Aquafina, Dasani, and CHA™ water refrigerated and at room temperature. Prior to use, the apparatus was calibrated according to the instructions in the operator's manual. The apparatus was calibrated with buffer standards of pH 4.00 and 10.00(±.02 at 25°C) which allows accurate measurement of the pH of the water samples.

A YSI Environmental 550A Dissolved Oxygen Instrument was used to determine the oxygen percent and concentration in tap water, lab prepared superoxygenated water, Dasani, and Mountain Fresh superoxygenated water. Each water sample was placed in a 400mL beaker on a

2. Martin, W. Carolina Biological Supply Company. Personal communication, 2005.

stirrer set to 100rpm. The purpose of the stirrer was to provide a constant flow of water across the oxygen electrode. The percent oxygen saturation and concentration of oxygen in each sample were determined in separate tests. The measurements for this test were recorded every minute for 45 minutes. The samples were then left uncovered for 48 hours and measured again. The same procedure was used for Mountain Fresh superoxygenated water one week after purchase. Lab prepared superoxygenated water was produced by bubbling oxygen into a container filled with $dH_2O$ for about 10 minutes.

The determination of oxygen percent saturation required a simple calibrating technique explained by the operator's manual. The apparatus was set to work at an altitude of 900 ft above sea level [3]. The salinity of the samples was set to 0 parts per million on the apparatus' settings.

The determination of oxygen concentration required a more complicated calibration process. The apparatus requires a standard solution of known oxygen concentration for calibration. The standard solution was prepared by letting a 400mL beaker filled with $dH_2O$ stand open in a room for 48 hours; this ensured that the oxygen concentration in the sitting water would be at equilibrium with the atmosphere. The oxygen concentration of the standard was determined as described in the introduction.

The next test analyzed the osmosis rates of the different water samples through the membrane of a chicken's egg. CHA™ – refrigerated and room temperature, reverse osmosis, Penta®, and tap water were studied in this section of the research. The first step involved removing the shells from the eggs. The eggs were left submerged for about 48 hours in vinegar – approximately 5% acetic acid. After the 48 hours, the shells were mostly dissolved; the remainder of the shell was gently rubbed off under cool water. Each egg was dried, weighed, and placed individually in the different water samples. Every 30 minutes for the first 3 hours,

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3. TVA map for Hickman Science Center. Southern Adventist University, Collegedale, TN. 1st Floor Hickman Science Center

the eggs were removed from the water, dried and weighed, and returned to the individual beakers. On the following day, 18 hours later, the eggs were weighed again. The test was repeated 5 times with each water sample.

## Results and Discussion

The pH values of the water samples gave varied results. The range of pH values in the samples tested was from 5.5, for Aquafina, to 9.6, for CHA™ water. Table I shows the pH test results.

**Table I: PH of water samples**

| Water Sample | Run 1 | Run 2 | Run 3 | Avg. |
|---|---|---|---|---|
| CHA™ (Room Temp.) | 9.60 | 9.58 | 9.60 | 9.59 |
| CHA™ (Refrigerated) | 9.61 | 9.59 | 9.62 | 9.61 |
| Dasani | 5.60 | 5.90 | 6.01 | 5.84 |
| Aquafina | 5.48 | 5.58 | 5.13 | 5.40 |
| Natural Springs | 7.37 | 7.56 | 7.49 | 7.47 |
| Tap | 6.92 | 7.02 | 6.99 | 6.98 |
| $dH_2O$ | 7.53 | 7.59 | 7.69 | 7.60 |

The pH test showed that most water samples had a pH in the range of 6.5 to 7.5. The only exceptions were Dasani, Aquafina, and CHA™ water. The pH measurement for CHA™ water was just as the manufacturer claimed it to be – pH of 9 to 10. It is interesting to note that Dasani and Aquafina water had acidic pH levels, while tap water was the closest to being neutral.

The dissolved oxygen tests gave mixed results. Two batches of superoxygenated water purchased the 25th and 26th of October, 2005, did not give the claimed levels of oxygen. These samples, purchased on separate days, yielded similar oxygen percentages to water samples which were not superoxygenated. Table II shows the comparison between oxygen percent in the superoxygenated water purchased on October 25, 2005 and Dasani water – which is not superoxygenated. This does not agree with the advertised five times more oxygen than any other water claim by the manufacturer.

**Table II: comparison of $O_2$ % of saturation in Superoxygenated and Dasani water.**
**Note: Superoxygenated water was purchased on (10/25/05)**

| Water Sample | 0 min | 1 min | 2 min |
|---|---|---|---|
| Mountain Fresh Superoxygenated | 79.1 $O_2$% | 80.1 $O_2$% | 80.5 $O_2$% |
| Dasani | 77.4 $O_2$% | 76.5 $O_2$% | 76.4 $O_2$% |

The test was stopped at the two minute mark due to the lack of super oxygenation in the water sample. In order to rule out the possibility of equipment malfunction, the apparatus was tested with oxygenated water that was prepared in lab. The superoxygenated water prepared in lab showed increased oxygen levels of 4 to 5 times more than the Mountain Fresh superoxygenated and Dasani water (compare table II to III). The superoxygenated water prepared in lab maintained its high oxygen percent for the next couple of hours.

More water was purchased in the month of November, 2005. The dissolved oxygen tests performed during this month gave more promising results for Mountain Fresh Superoxygenated water. Table III shows a comparison of lab prepared and Mountain Fresh superoxygenated water.

