The Best Team Ever (Team 4)

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Gigasniffer

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Introduction and problem description

New York produces 3.9 million tons of food waste annually [1]. The goal of "the GigaSniffer" is to reduce food waste in the homes of New Yorkers. The problem stems from New Yorkers buying far more than they need, as the NDRC estimates that 57% of food waste is edible when thrown out, suggesting that there is uncertainty about the edibility of the food at the time of the disposal [2]. Reducing this waste is far from simple, as seemingly simple solutions are challenging to implement. Suggesting that consumers buy less is an unrealistic request, as buying in higher quantities, or "in bulk," is known to be more cost-effective. Food waste is a problem, but several auxiliary issues are attached. Firstly, food waste has some significant environmental impacts that are often overlooked. When processed in New York State, garbage is brought to landfills, where it is left to sit and rot indefinitely. When this garbage includes food, not only is the volume of waste in landfills higher [3], but the gases released by the garbage are also more volatile and harmful [4]. Food waste left to rot in landfills over time releases methane, a 28x as potent as a greenhouse gas as Carbon Dioxide. For every 907 metric tons of food waste in landfills, 34 metric tons of methane are released [5]. Secondly, food waste is a significant economic loss and an overall waste of money. As of 2009, the United States has had around $198 billion in food waste-related yearly losses, equivalent to about $400 per American [6]. According to the US Department of Labor, accounting for the inflation that occurred since the late 2000's, this is about $597 per American today. Finally, having excess food waste in a city negatively impacts its cleanliness and hygiene. Food waste attracts vermin like raccoons, rats, cockroaches, and mice, all of which interact with garbage, fecal matter, sewer systems, and other mediums of bacteria. These vermin carry bacteria and are vectors of diseases like rabies and salmonella. Excessive food waste is a sure way to attract these vermin and increase their interaction with humans, according to research done by the NYC government. [7]. Food waste in New York is nearly unlimited in scope and impacts everyone who lives in the state. New Yorkers want a cleaner, cheaper, healthier state, which could start with reducing food waste.

Aside from the food waste from overconsumption and purchasing habits, a significant volume of trashed food results from expired and rotten food. The traditional framework of printed-on expiration dates does not cover the nuances of food storage conditions. A damp and warm area will naturally shorten a food product's lifespan. Yet the consumer would remain unaware, relying solely on the fact that the expiration date is still a month away. As such, more intelligent food packaging designs will help inform consumers of the food conditions they own [8]. These designs can come in stickers containing dyes released when a chemical reaction occurs with the presence of gasses resulting from decomposition, as shown in Figure 1.

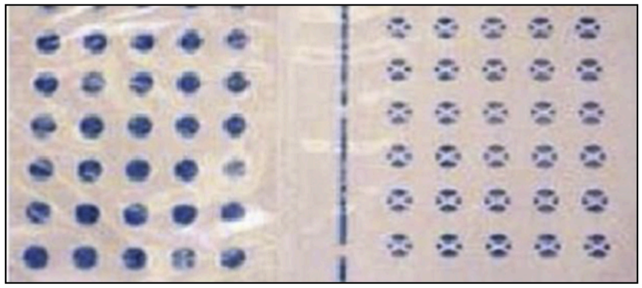

Figure 1: A sensor (Raflatac) that becomes transparent, showing white X's as a layer of silver reacts with hydrogen sulfite, a chemical released as fish and poultry deteriorate [8].

By utilizing chemical reactions, visual indicators in the form of labels and stickers will accurately indicate the status of food products and reduce the amount of food spoilage in average households. This approach offers valuable lessons in creating solutions that minimize waste generation while encouraging mindful consumer habits.

Fruit flies have two antennae through which they "smell," and they are covered in sensilla (thin hairs), which possess olfactory neurons. CO_2 and esters produced by rotting fruit enter the sensilla and attach themselves to the receptors, which send signals to the brain [9]. Researchers found that this is because the receptors that receive the specific odor of carbon dioxide can essentially talk to each other, and this largely depends on when and how they detect it. Additionally, it depends on the context in which they encounter ethanol, whether it's with other food-borne odors or with vinegar. Fruit flies' response heavily depends on concentration, the acceptable range between 1-10% by volume, with higher concentrations causing aversion. The source helps them differentiate between predatory and non-predatory food sources and/or where to lay their eggs [10].

