

Introduction

Ethylene is a very dynamic gaseous hormone involved in the growth and development of plants. Its significant role in plant physiology makes ethylene a target for study and manipulation in the scientific and agricultural fields. Whether for ethylene management in the fruit industry or pure scientific curiosity, it is essential to be able to accurately measure levels of ethylene. There are several methods for ethylene measurement on the market, with the 3 most current ones being gas chromatography, electrochemical sensing, and optical detection (Cristescu et al., 2012). CID Bio-Science utilizes electrochemical sensing in its CI-900 portable ethylene analyzer, where the current created by the oxidation of the sample gas in the electrochemical cell is translated into a concentration of ethylene. A disadvantage to electrochemical sensing is sensitivity to interfering gases. To combat this problem, CID included a filter in the CI-900 system, where gas can run through clean distilled water in chamber B (trapping polar interfering gasses and allowing the unique non-polar gas of ethylene to continue through) before hitting the electrochemical sensor. The following experiment was conducted to test the filtration feature and to display the functionality of the CI-900 in a real world application of monitoring the ethylene production by fruit.

Materials/Methods

Materials used: X-tronic good series power source, Oken Seiko Co. Rolling Pump, CI-900 ethylene analyzer and field kit, potassium permanganate, HP 5890 series II gas chromat

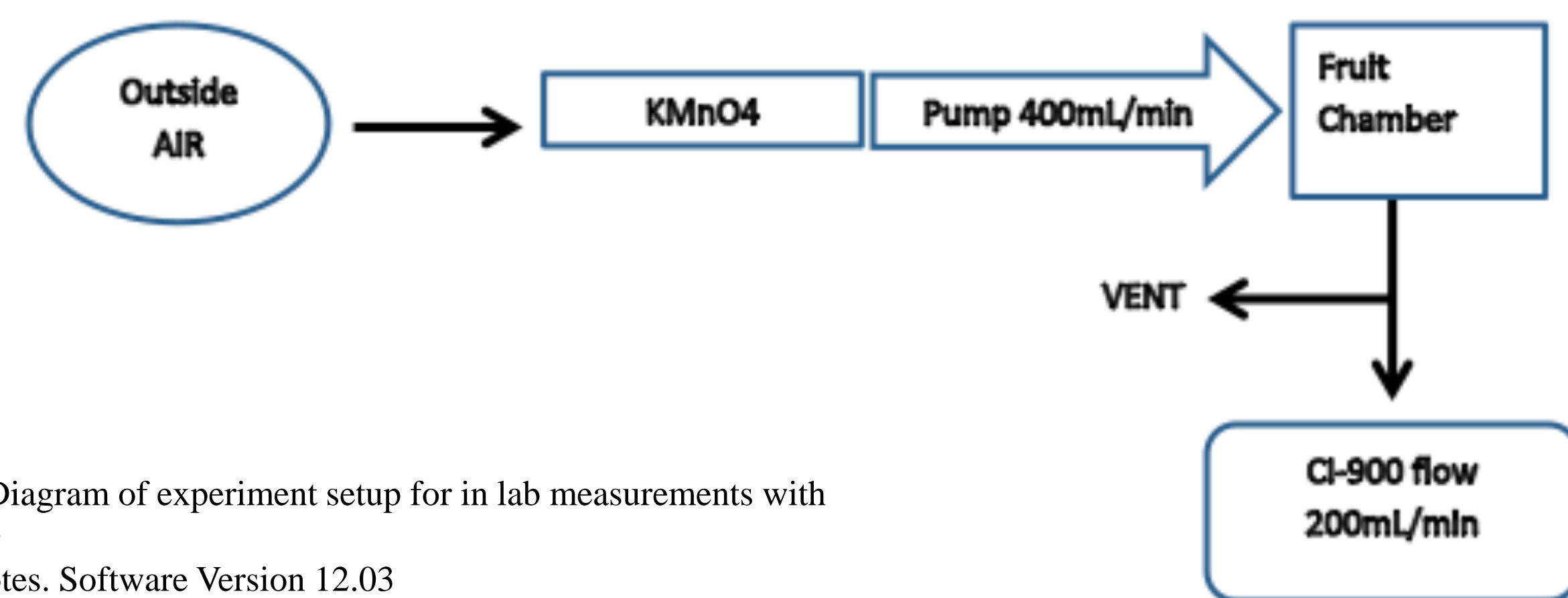


Figure 1. Diagram of experiment setup for in lab measurements with the CI-900
CI-900 notes, Software Version 12.03