**Table III: Superoxygenated $O_2$ % of saturation results over time**

| | Superoxygenated water purchased (11/30/05) | | | | Superoxygenated water prep. in lab (11/30/05) | | |
|---|---|---|---|---|---|---|---|
| Time (min) | $O_2$ % | Time (min) | $O_2$ % | Time (min) | $O_2$ % | Time (min) | $O_2$ % |
| 0 | 147.0 | 10 | 138.1 | 0 | 365.3 | 10 | 337.2 |
| 1 | 146.7 | 11 | 136.0 | 1 | 364.8 | 11 | 335.4 |
| 2 | 146.3 | 12 | 136.0 | 2 | 356.4 | 12 | 333.1 |
| 3 | 145.9 | 13 | 135.9 | 3 | 356.3 | 13 | 329.6 |
| 4 | 144.9 | 14 | 135.7 | 4 | 353.5 | 14 | 327.4 |
| 5 | 144.5 | 15 | 135.2 | 5 | 349.9 | 15 | 322.8 |
| 6 | 143.7 | 30 | 129.9 | 6 | 347.5 | 30 | 315.8 |
| 7 | 143.1 | 45 | 123.2 | 7 | 345.3 | 45 | 284.0 |
| 8 | 141.1 | 48 hr | 91.1 | 8 | 343.6 | 48 hr | 86.6 |
| 9 | 140.1 | | | 9 | 339.5 | | |

To further compare the levels of oxygen between the water samples under study, the oxygen meter was used to determine oxygen concentration. The concentrations were compared in the same manner as the oxygen percentages. Tables IV through VII, in the Appendix, show the results for the oxygen concentration test. Figure 1, in the appendix, shows the graphical comparison of the oxygen concentration loss over time per water sample. The samples show fairly rapid oxygen loss over time. The one week old Mountain Fresh superoxygenated water sample (stored in a capped container) gave a higher oxygen concentration result than tap water. At the end of the 48 hours, the test shows that all of the water samples left in the open had similar oxygen concentrations.

The osmosis rate test gave a narrow range of results. As can be seen in Figures 2 and 3 (and tables VIII through XII) in the Appendix, the average amount of water flowing into the eggs over a period of time for each water sample is rather close. Figure 2 shows how Penta® water compares to RO and tap water. Figure 3 shows how CHA™ water compares to RO and tap water. Tap water in this test was shown to be the slowest at penetrating the membrane. Due to its relatively high mineral content, tap water can be expected to flow at a slower rate through the membrane of the egg. This is due to the fact that osmosis is affected by the concentrations on both sides of the membrane. In other words, the greater the concentration difference, the faster the water flow. Thus, the water with the least amount of dissolved minerals will travel the fastest. In this experiment Penta® and RO water gave the fastest rates of osmosis. It can only be hypothesized that tap water was 15 % slower than Penta® water because of impurities found in the tap water sample. This only goes to show that these two samples, RO and Penta®, were the cleanest tested. The tests performed on CHA™ water did not give faster rates than Penta® or

RO water. The refrigerated CHA™ water gave the slowest average rate for the first hour. This could be due to slower molecular interactions caused by the lowered temperature.

## Conclusions

The three tests performed on the water samples gave results which help better understand the claimed properties of the bottled water brands under study. These tests also showed how CHA™, Penta®, and Mountain Fresh superoxygenated water compare to tap, Dasani, Aquafina, and reverse osmosis water.

The Charged, Hydration, and Alkalinity properties of CHA™ water are doubtful. The testing for the charge of CHA™ water is not covered by this research. This is largely due to there being no known method of making that determination. A permanent charge would not be able to remain once the water is set on a grounded surface. The hydration claim is also questionable; CHA™ water samples tested did not give results which were better than reverse osmosis water. CHA™ water samples had a slightly faster osmosis rate than tap water. The pH test supported the claimed levels. The only concern is if the claimed benefits are real. The pH level of the stomach is very acidic and may be anywhere between pH 1 and 4 (10). As the CHA™ water enters the stomach and mixes with the gastric juices, the pH will no longer be maintained at basic levels as the base is neutralized by the stomach acid. Since CHA™ water must pass through the stomach before it is absorbed by the body, the alkalinity of CHA™ water will no longer be beneficial to the body as claimed by the manufacturer.

Penta® water gave results which were very close to RO and tap water samples. Although the results from this research may support the claims made by the manufacturer, the interpretation of the results differs. Penta® water may diffuse through the egg membrane at a faster rate due to its purity, not any special properties which may be patented by the manufacturer.

Superoxygenated water gave negative results during the first tests. When a batch of water containing higher levels of oxygen was obtained, the results were nowhere near the level claimed. None of the samples contained the claimed five times more oxygen than tap water. There is no way to test whether increased levels of oxygen in water reach the blood stream through the stomach. The manufacturer does not provide scientific evidence that explains how oxygen is capable of penetrating the lining of the stomach. Another aspect to be considered is the amount of oxygen in superoxygenated water versus the amount of oxygen in a breath of air. The average human lungs can breath in approximately of 3.0 Liters of air (11). At 1 atmosphere of pressure, 0% relative humidity, and a temperature of 20°C there would be, according to the ideal gas law, 838 mg of oxygen in a single breath full of air. If superoxygenated water were to be five times more oxygenated than tap water (~9mg/L from the experiment), there would be around 45 mg of oxygen in one liter of superoxygenated water. This means that if the human stomach and the lungs were just as efficient at absorbing oxygen it would take about 19 liters of superoxygenated water to provide for the same amount of oxygen found in one breath of air. It can only be theorized that the single benefit from having raised levels of oxygen in water is for better taste.

Three different types of tests were performed in order to verify claims of the bottled water manufactures: pH level, oxygen percent and concentration, and osmosis rate. While the pH testing reinforced the claim that CHA™ water is alkaline, the other two tests proved the other claims wrong. Superoxygenated water did not have five times more oxygen than tap water. Penta® and CHA™ water did not cross the egg membranes much faster than any other. As new bottled water brands hit the market, customers should be aware that the claims made by these manufacturers are not always completely true.