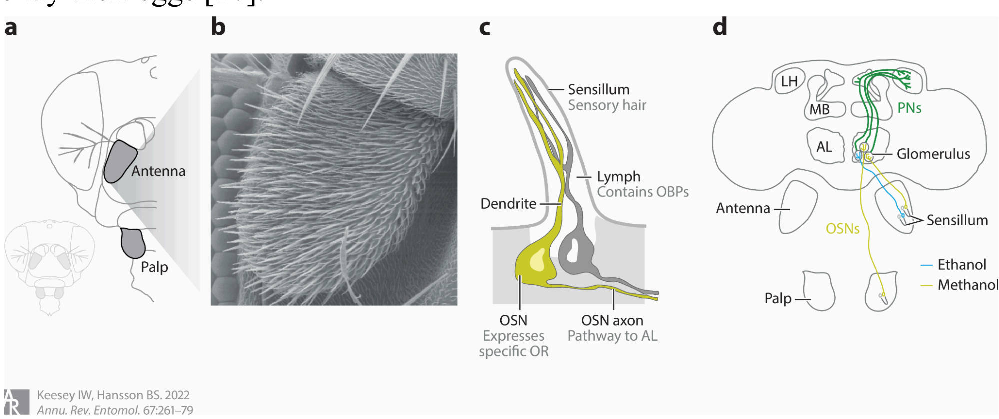

Figure 2: Process of detection by fruit flies, from odor received by the antenna, absorbed through the sensilla, then received by the OBP (odorant binding protein) and processed by the brain [10].

Design and Build

Inspired by the natural ability of fruit flies to detect rotting fruits through emitted gases, a device was developed to measure carbon dioxide and ethanol concentrations to evaluate fruit freshness and identify spoilage. The design replicates this biological process by incorporating CO2 and ethanol sensors, offering a non-invasive and efficient approach to spoilage detection. The design's success hinges on two key metrics: sensitivity to gas concentration changes and portability. The device must detect subtle variations in carbon dioxide and ethanol levels while remaining compact and lightweight. These metrics ensure the device is both accurate and practical, delivering a reliable solution for spoilage detection.

The prototypes, guided by principles of portability and reusability, underwent several iterations to optimize functionality and design. The initial concept, as shown in Figure 3, involved a model that combined a CO_2 sensor with a weight scale to calculate gas emissions per unit mass. While effective in theory, this design conflicted with initial portability goals and occupied too much space.

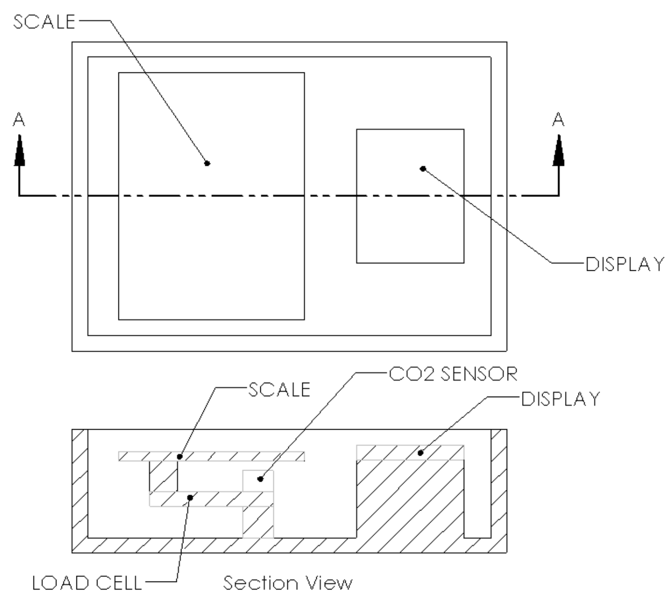

Figure 3: Initial prototype design, including a scale, CO2 sensor, and display for measuring gas concentrations and providing real-time feedback.

A compact, wand-like prototype was developed, replacing the scale with an ethanol sensor for mass-independent measurements. This design, shown in Figure 4, reduced the device's overall footprint while enhancing its versatility across various settings.

