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The use of a VOC Sensor to Measure Freshness of Fruits

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Abstract — **With North America having one of the larger food wastages by consumers, there is a need for a system that will bring awareness to the state of the food, to reduce food waste. Fruits have been known to release volatile organic compounds (VOC) throughout their lifecycle, a VOC measuring device has been applied to measure the freshness level. A banana, cocktail tomatoes and a yellow pepper were used as samples. Although a correlating trend between the samples could not be determined, the variance in measurement readings for each sample showed promising results.**

Keywords — **Volatile organic compound, sensor, fruits**

I. Introduction

A study conducted by the Food and Agriculture Organization of the United Nations reported that about one third of food produced for human consumption was either lost or wasted [1]. With North America having significant food wastage of 95-115 kg/year per capita by consumers [1]. Fruits and vegetables were found to have one of the highest wastage rates of any food group [1]. This wasted food can negatively impact the environment, and producers and consumers economically [1].

In recent years, the need for fruits and vegetables to be processed to increase their functionality without affecting their freshness has been on the rise [2]. The act of minimally processing fruits and vegetables has led to an increase in perishability [2]. The standard methods of measuring the ripeness level of fruits and vegetables are based on the visual inspection, then based on the taste, aroma (smell) and texture [3]. Since descriptive panels have been shown to have variance in the results of the quality of the samples, instrumental techniques have been used [3]. Instrumental technologies can overcome the challenge of variable results by providing precise and accurate physical and chemical composition results [3].

As fruit ripen, they produce and progressively release volatile organic compounds (VOCs) [4], [5]. These VOCs make up the fruit aroma characteristic with ester, terpenoids, lactones being some of the dominant volatile organic compounds within the aromas [5]. It has been determined that climacteric fruits, such as bananas and tomatoes have a peak in edible ripeness when a burst of ethylene is produced [6]. After the climacteric point, the fruit starts to deteriorate [6].

Insignia Technologies Ltd. has developed a colour changing label based on changes in CO2 level and temperature, this label gives a visual indication of the food expiration date or how long a package has been opened [7]. Though with this type of label it only has a single use and is not capable of analyzing the food directly. There have been studies using various sensing techniques to determine fruit quality without destruction, such as machine vision, Nuclear Magnetic Resonance (NMR), electrical properties of fruits, and electronic noses (e-nose) [8]. E-nose sensors measure the emitted VOCs during the ripening for the determination of freshness [5], [8]. When it comes to e-nose systems, there has yet to be implemented a consumer-based system, where the freshness of their food can be readily available and determine when it is no longer safe for consumption.

In this paper, the feasibility of using a general-purpose VOC sensor-based system to determine the freshness of certain fruits was examined. This system will be used to provide consumers with a reliable, reusable, and user-friendly means of measuring the chemical composition of certain fruit, to determine whether the fruit is still edible. This measuring device has the potential to reduce food waste and improve the health of individuals.

II. Theory

The food quality indicator uses the Figaro TGS 2620 VOC sensor to determine the freshness level of the food within a storage container. The concentration of VOC gases in the air alters the electrical conductivity of a semiconductor within the sensor. The conductivity increases as the level of VOC concentration increases. The voltage across a resistor is measured with the Arduino Nano, which correlates to the VOC concentration released by the fruits. This measured voltage is converted to a freshness level from 1 to 5, and the corresponding LED lights are turned on to inform the user.

III. Materials and Methodology

A. Determination of Freshness

The Figaro TGS 2620 VOC Sensor was used to measure the VOC concentration within the sample. The VOC sensor is comprised of a metal-oxide semiconducting layer with an alumina substrate of a sensing chip. The VOC sensor was connected in parallel with a load resistor, as per the Figaro specifications [9]. The Arduino Nano microcontroller was used to supply 5V to the VOC sensor, which is required as the input voltage and to heat the sensor. The outputs of the VOC sensor were sent to the microcontroller, where the controller determined which LED lights to turn on depending on the VOC concentrations (see Fig. 1).