# Appendix

**Figure 1: Oxygen concentration - Average $[O_2]$ (mg/L) of water over time**

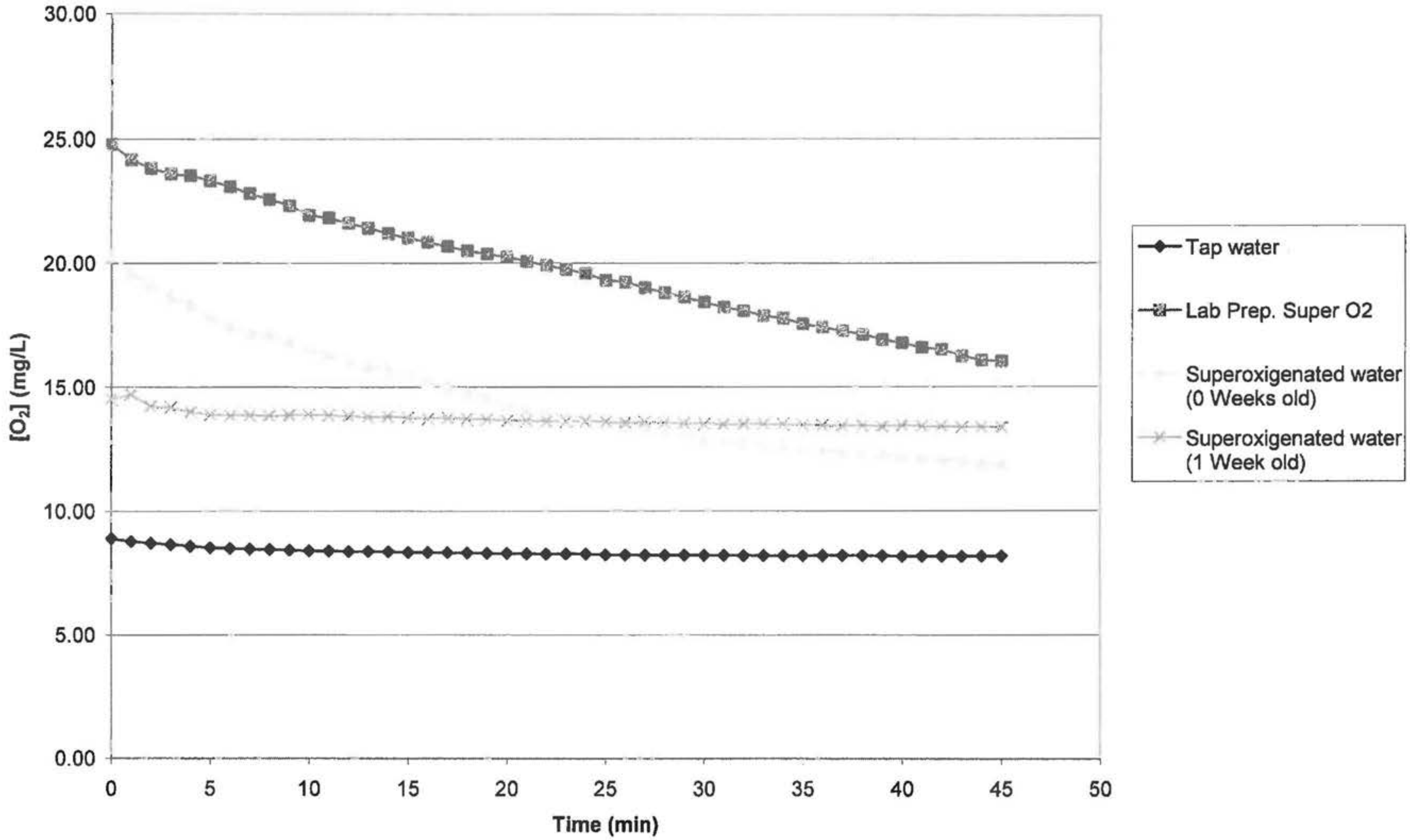

**Table IV: $[0_2]$/(mg/L) in Superoxygenated water purchased (3/13/06) - 1 week Old**

| Time (min) | Run 1 $[O_2]$ | Run 2 $[O_2]$ | Run 3 $[O_2]$ | Avg. |
|---|---|---|---|---|
| 0 | 14.01 | 13.98 | 15.49 | 14.49 |
| 1 | 13.89 | 13.82 | 16.36 | 14.69 |
| 2 | 14.05 | 13.65 | 14.89 | 14.20 |
| 3 | 13.95 | 13.60 | 14.93 | 14.16 |
| 4 | 13.70 | 13.53 | 14.67 | 13.97 |
| 5 | 13.65 | 13.42 | 14.58 | 13.88 |
| 6 | 13.63 | 13.48 | 14.40 | 13.84 |
| 7 | 13.61 | 13.58 | 14.37 | 13.85 |
| 8 | 13.47 | 13.55 | 14.44 | 13.82 |
| 9 | 13.48 | 13.57 | 14.50 | 13.85 |
| 10 | 13.52 | 13.53 | 14.57 | 13.87 |
| 11 | 13.50 | 13.51 | 14.53 | 13.85 |
| 12 | 13.47 | 13.45 | 14.50 | 13.81 |
| 13 | 13.42 | 13.42 | 14.47 | 13.77 |
| 14 | 13.44 | 13.48 | 14.44 | 13.79 |
| 15 | 13.40 | 13.38 | 14.46 | 13.75 |
| 16 | 13.37 | 13.35 | 14.38 | 13.70 |
| 17 | 13.36 | 13.39 | 14.41 | 13.72 |
| 18 | 13.35 | 13.34 | 14.39 | 13.69 |
| 19 | 13.37 | 13.29 | 14.36 | 13.67 |
| 20 | 13.32 | 13.27 | 14.30 | 13.63 |
| 21 | 13.30 | 13.26 | 14.33 | 13.63 |
| 22 | 13.26 | 13.21 | 14.31 | 13.59 |
| 23 | 13.28 | 13.24 | 14.27 | 13.60 |
| 24 | 13.27 | 13.20 | 14.29 | 13.59 |
| 25 | 13.24 | 13.21 | 14.29 | 13.58 |
| 26 | 13.19 | 13.17 | 14.22 | 13.53 |
| 27 | 13.18 | 13.28 | 14.24 | 13.57 |
| 28 | 13.20 | 13.22 | 14.20 | 13.54 |
| 29 | 13.16 | 13.23 | 14.18 | 13.52 |
| 30 | 13.17 | 13.20 | 14.16 | 13.51 |
| 31 | 13.14 | 13.14 | 14.15 | 13.48 |
| 32 | 13.12 | 13.18 | 14.17 | 13.49 |
| 33 | 13.16 | 13.14 | 14.16 | 13.49 |
| 34 | 13.13 | 13.20 | 14.12 | 13.48 |
| 35 | 13.10 | 13.17 | 14.10 | 13.46 |
| 36 | 13.09 | 13.15 | 14.11 | 13.45 |
| 37 | 13.08 | 13.10 | 14.09 | 13.42 |
| 38 | 13.10 | 13.12 | 14.05 | 13.42 |
| 39 | 13.11 | 13.07 | 14.02 | 13.40 |
| 40 | 13.09 | 13.11 | 14.07 | 13.42 |
| 41 | 13.10 | 13.10 | 14.00 | 13.40 |
| 42 | 13.08 | 13.09 | 13.98 | 13.38 |
| 43 | 13.05 | 13.05 | 14.01 | 13.37 |
| 44 | 13.04 | 13.09 | 13.96 | 13.36 |
| 45 | 13.08 | 13.07 | 13.93 | 13.36 |
| 48 hr | 8.89 | 9.15 | 8.75 | |