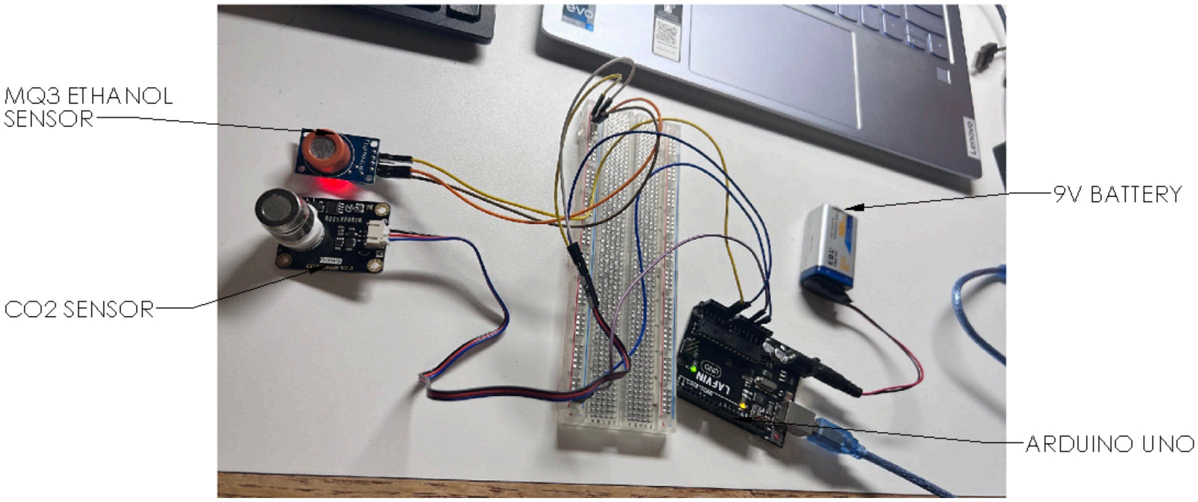

Figure 4: The second iteration of the prototype, incorporating ethanol and CO2 sensors connected to an Arduino Uno via a breadboard for improved functionality and testing.

Testing revealed that accurate gas measurements required an enclosed environment to minimize external interference. A box enclosure was designed using laser-cut acrylic and wood to address this challenge. This solution, shown in Figure 5, ensured the necessary isolation for reliable sensor readings while maintaining a sleek and functional design. Additionally, a display was integrated to provide real-time feedback on gas concentrations and freshness status, enhancing the overall user experience.

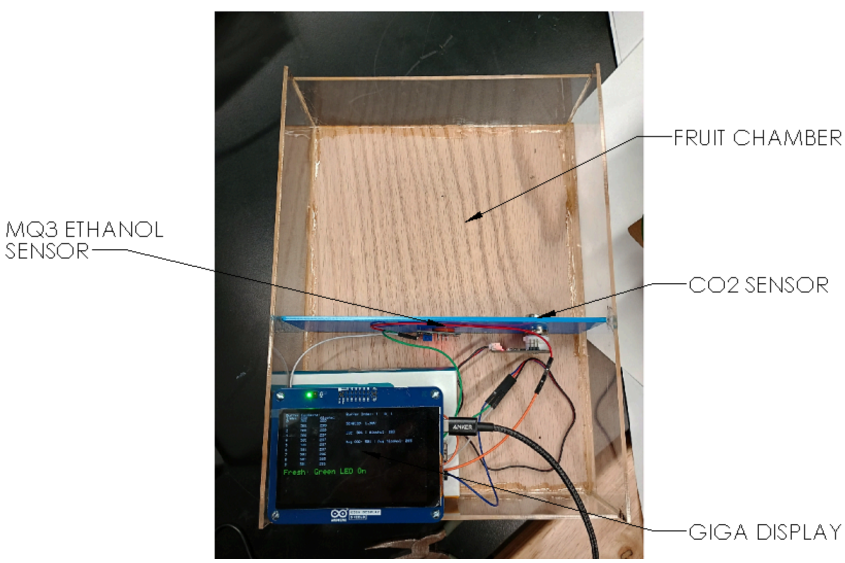

Figure 5: Final prototype with CO2 and ethanol sensors mounted to face an enclosed compartment within the box, designed to house the fruit and ensure accurate gas concentration measurements.

Prototyping involved iterative enhancements to both hardware and software, aiming to improve functionality and reliability. Initially, the software was designed to read sensor outputs and display raw data without additional processing. Subsequent iterations introduced advanced features, including calculating variations in gas concentrations relative to the averages of the ten most recent samples. These enhancements enabled the system to trigger alerts based on elevated concentrations, allowing real-time freshness assessments. The following pseudocode in Figure 6 demonstrates the algorithm used to determine the freshness status of the fruit.

```
Set fresh to true
Set soon to true
Set rot to true

If alcoholDifference is greater than ALCOHOL_DIFFERENCE_THRESHOLD:
    Set fresh to false
    Set soon to false
    Set rot to true
Else if co2Difference is greater than CO2_DIFFERENCE_THRESHOLD
        AND alcoholDifference is less than ALCOHOL_DIFFERENCE_THRESHOLD:
    Set fresh to false
    Set soon to true
    Set rot to false
Else:
    Set fresh to true
    Set soon to false
    Set rot to false
```

Figure 6: Pseudocode that demonstrates the algorithm that determines the freshness status of the fruit.

