Comparison of Fruit Respiration Rates Measured by IR and GC/Jetanizer-FID

Application Note

Carbon dioxide

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Abstract

The respiration rates of various fruits and vegetables (citrus, tomato, brussels sprouts, and broccoli) were estimated from CO_2 concentration measurements using both an infrared sensor and a GC/FID equipped with a Jetanizer. The infrared sensor provided accurate measurements of CO_2 respiration rates (change in CO_2) above 10 mL CO_2/kg·hr and the Jetanizer provided accurate measurements of CO_2 respiration at all concentrations measured.

Introduction

Respiration rates measurements can provide valuable insight into the metabolic and physiological state of the fruit or vegetable. Changes in respiration rates can indicate events of senescence and ripening (Figure 1). CO_2 sensors can be used to monitor the rate of production. These can have a limited concentration range and response time. These also need to be calibrated (offset) to a known standard of CO_2 prior to analysis (usually, the sensors are calibrated to air upon startup with a rough estimate of ~400 ppm CO_2). More accurate and precise measurements of CO_2 can be accomplished with laboratory grade gas chromatography coupled with flame ionization detection (FID) and a methanizer.

In this study, we compare the accuracy of respiration rate measurements from CO_2 sensor data with rates measured using a laboratory gas chromatograph (GC). CO_2 concentrations were measured using GC-FID with an in-jet methanizer from Activated Research Company (Jetanizer). Respiration rate data is presented on fruit and vegetables that span from very slow to fast rates. The accuracy of the sensor data is evaluated and recommendations for optimal use conditions are given.

Figure 1. Ripening avocados

Experimental

Fruit and vegetable samples were placed in sealed 950 mL glass jars, each equipped with a circulation fan, infrared sensor (CozIR, CM-0187) and polymer septum for syringe sampling (Figure 2). Gas samples were taken with a 1 mL syringe and injected onto an Agilent 7890 GC equipped with an FID and methanizer (Jetanizer™, Activated Research Company) for the measurement of respiration gases. The GC was calibrated using an external mixture of CO_2 and ethylene (1000 and 100 ppm mixtures in nitrogen from Gasco, Oldsmar, FL). Respiration rates were determined from the rate of change of CO_2 gas concentrations measured every 5 seconds (infrared sensor) or every 1-10 min (GC).

GC conditions

Oven	50 °C isothermal
Injection volume	1 mL
Column	GasPro (15 m × 0.32 mm)

FID/Jetanizer conditions

Temperature	400 °C
H_2	40 sccm
Air	350 sccm
Makeup	5 sccm (He)
Sampling rate	50 Hz

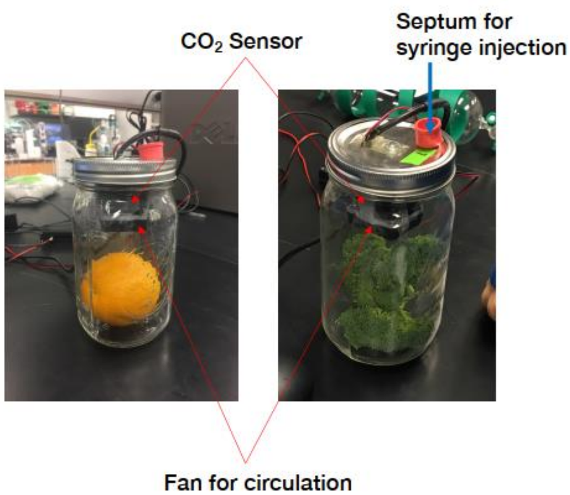


Figure 2. Respiration measurement setup

Results and Discussion

Measurement of Respiration Rates

Figure 3 shows the chromatogram resulting from subsequent injections of avocado respiration gas. The increasing peak areas indicate increasing CO_2 concentration with time.

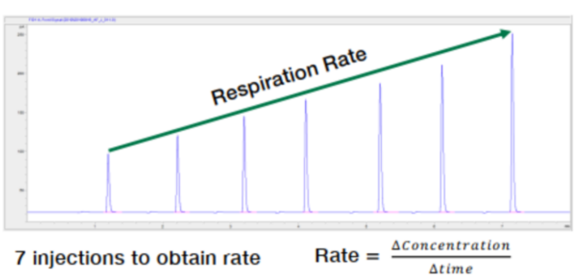


Figure 3. GC/Jetanizer-FID chromatogram of 7 injections of avocado respiration gas every 10 min.