Procedure: For this experiment, un-gassed mature fruit donated by the Organically Grown Company in Gresham Oregon was used. 13 green bananas, 3 yellow bananas, 6 avocados, and 4 mangos were tested. Additionally, 4 store-bought Fuji apples from Whole Foods were tested for comparative reasons. Each individual fruit was weighed, labeled, and then tested in three different ways. Method 1 was an initial loop test with no filtration/trapping. The CI-900 initial loop feature was used in the experiment to have a standard measurement time and process. The purpose of method 1 was to determine what response the sensor had without the trapping of interfering gases. First, the experiment was set up as shown in figure 1. The sample specimen was loaded into the fruit chamber and ethylene measurement by the CI-900 began. After sampling the headspace for exactly 3 minutes, a manual initial loop was initiated. Simultaneously, a 1 cc syringe sample of gas was taken from the vent tube. This sample was then run through the gas chromatograph. The results from the gas chromatograph and initial loop were then recorded. The fruit was removed and the fruit chamber was allowed to thoroughly vent to flush out any plant gas before beginning method 2.

Method 2 was the same as method 1 except Chamber B was filled with clean distilled water and then turned on for the test. The purpose of this method was to determine what response the sensor had with the trapping of interfering gases. Method 3 was a long-term monitor test with filtration. The purpose of this method was to determine the effectiveness of the interfering gas trap for long-term measurements. A file was created to save the data and Chamber B was filled with clean distilled water and set to special mode with a standard 4 minutes measure and 6 minutes clean. Next, the sample specimen was loaded into the fruit chamber and the test continued like methods 1 and 2, except after the initial loop, the system was allowed to run for 5 measurement and cleaning cycles (about 50 minutes). After which, the chamber was vented and then the next fruit specimen was tested, beginning with method 1 again. Method 3 was not conducted on the store-bought Fuji apples since they were only used to have another reading on the gas chromatograph.

Results

The results from methods 1 and 2 are displayed below in figure 2. When results from the gas chromatograph were undetectable, they were omitted from the graph. For all the fruit, the initial loop values without filtration/trapping (method 1) were higher than the initial loop values with filtration/trapping (method 2). The greatest difference was with the yellow bananas where method 1 gave a result 1.481 ppm greater than method 2. The gas chromatograph (GC) only gave detectable results with the avocados and apples. The GC results were found using comparison to a calibration curve created for this experiment. When a gas chromatograph reading was detectable, it similarly reflected that of method 2, give or take about 10 ppb.

Using the method 2 results, ethylene production rates were also calculated for each fruit and converted to $\mu\text{l C}_2\text{H}_4/\text{kg}\cdot\text{hr}$ for ease of comparison to literature in the conclusion. These rates were: 5.782 for the green bananas, 10.640 for the yellow bananas, 8.722 for the avocados, 2.273 for the mangos, and 14.128 for the apples.