**Table V: $[0_2]$/(mg/L) in Superoxygenated water prep. In lab (3/21/06) - 0 weeks old**

| Time (min) | Run 1 $[O_2]$ | Run 2 $[O_2]$ | Avg |
|---|---|---|---|
| 0 | 24.98 | 24.61 | 24.80 |
| 1 | 24.13 | 24.21 | 24.17 |
| 2 | 23.78 | 23.86 | 23.82 |
| 3 | 23.50 | 23.70 | 23.60 |
| 4 | 23.40 | 23.68 | 23.54 |
| 5 | 23.28 | 23.38 | 23.33 |
| 6 | 23.00 | 23.20 | 23.10 |
| 7 | 22.68 | 22.95 | 22.82 |
| 8 | 22.45 | 22.71 | 22.58 |
| 9 | 22.20 | 22.45 | 22.33 |
| 10 | 22.10 | 21.78 | 21.94 |
| 11 | 21.68 | 21.98 | 21.83 |
| 12 | 21.38 | 21.84 | 21.61 |
| 13 | 21.24 | 21.60 | 21.42 |
| 14 | 20.97 | 21.42 | 21.20 |
| 15 | 20.75 | 21.28 | 21.02 |
| 16 | 20.63 | 21.07 | 20.85 |
| 17 | 20.41 | 20.95 | 20.68 |
| 18 | 20.22 | 20.79 | 20.51 |
| 19 | 20.14 | 20.61 | 20.38 |
| 20 | 20.00 | 20.49 | 20.25 |
| 21 | 19.82 | 20.33 | 20.08 |
| 22 | 19.60 | 20.20 | 19.90 |
| 23 | 19.49 | 20.01 | 19.75 |
| 24 | 19.31 | 19.83 | 19.57 |
| 25 | 19.10 | 19.52 | 19.31 |
| 26 | 18.89 | 19.58 | 19.24 |
| 27 | 18.80 | 19.20 | 19.00 |
| 28 | 18.50 | 19.12 | 18.81 |
| 29 | 18.26 | 19.00 | 18.63 |
| 30 | 18.01 | 18.85 | 18.43 |
| 31 | 17.87 | 18.57 | 18.22 |
| 32 | 17.67 | 18.49 | 18.08 |
| 33 | 17.43 | 18.32 | 17.88 |
| 34 | 17.32 | 18.22 | 17.77 |
| 35 | 17.12 | 17.94 | 17.53 |
| 36 | 16.98 | 17.82 | 17.40 |
| 37 | 16.81 | 17.71 | 17.26 |
| 38 | 16.65 | 17.56 | 17.11 |
| 39 | 16.45 | 17.35 | 16.90 |
| 40 | 16.32 | 17.21 | 16.77 |
| 41 | 16.10 | 17.06 | 16.58 |
| 42 | 16.03 | 16.98 | 16.51 |
| 43 | 15.78 | 16.69 | 16.24 |
| 44 | 15.63 | 16.50 | 16.07 |
| 45 | 15.60 | 16.43 | 16.02 |
| 48 hr | 8.99 | 8.87 | |