The integrated peak areas are proportional to the amount of CO_2 respired from the fruit. The slope of the line formed from peak areas versus their sampling time represents the rate of CO_2 production. Normalizing by the mass of the avocado gives the respiration rate.

Respiration rates were measured from the sensor by reading the output value and correcting with the calibration response factor. The CO_2 reading was logged and recorded every 5 seconds and after a predetermined amount of time the resulting rate was calculated as the change in concentration over time.

Comparison of Performance

Figure 4 shows the average measured respiration rates of 8 avocados over 5 days. Respiration rates follow similar trends with both the IR sensor and GC/Jetanizer-FID, however, the sensor consistently reports higher concentration changes (rates) than the GC by 20%-40%. This difference could be due to calibration issues with the sensor or inaccuracies in measuring the small changes in CO_2.

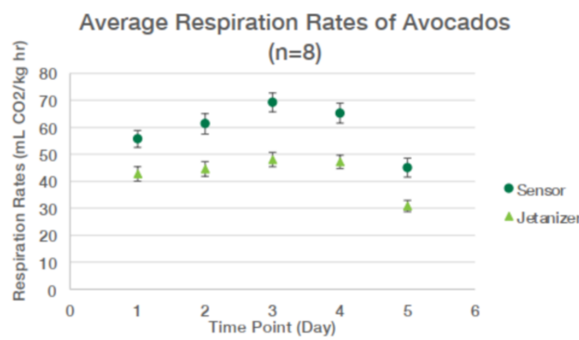


Figure 4. Average respiration rates of 8 avocados over 5 days, measured by infrared sensor (dark green circles) and GC/Jetanizer-FID (light green triangles).

Figure 5 compares the respiration rates of each avocado (8 total) measured by the IR sensor with those measured by GC/Jetanizer-FID. The two measurements are correlated; however, the sensor consistently overestimates the respiration rate by as much as 40%. These differences are most likely due to the propagation of error from single point calibrations of the IR sensor.

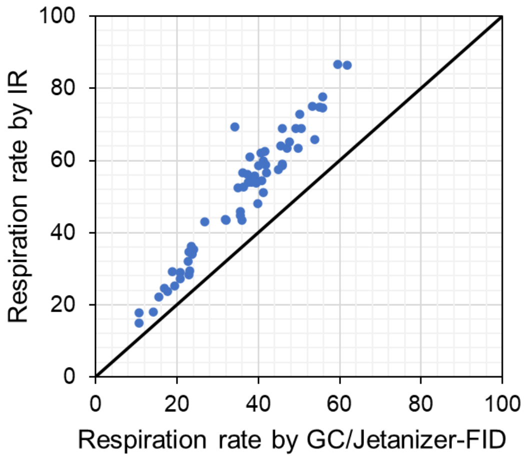
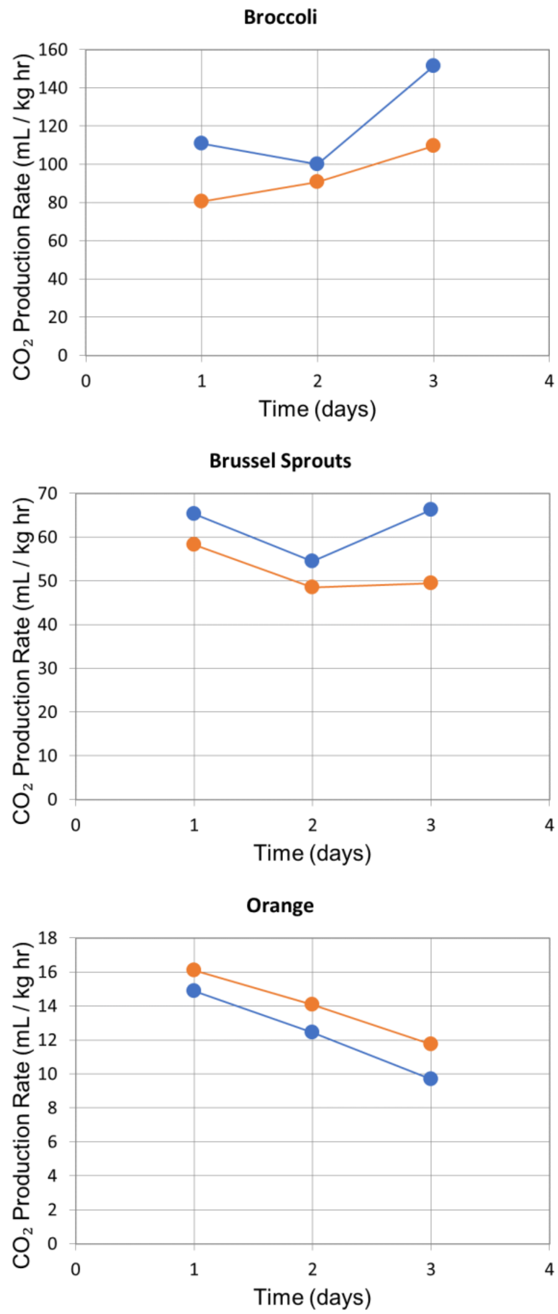