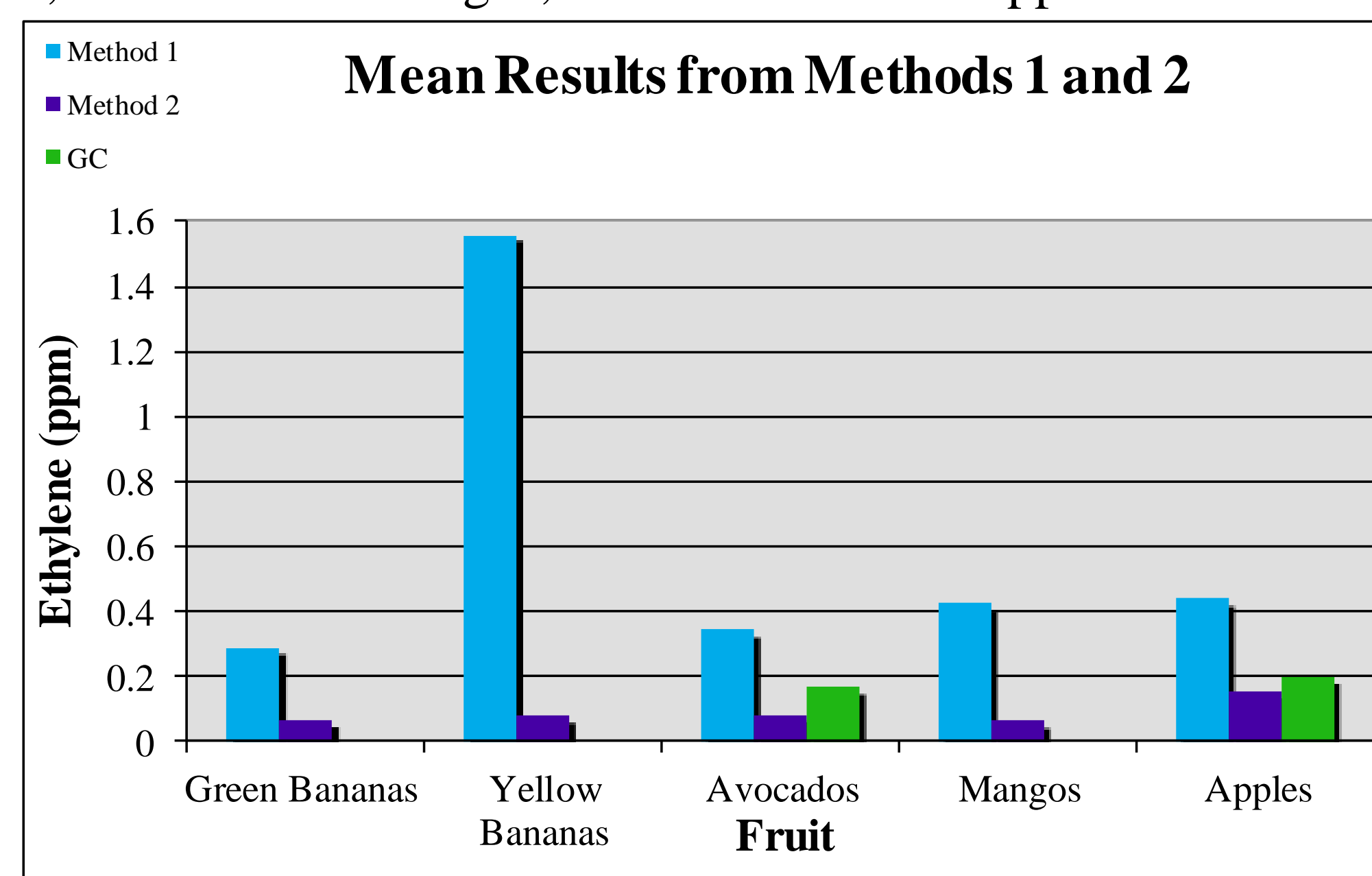


Figure 2.

For method 3, only the results from the green bananas and yellow bananas are displayed below. The green bananas had similar stable results between one another, while the yellow bananas had similar results that increased over time. Method 3 for the mangos and avocados looked similar to that of the green bananas.