**Table VI: [$0_2$]/(mg/L) in tap water (4/3/06)**

| Time (min) | Run 1 [$O_2$] | Run 2 [$O_2$] | Run 3 [$O_2$] | Avg |
|---|---|---|---|---|
| 0 | 8.63 | 9.31 | 8.76 | 8.90 |
| 1 | 8.61 | 9.09 | 8.66 | 8.79 |
| 2 | 8.56 | 9.00 | 8.6 | 8.72 |
| 3 | 8.48 | 8.93 | 8.57 | 8.66 |
| 4 | 8.41 | 8.86 | 8.5 | 8.59 |
| 5 | 8.34 | 8.79 | 8.46 | 8.53 |
| 6 | 8.30 | 8.78 | 8.43 | 8.50 |
| 7 | 8.32 | 8.73 | 8.4 | 8.48 |
| 8 | 8.31 | 8.69 | 8.39 | 8.46 |
| 9 | 8.26 | 8.68 | 8.39 | 8.44 |
| 10 | 8.25 | 8.65 | 8.34 | 8.41 |
| 11 | 8.23 | 8.63 | 8.34 | 8.40 |
| 12 | 8.21 | 8.59 | 8.32 | 8.37 |
| 13 | 8.23 | 8.58 | 8.33 | 8.38 |
| 14 | 8.23 | 8.56 | 8.32 | 8.37 |
| 15 | 8.20 | 8.54 | 8.28 | 8.34 |
| 16 | 8.19 | 8.53 | 8.3 | 8.34 |
| 17 | 8.19 | 8.50 | 8.29 | 8.33 |
| 18 | 8.17 | 8.50 | 8.29 | 8.32 |
| 19 | 8.17 | 8.47 | 8.29 | 8.31 |
| 20 | 8.16 | 8.48 | 8.24 | 8.29 |
| 21 | 8.14 | 8.45 | 8.23 | 8.27 |
| 22 | 8.14 | 8.44 | 8.21 | 8.26 |
| 23 | 8.12 | 8.45 | 8.25 | 8.27 |
| 24 | 8.12 | 8.43 | 8.24 | 8.26 |
| 25 | 8.09 | 8.40 | 8.2 | 8.23 |
| 26 | 8.11 | 8.38 | 8.2 | 8.23 |
| 27 | 8.10 | 8.36 | 8.2 | 8.22 |
| 28 | 8.10 | 8.35 | 8.21 | 8.22 |
| 29 | 8.10 | 8.36 | 8.22 | 8.23 |
| 30 | 8.08 | 8.37 | 8.19 | 8.21 |
| 31 | 8.08 | 8.37 | 8.19 | 8.21 |
| 32 | 8.09 | 8.33 | 8.19 | 8.20 |
| 33 | 8.08 | 8.32 | 8.2 | 8.20 |
| 34 | 8.08 | 8.32 | 8.17 | 8.19 |
| 35 | 8.07 | 8.32 | 8.18 | 8.19 |
| 36 | 8.08 | 8.36 | 8.18 | 8.21 |
| 37 | 8.08 | 8.34 | 8.18 | 8.20 |
| 38 | 8.09 | 8.32 | 8.18 | 8.20 |
| 39 | 8.08 | 8.34 | 8.16 | 8.19 |
| 40 | 8.06 | 8.30 | 8.15 | 8.17 |
| 41 | 8.06 | 8.30 | 8.15 | 8.17 |
| 42 | 8.06 | 8.31 | 8.15 | 8.17 |
| 43 | 8.06 | 8.27 | 8.16 | 8.16 |
| 44 | 8.06 | 8.29 | 8.16 | 8.17 |
| 45 | 8.07 | 8.30 | 8.14 | 8.17 |
| 48 hr | 8.77 | 8.86 | 8.77 | |

**Table VII: [02]/(mg/L) in Superoxygenated water purchased (4/5/06) - 0 weeks old**

| Time (min) | Run 1 [$O_2$] | Run 2 [$O_2$] | Run 3 [$O_2$] | Avg |
|---|---|---|---|---|
| 0 | 20.27 | 20.50 | 20.12 | 20.30 |
| 1 | 19.64 | 19.71 | 19.51 | 19.62 |
| 2 | 19.01 | 19.20 | 19.16 | 19.12 |
| 3 | 18.45 | 18.62 | 18.79 | 18.62 |
| 4 | 18.20 | 18.30 | 18.45 | 18.32 |
| 5 | 17.67 | 17.80 | 17.95 | 17.81 |
| 6 | 17.43 | 17.40 | 17.55 | 17.46 |
| 7 | 17.25 | 17.15 | 17.19 | 17.20 |
| 8 | 17.17 | 17.05 | 17.15 | 17.12 |
| 9 | 16.79 | 16.87 | 16.82 | 16.83 |
| 10 | 16.49 | 16.52 | 16.55 | 16.52 |
| 11 | 16.29 | 16.28 | 16.32 | 16.30 |
| 12 | 16.04 | 15.99 | 16.01 | 16.01 |
| 13 | 15.85 | 15.84 | 15.80 | 15.83 |
| 14 | 15.71 | 15.60 | 15.61 | 15.64 |
| 15 | 15.51 | 15.39 | 15.43 | 15.44 |
| 16 | 15.25 | 15.22 | 15.28 | 15.25 |
| 17 | 14.88 | 14.94 | 15.00 | 14.94 |
| 18 | 14.81 | 14.77 | 14.72 | 14.77 |
| 19 | 14.51 | 14.59 | 14.50 | 14.53 |
| 20 | 14.21 | 14.32 | 14.29 | 14.27 |
| 21 | 14.08 | 14.16 | 13.99 | 14.08 |
| 22 | 13.89 | 13.98 | 13.86 | 13.91 |
| 23 | 13.81 | 13.90 | 13.72 | 13.81 |
| 24 | 13.73 | 13.85 | 13.60 | 13.73 |
| 25 | 13.53 | 13.59 | 13.44 | 13.52 |
| 26 | 13.42 | 13.49 | 13.38 | 13.43 |
| 27 | 13.35 | 13.42 | 13.22 | 13.33 |
| 28 | 13.25 | 13.23 | 13.05 | 13.18 |
| 29 | 13.09 | 13.06 | 12.91 | 13.02 |
| 30 | 12.98 | 12.95 | 12.75 | 12.89 |
| 31 | 12.85 | 12.81 | 12.64 | 12.77 |
| 32 | 12.78 | 12.77 | 12.60 | 12.72 |
| 33 | 12.72 | 12.70 | 12.55 | 12.66 |
| 34 | 12.65 | 12.70 | 12.48 | 12.61 |
| 35 | 12.57 | 12.67 | 12.39 | 12.54 |
| 36 | 12.50 | 12.53 | 12.27 | 12.43 |
| 37 | 12.44 | 12.47 | 12.19 | 12.37 |
| 38 | 12.41 | 12.40 | 12.12 | 12.31 |
| 39 | 12.38 | 12.35 | 12.08 | 12.27 |
| 40 | 12.32 | 12.29 | 12.03 | 12.21 |
| 41 | 12.25 | 12.21 | 11.97 | 12.14 |
| 42 | 12.13 | 12.17 | 11.93 | 12.08 |
| 43 | 12.09 | 12.12 | 11.89 | 12.03 |
| 44 | 12.01 | 12.00 | 11.77 | 11.93 |
| 45 | 11.95 | 11.90 | 11.60 | 11.82 |
| 48 hr | 8.91 | 8.87 | 8.90 | |