Hardware adjustments included upgrading from an Arduino Uno to a Mega to address memory limitations, which had caused the initial code to crash. These iterations, combined with efficient fabrication methods like laser cutting, allowed us to rapidly improve prototypes and ensure they met formerly established design principles and performance metrics.

Testing and Results

The final prototype was tested using three fruits: pears, raspberries, and bananas. These fruits were chosen due to the short duration of freshness. Pears and raspberries quickly rot from friction, while bananas take slightly longer to rot but brown quickly. Due to the fast decay rate, using these fruits allowed us to test the device's effectiveness in a shorter period. After testing with the initial setup, the observed values reflected a negligible increase. To improve the results, testing circumstances were adjusted–each reading was taken by putting the fruits in a box alongside the box. The fruits were left out over eight days, the CO_2 and ethanol values were read every 24 hours, and day-by-day pictures were taken.

Date	Item	Standard CO_2	Measured CO_2	CO_2 Difference	Standard Ethanol	Measured Ethanol	Ethanol Difference
Day 1	Raspberries	466	472.5	6.5	124.5	127	2.5
	Banana	466	474	8	124.5	190.5	66
	Pear	466	472.5	6.5	124.5	147	22.5
Day 2	Raspberries	456.5	470	13.5	103.5	120	16.5
	Banana	456.5	472	15.5	103.5	190.5	66
	Pear	456.5	471	14.5	103.5	256	152.5
Day 3	Raspberries	468.5	478	9.5	105	184.5	172
	Banana	468.5	469	0.5	105	340	211
	Pear	468.5	483	14.5	105	282	114
Day 4	Raspberries	479	512	33	108	282	174
	Banana	479	512	33	108	401	293
	Pear	479	506	27	108	294	186
Day 5	Raspberries	480	505	25	168	340	172
	Banana	480	503	2	168	480	312
	Pear	480	496	5	168	229	61
Day 6	Raspberries	492	525	33	180.5	375	194.5
	Banana	492	527	47	180.5	236	55.5
	Pear	492	510	18	180.5	275	94.5
Day 7	Raspberries	498.5	523	24.5	118	336	218
	Banana	498.5	511	8.5	118	285	167
	Pear	498.5	521	1.5	118	233	115
Day 8	Raspberries	500	545	45	172.5	356	183.5
	Banana	500	527	10	172.5	315	142.5

Table 1: Chart showing the standard and measured CO2 levels, CO2 differences, standard and measured ethanol concentrations, and ethanol differences for each fruit from day 1 to day 8.