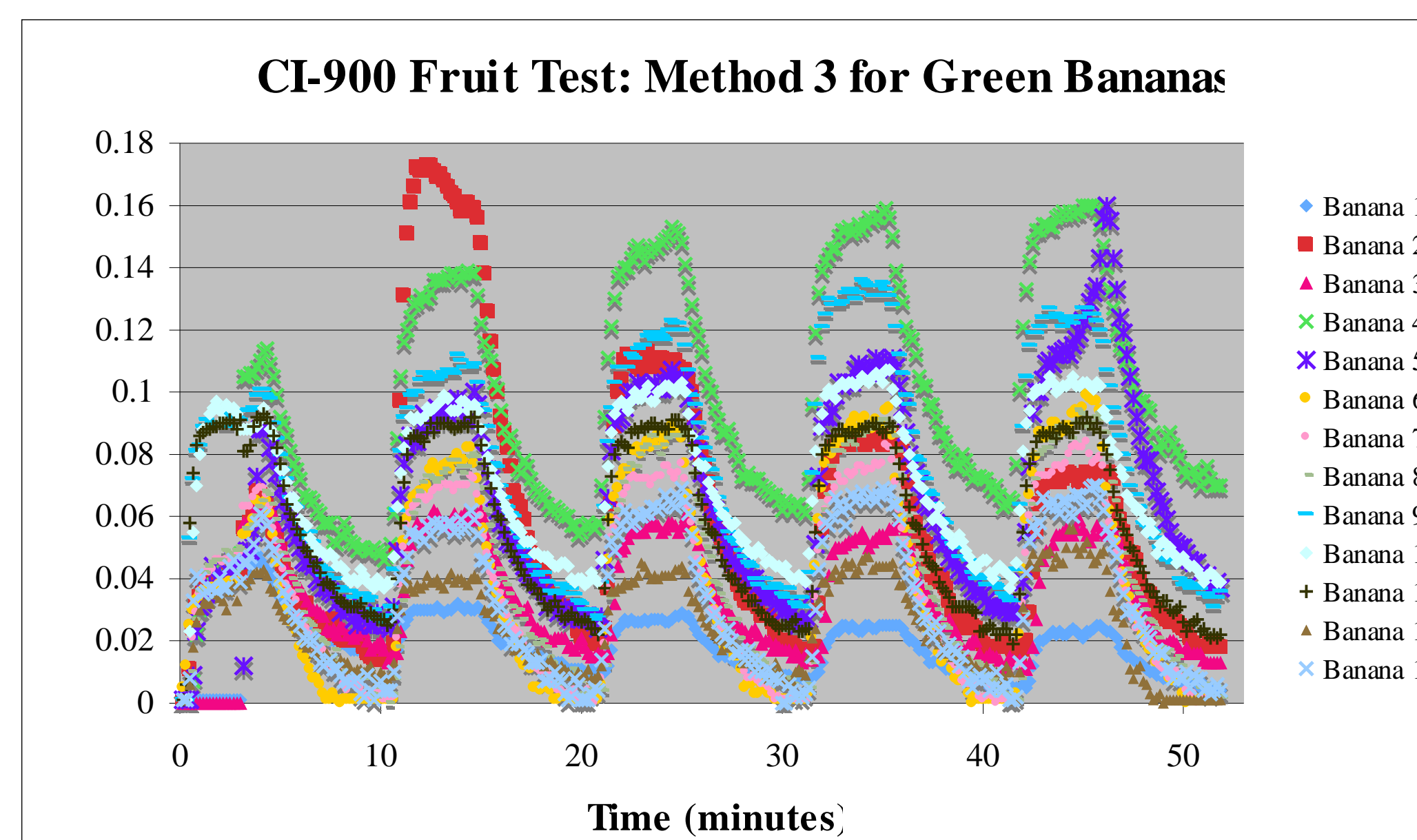


Figure 3.