**Figure 2: Average amount of Penta®, RO, and tap water entering egg over first three hours**

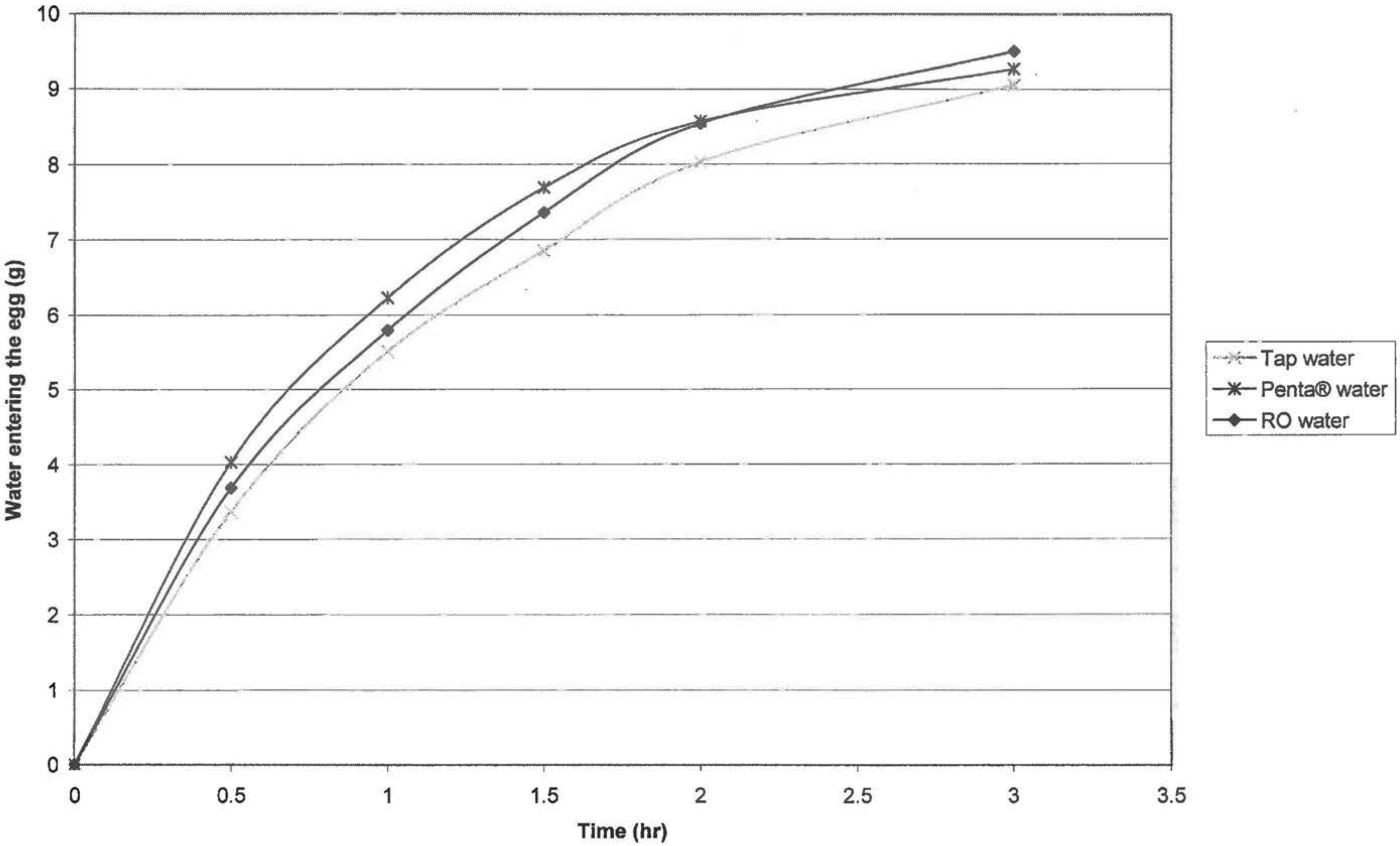

Figure 3: Average amount of CHA™, RO, and tap water entering egg over first three hours