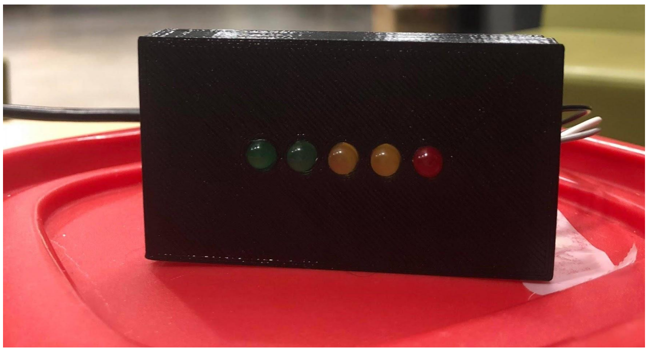

Fig. 1 LED Indicator

It was determined that a measurement between 0 and 300 (0 V and 1.47 V) would result in all five lights being illuminated, which indicates very fresh. A reading between 300 and 500 (1.47 V and 2.44 V) would result in four lights being illuminated, which indicates fresh. A reading between 500 and 600 (2.44 V and 2.93 V) would result in three lights being illuminated, which indicates somewhat fresh. A reading between 600 and 700 (2.93 V and 3.42 V) would result in two lights being illuminated, which indicates not very fresh. A reading between 700 and 800 (3.42 V and 3.91 V) would result in one light being illuminated, which indicates not fresh. Finally, a reading between 800 and 1023 (3.91 V and 5 V) would result in no lights to be illuminated, which would indicate extremely not fresh. A schematic diagram with the electrical configuration is shown in Fig. 2.

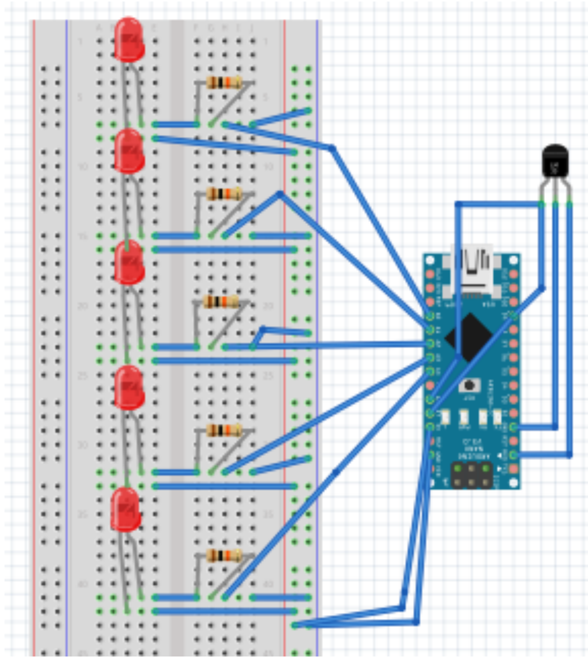

Fig. 2 System Schematic

B. Food Quality

The samples selected for testing the Figaro VOC sensor were a banana, four cocktail tomatoes, and yellow bell pepper which were purchased at a local store. The test samples were individually placed into airtight containers, each requiring the same lid. The samples were sealed into their respective containers and allowed to sit for 24 hours before the first measurement was taken. In a 4th compatible lid, a 1 cm diameter hole was made to allow for the insertion of the VOC sensor. At the time of measurements, each sample was enclosed individually using the lid equipped with the VOC sensor (See Fig. 3). The sensor was allowed time to reach a stable reading, which was defined as a steady reading value measured for a period lasting at least 15 seconds.

Fig. 3 VOC Measurement Method

IV. Results

Measurements were taken of the banana, pepper and tomatoes and a photo of each sample was taken on days 1,3,5 and 8 to act as a visual representation. The results are shown below in Fig. 4. Fig. 5 shows the voltage measurements that correlate with the amount of VOCs present in the container. A line of best fits was added to determine the overall trend of each sample.