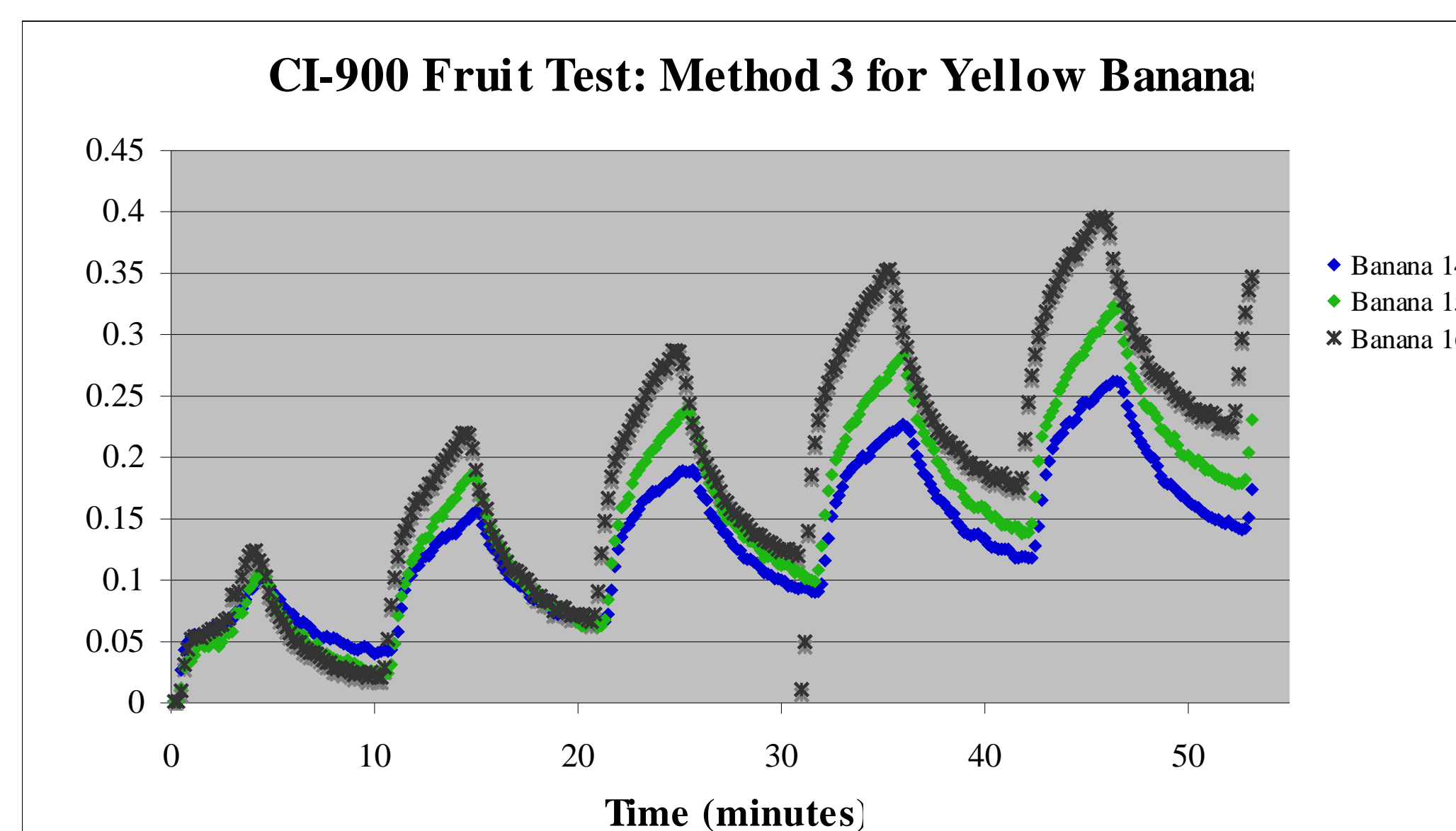


Figure 4.



Figure 5. Action shots from the experiment

Discussion/Conclusion

The results from methods 1 and 2 display a clear difference between the baseline setting and the filtration setting on the CI-900. Overall, the ethylene readings were significantly higher for method 1 without filtration. This is due to the fact that the electrochemical cell was sensitive to interfering gases, especially with the yellow bananas, and without filtration these other gases were oxidized by the sensor and measured as ethylene. With the filtration, such polar interfering gases were trapped in the water and only ethylene passed through and was measured by the sensor. The results from methods 1 and 2 show the effectiveness and importance of this new filtration feature. The GC was rather inaccurate with levels lower than about 100 ppb and was therefore unable to detect the ethylene levels of the bananas and mangos. However, the ethylene levels that were detectable showed a similar reading to the CI-900, suggesting that method 2 was fairly accurate. Although unlikely, there could have been some error with the GC, and so literature was also referenced to ensure that the CI-900 was reading accurate ethylene rates. Compared to UC Davis's published known production rates, the rates measured by the CI-900 were all in the correct range. The results from method 3 show that the CI-900 can give repeatable results for long term monitoring; figures 3 and 4 display consistent results between the tested fruit. The yellow bananas showed an increase in ethylene values over time due to a build up of interfering gases and should have had a greater cleaning period, but a standard 4 minutes measure and 6 minutes clean was used to maintain control within the experiment.

Electrochemical cells can also be sensitive to temperature and humidity. The temperature and humidity within the lab stayed relatively stable, but the humidity within the sensor changed dramatically. In methods 2 and 3, the gas bubbled through water in chamber B, making the relative humidity about 30% higher than in method 1. The difference in humidity could have caused inconsistency in the results.

Since this experiment, there have been many changes to the CI-900. A new code has been implemented to account for the effects of humidity and temperature on the electrochemical sensor and the initial loop feature, which turned out to be a useless aspect that was only used in this experiment for the sake of control, has been discarded. The tests in this experiment will be repeated with the new code.

The purpose of this project was to display the functionality of the CI-900 through real fruit tests. Overall, the filtration and monitor mode aspects of the CI-900 were displayed and the instrument gave results similar to that of the gas chromatograph and within the known ranges published by UC Davis. There are still some issues with the CI-900, but with further testing and improvement, it can become a reliable and greatly successful new instrument.

References

Cristescu, S.M., Mandon, J., Arslanov, D., Pessemier, J.D., Hermans, C., & Harren, F. (2012). Current methods for detecting ethylene in plants. *Annals of Botany*, 1-14. 10.1093/aob/mcs259

UC Davis. (2013). Recommendations for maintaining postharvest quality. UC Davis Postharvest Technology Guide. <http://postharvest.ucdavis.edu/producefacts/>

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