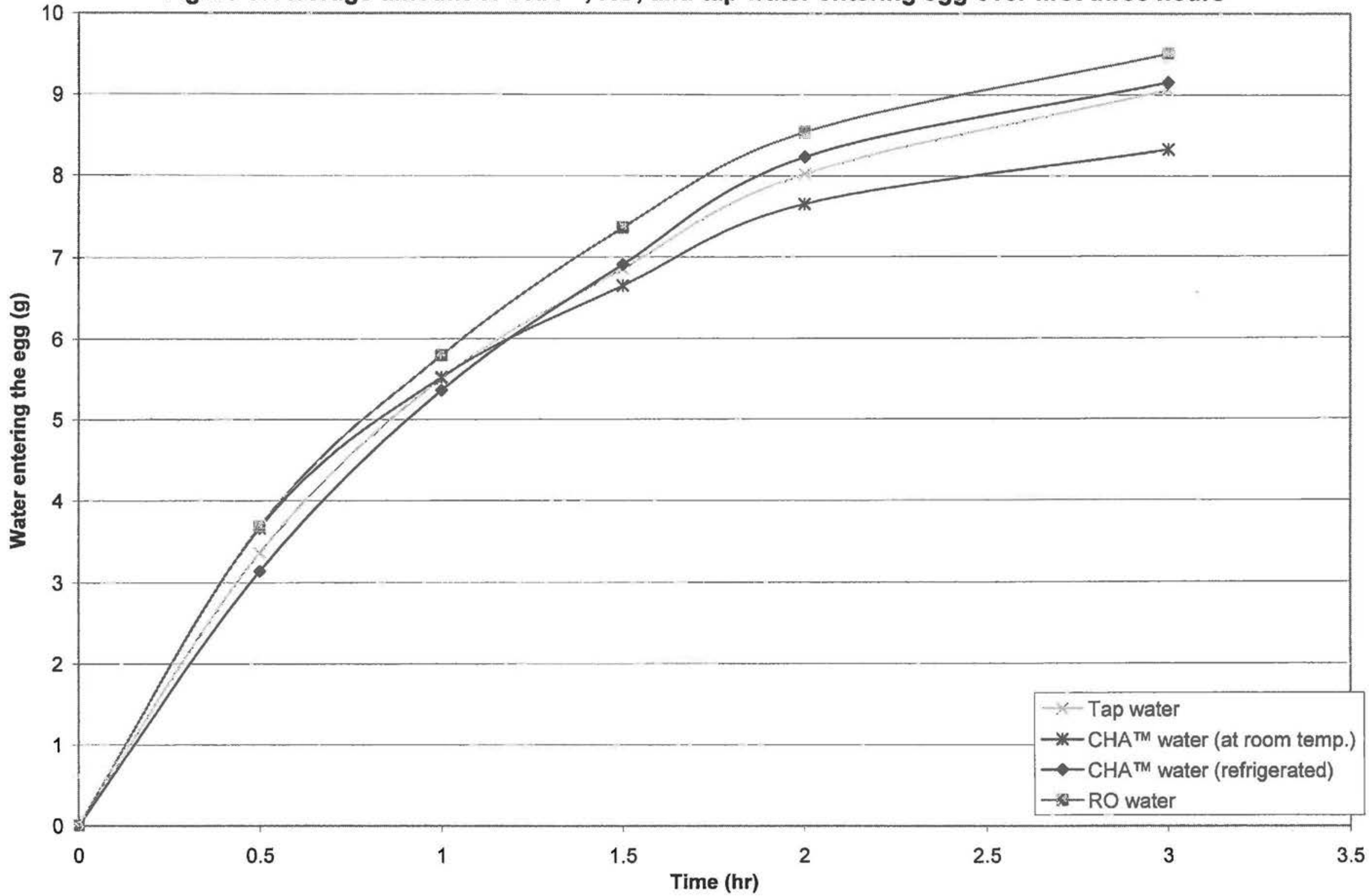

**Table VIII: Osmosis rate test - Penta® water**

| Time (hr) | Run 1 (g) | Run 2 (g) | Run 3 (g) | Run 4 (g) | Run 5 (g) | Avg. total water flow (g) |
|---|---|---|---|---|---|---|
| 0 | 76.997 | 92.881 | 94.512 | 81.140 | 88.317 | 0 |
| 0.5 | 81.861 | 97.001 | 98.105 | 84.855 | 92.179 | 4.03 |
| 1.0 | 83.261 | 99.174 | 100.473 | 87.615 | 94.449 | 6.23 |
| 1.5 | 84.256 | 100.581 | 101.711 | 89.523 | 96.220 | 7.69 |
| 2.0 | 85.031 | 101.037 | 102.715 | 90.623 | 97.297 | 8.57 |
| 3.0 | 85.754 | 101.097 | 103.080 | 91.900 | 98.373 | 9.27 |
| 18.0 | 85.805 | 102.456 | 105.227 | 93.904 | 100.203 | 10.75 |

**Table IX: Osmosis rate test - CHA™ water**

| Time (hr) | Run 1 (g) | Run 2 (g) | Run 3 (g) | Run 4 (g) | Run 5 (g) | Avg. total water flow (g) |
|---|---|---|---|---|---|---|
| 0 | 68.107 | 87.903 | 87.149 | 73.530 | 85.936 | 0 |
| 0.5 | 71.766 | 91.575 | 90.704 | 76.820 | 90.111 | 3.67 |
| 1.0 | 72.702 | 93.585 | 92.811 | 78.648 | 92.497 | 5.52 |
| 1.5 | 73.302 | 94.865 | 93.927 | 79.778 | 93.994 | 6.65 |
| 2.0 | 73.954 | 95.880 | 94.755 | 81.090 | 95.183 | 7.65 |
| 3.0 | 74.426 | 95.973 | 95.861 | 82.000 | 96.001 | 8.33 |
| 18.0 | 76.063 | 100.273 | 98.538 | 84.080 | 97.677 | 10.80 |

**Table X: Osmosis rate test - CHA™ water (Refrigerated)**

| Time (hr) | Run 1 (g) | Run 2 (g) | Run 3 (g) | Run 4 (g) | Run 5 (g) | Avg. total water flow (g) |
|---|---|---|---|---|---|---|
| 0 | 80.917 | 92.948 | 90.050 | 74.541 | 77.425 | 0 |
| 0.5 | 84.051 | 95.847 | 92.894 | 77.283 | 80.791 | 3.14 |
| 1.0 | 86.186 | 98.501 | 94.510 | 79.248 | 83.524 | 5.36 |
| 1.5 | 87.645 | 100.048 | 95.832 | 80.819 | 85.351 | 6.91 |
| 2.0 | 89.492 | 100.853 | 96.480 | 82.411 | 87.090 | 8.23 |
| 3.0 | 90.484 | 101.686 | 96.988 | 83.652 | 88.132 | 9.16 |
| 18.0 | 96.516 | 102.963 | 97.365 | 86.005 | 90.233 | 11.58 |