	Banana	Yellow Bell Pepper	Cocktail Tomatoes
DAY 1			
DAY 3			
DAY 5			
DAY 8			

Fig. 4 Visual Representation of Samples

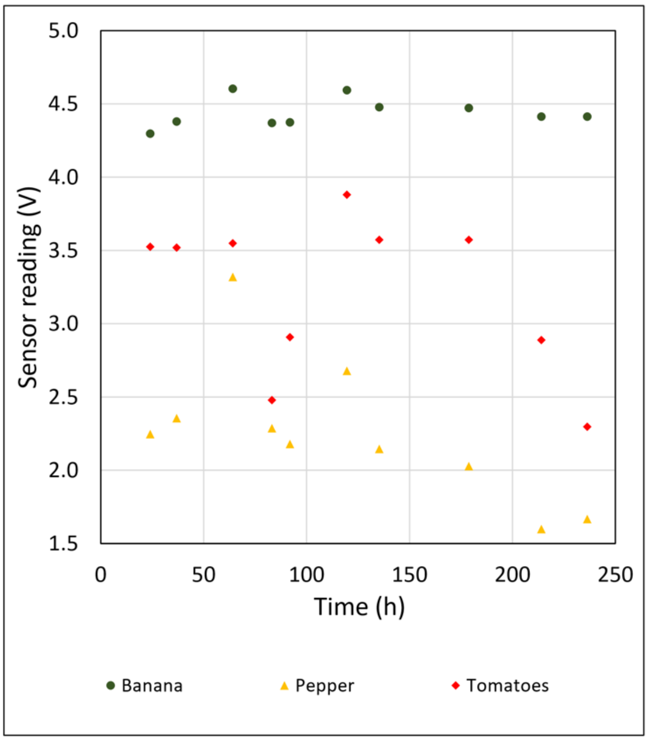

Fig. 5 Sensor Measurement of Samples

V. Discussion

The graphs generated (Fig. 5) indicate that the VOC voltage readings of the samples were consistent to a point, but a predictable trend could not be established. Upon analyzing the data, it was observed that the banana had an overall increasing VOC value. Additionally, it was observed that the tomatoes and pepper had a decreasing sensor reading. The inconsistency in the data can potentially be attributed to the pepper and tomatoes' method of ripening, the production of mold (See Fig. 4), or the varying condition in which the measurements were taken.

It was observed that the VOC concentration of each sample was significantly different. This was presumably due to the amount of emissions of the different samples. This method of determining what type of fruit or vegetable is present could be used in the food transportation industry as an alternative to visual inspection.

Additionally, the readings were not taken with the equipment and samples in the same location each time. This was related to availabilities of research team members throughout the measurement period. Variations in air quality between locations may be responsible for improper calibration of the sensor from one reading to the next. Therefore, it is recommended that in future runs of similar experiments, all equipment remains in one location, and measurements are recorded on a regular schedule.

It is recommended to do further analysis into the freshness level of fruits by:

1. Start the measurement process with unripe fruits.
2. Use glass containers, to avoid any unwanted VOCs.
3. Performing sample readings on an hourly basis.
4. Using three of the same fruit or vegetable for each sample.
5. Performing measurements with of samples with two VOC sensor to ensure proper functionality.
6. Identifying new bounds for different fruits.
7. Determine the effects of mold production on VOC emissions.

VI. Conclusion

It has been determined that a VOC sensor alone is unable to be used for the determination of the freshness level of fruit and vegetable samples. However, the sensor can differentiate between different fruits to a certain degree via analysis of reading levels. Specific trends in freshness could not be identified, based on individual samples. Further investigation will need to be conducted to identify accurate freshness levels of the samples.

Conflict of Interest

Throughout the course of this project, no conflicts of interest were identified among members of the team.

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