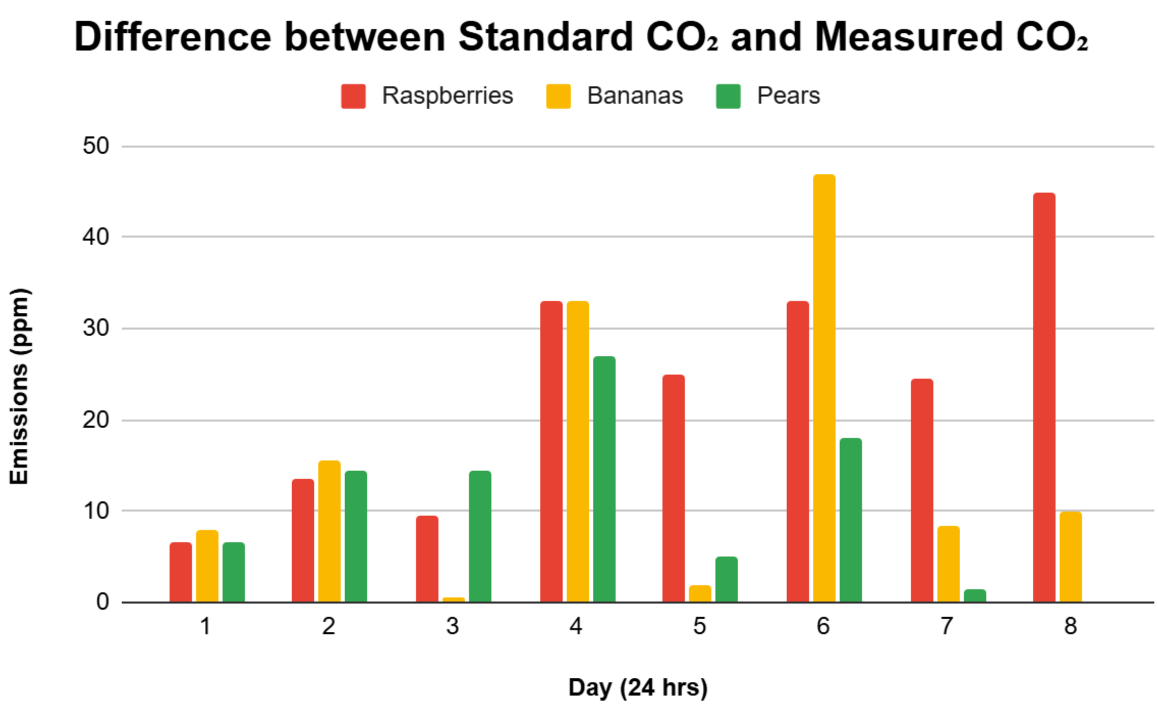

Figure 7: Excess CO_2 produced by the tested fruits measured daily over a week.

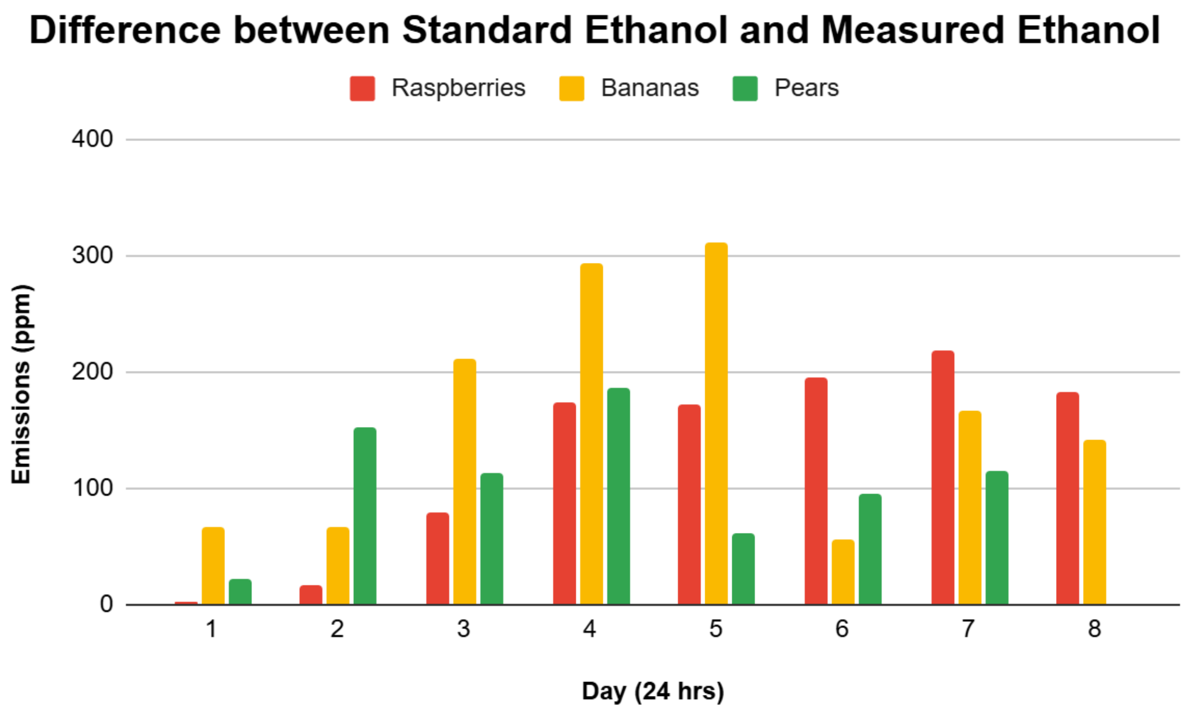

Figure 8: Excess ethanol produced by the tested fruits measured daily over a week.