**Table XI: Osmosis rate test - RO water**

| Time (hr) | Run 1 (g) | Run 2 (g) | Run 3 (g) | Run 4 (g) | Run 5 (g) | Avg. total water flow (g) |
|---|---|---|---|---|---|---|
| 0 | 72.163 | 92.171 | 84.297 | 71.800 | 71.824 | 0 |
| 0.5 | 76.520 | 95.603 | 88.087 | 74.713 | 75.767 | 3.69 |
| 1.0 | 77.692 | 98.001 | 90.684 | 77.664 | 77.180 | 5.79 |
| 1.5 | 78.270 | 98.713 | 92.100 | 79.142 | 80.808 | 7.36 |
| 2.0 | 78.713 | 99.505 | 92.914 | 81.101 | 82.716 | 8.54 |
| 3.0 | 79.202 | 99.722 | 93.866 | 82.685 | 84.310 | 9.51 |
| 18.0 | 79.814 | 103.37 | 95.937 | 83.278 | 84.792 | 10.99 |

**Table XII: Osmosis rate test - Tap water**

| Time (hr) | Run 1 (g) | Run 2 (g) | Run 3 (g) | Run 4 (g) | Run 5 (g) | Avg. total water flow (g) |
|---|---|---|---|---|---|---|
| 0 | 70.499 | 87.047 | 85.460 | 68.730 | 78.524 | 0 |
| 0.5 | 74.884 | 90.570 | 88.522 | 71.672 | 81.437 | 3.37 |
| 1.0 | 76.265 | 92.618 | 90.745 | 74.155 | 84.001 | 5.51 |
| 1.5 | 77.152 | 93.600 | 92.671 | 75.484 | 85.606 | 6.85 |
| 2.0 | 78.008 | 94.412 | 93.869 | 77.050 | 87.030 | 8.02 |
| 3.0 | 78.763 | 94.539 | 95.316 | 78.418 | 88.512 | 9.06 |
| 18.0 | 80.240 | 95.962 | 97.815 | 80.346 | 90.446 | 10.91 |

## Works Cited

1. CHA Water Home Page: http://www.chawater.com (accessed November 5, 2006)

2. Penta Water Home Page: http://www.pentawater.com/ (accessed November 2, 2006)

3. Mountain Fresh Water pamphlet.

4. Lewis, R. *Hawley's Condensed Chemical Dictionary*, 13th Ed.; Wiley & Sons: New York, 1997.

5. CLIVAR and Carbon Hydrographic Data Office. Determination of dissolved oxygen in sea water by Winkler titration. http://whpo.ucsd.edu/manuals.htm (accessed October 31, 2005).

6. Nestle, N.; Dakkouri, M.; Hubert, R. Superoxygenated water as an experimental sample for NMR relaxometry. *J. Chem. Educ.* **2004,** 81(7), p 1040-1041.

7. Water vapor pressure vs temp: http://www.chem.brown.edu/chem12/Chem-IRC/ircDisc98/images/VPH_2OvsT.html (accessed February 1, 2006)

8. Williams, D. Earth Fact Sheet. NASA Goddard Space Flight Center. http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html (accessed February 2, 2006)

9. Rettich, T. R.; Battino, R.; Wilhelm, E. Solubility of gases in liquids. 22. High-precision determination of Henry's law constants of oxygen in liquid water from T = 274K to T = 328K. *J. Chem. Thermodyn.* **2000,** 32(9), p 1145-1156.

10. Marieb, E. *Human Anatomy & Physiology*, 6th Ed.; Pearson Benjamin Cummings: San Francisco, 2004.

11. Berne, R.; Levy, M; Koeppen, B.; Staton, B. *Physiology*, 4th Ed.; Mosby: St. Louis, Missoury, 1998.

12. Shakhashiri, B. Osmosis Through the Membrane of an Egg. *Chemical Demonstrations*; University of Wisconsin press.: Madison, WI, 1988; Volume 3, p 283-285.

**Southern Scholars Honors Program**
**Senior Project**

Name Henry Pinango Date 1/31/06

Major Biochemistry

SOUTHERN
ADVENTIST UNIVERSITY

Southern Scholars
southernscholars.southern.edu
wmclarty@southern.edu

A significant scholarly project, involving research, writing, or special performance, appropriate to the major in question, is ordinarily completed the senior year. The project is expected to be of sufficiently high quality to warrant a grade of A and to justify public presentation.

Under the guidance of a faculty advisor, the Senior Project should be an original work, should use primary sources when applicable, should have a table of contents and works cited page, should give convincing evidence to support a strong thesis, and should use the methods and writing style appropriate to the discipline.

The completed project, to be turned in ~~in~~ duplicate, must be approved by the Honors Committee in consultation with the student's supervising professor three weeks prior to graduation. Please include the advisor's name on the title page. The 2 3 hours of credit for this project is done as directed study or in a research class.

Keeping in mind the above Senior Project description, please describe in as much detail as you can the project you will undertake. You may attach a separate sheet if you wish:

none

Signature of faculty advisor J. Bruce Schilling Expected date of completion 4/14/06

This project has been completed as planned (date) ___________

This is an "A" project _______ This project is worth 2-3 hours of credit _________

Advisor's Final Signature J. Bruce Schilling

Chair, Honors Committee ____________________ Date Approved ________

Dear Advisor, please write your final evaluation of the project on the reverse side of this page. Comment on the characteristics that make this A "quality work.

This research project deals with testing the validity of the claims made by the producers of CHA, Penta, and Superoxygenated water. Experiments have been devised to compare how these brands compare to tap, reverse osmosis, Dassani, and Aquafina water. There are three parts to the experiment. The first deals with measuring the oxygen concentrations over time in several different water samples. The second part analyzes the traveling rates of the different water samples through different types of membranes. The last part tests the pH levels of each water sample.