Figure 5. Avocado respiration rates over one week for 8 avocados

Beyond Avocados

Next, we compare the respiration rates of broccolis, brussels sprouts, oranges, tomatoes, and lemons to evaluate measurements over a wider range of CO_2 concentrations and respiration rates (Figure 6). The sensor (blue) and FID (orange) show similar trends in respiration rates for oranges and tomatoes where respiration rates fall between 10-20 mL CO_2/kg·hr and CO_2 concentrations were in the range of 100 to 500 ppm. Above 20 mL CO_2/kg·hr, the sensor overestimates the rate by as much as 28%, and shows slightly different trends. For example, the sensor shows that the respiration rate of brussels sprouts is relatively constant over 3 days, however, the FID measures a slight decrease from 58 to 49 mL CO_2/kg·hr.

Below 10 mL CO_2/kg·hr (e.g., with lemons), the sensor measures very different respiration rates than the FID. This is probably due to sensitivity and precision errors with the sensor at these low CO_2 concentration changes.



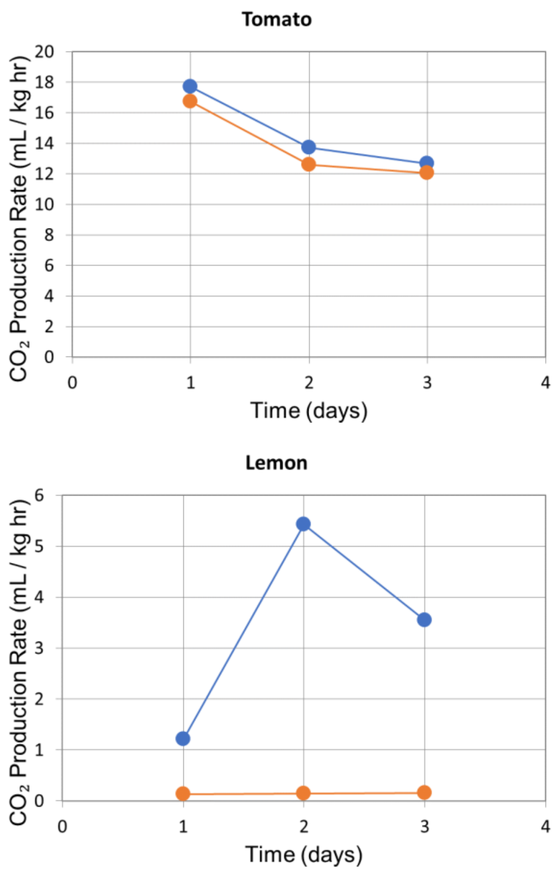


Figure 6. Respiration rates of broccolis, brussels sprouts, tomatoes, oranges, and lemons measured with an IR sensor (blue) and GC/Jetanizer-FID (orange).

Conclusions

Respiration rates of fruit and vegetables are important parameters for understanding senescence and ripening. The results obtained from the GC/Jetanizer-FID agree well with those obtained from the use of IR sensors except at low (<10 mL CO_2/kg·hr) respiration rates. The GC/Jetanizer-FID allows for a broad range of applicability and can be used with a variety of produce ranging from slow to fast respiration rates with a high degree of accuracy.

Recommendations

We recommend the use of the infrared sensor when high accuracy is not required and CO_2 production rates are >10 mL/kg·hr, due to its simplicity of implementation and low cost. The GC/FID with Jetanizer is recommended for all use cases, but especially for low respiration rates (<10 mL/kg·hr, e.g., nuts, dates, apples, citrus fruits, grapes), or when high accuracy is desired. Another benefit of GC is the ability to simultaneously measure other respiration gases with high accuracy, including ethylene, acetaldehyde, and ethanol. However, GC requires larger, more expensive equipment and a higher degree of technical aptitude to use.

Contact Us

For more information or to purchase a Jetanizer™, please contact us at 612-787-2721 or contact@activatedresearch.com.

Please visit our website for details and additional technical literature.

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