Based on the data given from the figures, a noticeable trend can be found: the differences between standard and measured carbon dioxide and ethanol increase with respect to time. To create a device that indicates the freshness of produce, a threshold value had to be set which, when going over the value, indicated the freshness of your food. The threshold values selected for carbon dioxide and ethanol were 25 ppm and 165 ppm, respectively. Before experimentation, research was done to find the ideal threshold values for these fruits. However, results were sparse. Firstly, the device was not programmed to accept user input. As a result, it cannot identify the produce item inside, which would otherwise allow us to set a specific threshold value. Additionally, online sources only provided emissions values for post-rot rot, which would make the device useless. Therefore, the thresholds were obtained from observing common trends in the data (i.e., similar excess values).

Figure 9: Day four: The condition of the fruits, noticeable changes in texture and color, and signs of spoilage.

Notably, by day four, the levels of carbon dioxide and ethanol increased drastically, prompting us to set threshold values similar to the emitted values of that day. By impleneting those values into code, it became possible to observe the difference between the carbon dioxide and ethanol emitted by the fruits and the set threshold values. This implementation allowed us to create the code indicating to the user the freshness of their produce. To ensure accuracy, the code measured the average levels of carbon dioxide and ethanol emitted, preventing any outlying readings from disrupting the testing.

While the results are promising in predicting the freshness of different fruits, using the freshness indicator takes longer than many users will probably have patience for. It would be beneficial to adjust the design by using a type of sensing that doesn't involve electrochemical processes so that the implementation time is more efficient, thereby becoming much more convenient for consumers.

Conclusion

Based on the findings, success metrics were partially achieved. The final prototype accurately measured the carbon dioxide and ethanol levels emitted from the fruits, allowing us to determine whether the fruit was fresh, nearing spoilage, or should be discarded. This fulfilled the primary objective of helping users avoid unnecessary food waste by providing actionable and durable freshness indicators.

However, the testing process revealed areas for improvement. While the device successfully identified changes in $CO2$ and ethanol levels corresponding to the freshness of pears, raspberries, and bananas, its reliance on electrochemical sensing made it less user-friendly or time-efficient than intended. The readings required consistent monitoring over eight days, exceeding most users' practical time frame.

The bigger picture for this project is providing a method to reduce the amount of food waste as a result of mismanagement. The results of the Gigasniffer were promising, meaning that it could offer a possible solution for individual households on a local level… In the future, the wish would be to speed up the sensing process by moving away from relying on electrochemical methods. It would also be beneficial to test the product with multiple users to determine whether it effectively mitigates food waste due to mismanagement. Also, instead of focusing on three specific types of fruit, as was done in the sample, it is desirable to make the data and analysis more universal. Hence, it works for all fruits—and potentially other foods—regardless of type. This will help make the solution more adaptable and effective overall. Moving forward, the goal is to prioritize user privacy by ensuring data is anonymized and securely stored. Accuracy in determining freshness is crucial to avoid food waste or health risks, so continuous and rigorous testing of the device is necessary. The aim is to use eco-friendly materials and design for recyclability. To ensure accessibility, the focus is on affordability and inclusivity for low-income groups. These considerations will help ensure the Gigasniffer is practical, sustainable, and beneficial for all users. The Gigasniffer is more than just a tool—it's a step toward a future where food waste due to mismanagement is dramatically reduced and the environment is protected. By empowering consumers to make smarter decisions about food freshness, the Gigasniffer can save millions of pounds of food from being wasted but also spark a broader movement toward more sustainable living. With further testing and improvements, the Gigasniffer is bound to make a real difference.

Process reflection

This project improved The Best Team Ever's collaboration skills and ability to work through obstacles. The design process was adapted after realizing that specific design schematics would be less effective. It became clear how much intricate planning and detail goes into the formulation of a design. Additionally, the importance of setting aside ample time for testing and potential mishaps became understood throughout the project process. In the case of the freshness indicator product, over a week of testing was required, as the fruits had to be allowed to decompose organically. Collaboration throughout the project timeline proved essential, especially when making adjustments during unexpected setbacks. The skills gained—teamwork, perseverance, and attention to detail—will be carried forward into the future across the multidisciplinary fields of engineering.

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Contributions

- Introduction and problem description - Zehra, Zeshui, Christopher
- Design and Build - Zeshui, Zehra
- Testing and results - Allen, Ahikara, Somin
- Conclusion - Allen, Ahikara, Somin
- Process reflection - Ahikara, Allen, Somin