

Introduction

Current Problem:

- The average American family **wastes \$2,900/year** on food; the beef industry alone loses \$3.73 billion annually due to color-based rejection.
- 1 in 7 Americans contract food poisoning every year. Poultry alone accounts for **19% of all food related deaths**.
- Wasting a **single pound of beef wastes over 1,800 gallons of water** and releases methane.
- Dangerous pathogens often proliferate to harmful levels long before food looks or smells spoiled.

Figure 1: Rotten Meat

Status Quo:

- Current detectors cannot calibrate for specific meat types (e.g., **distinguishing fish from beef**).
- Affordable sensors frequently suffer from noise and interference from humidity.
- Expiration dates are conservative estimates**, not real-time safety data, leading to the disposal of safe food.
- Consumers rely on the **"smell test," which is inconsistent and fails to detect odorless bacteria**.



Experiment Methodology

- Initial Approach:** Originally, the experiment used a single sealed container for each meat sample, which was opened daily to insert the sensor and record readings.
- Identified Issue:** Opening the container every 24 hours caused the ammonia to escape. This "reset" the concentration level, preventing the sensor from measuring the true cumulative buildup of ammonia emitted from the meat samples.
- Revised Methodology:** To ensure independent measurements, ten separate containers were used, with one container opened every 24 hours to assess total ammonia accumulation.
- Result:** By opening each container only once on its designated day, the new methodology ensured that no gas was lost. This resulted in reliable and valid scientific data in measuring the total ammonia concentration over time.

Figure 2: Electronic Circuit
Photograph taken by Finalist, 2026

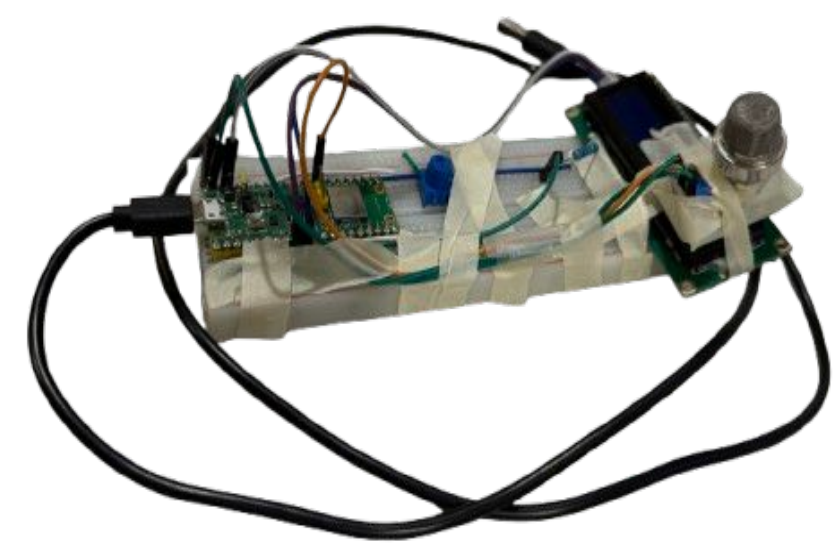


Figure 3: Meat Sample Container
Image created by Finalist using BioRender, 2026



Microcontroller Unit:

- Microcontroller coordinates external sensors
- Coded in MicroPython
- Utilizes a breadboard to connect components
- Incorporates dedicated gas sensing chamber
- Integrated digital display provides real-time status output

Meat's Container for Experimentation:

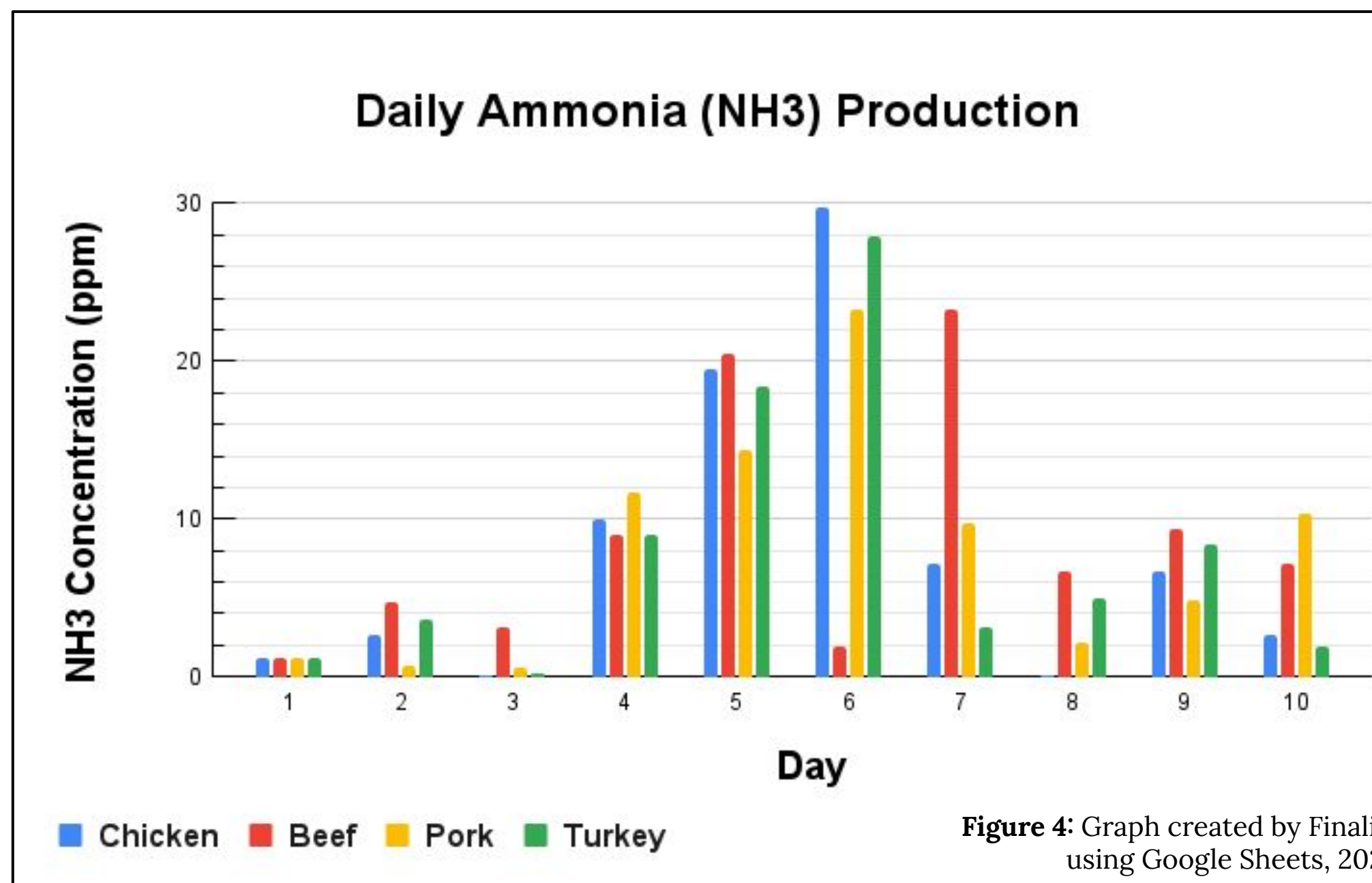
- Built with an airtight plastic container
- Sealed direct-flow channeling directs headspace gas directly to the sensing chamber
- The Binder clip constrains the ammonia gas within the container
- Custom airtight mechanical coupler ensures consistent sensor contact without ambient gas loss

MEAT FRESHNESS MONITOR

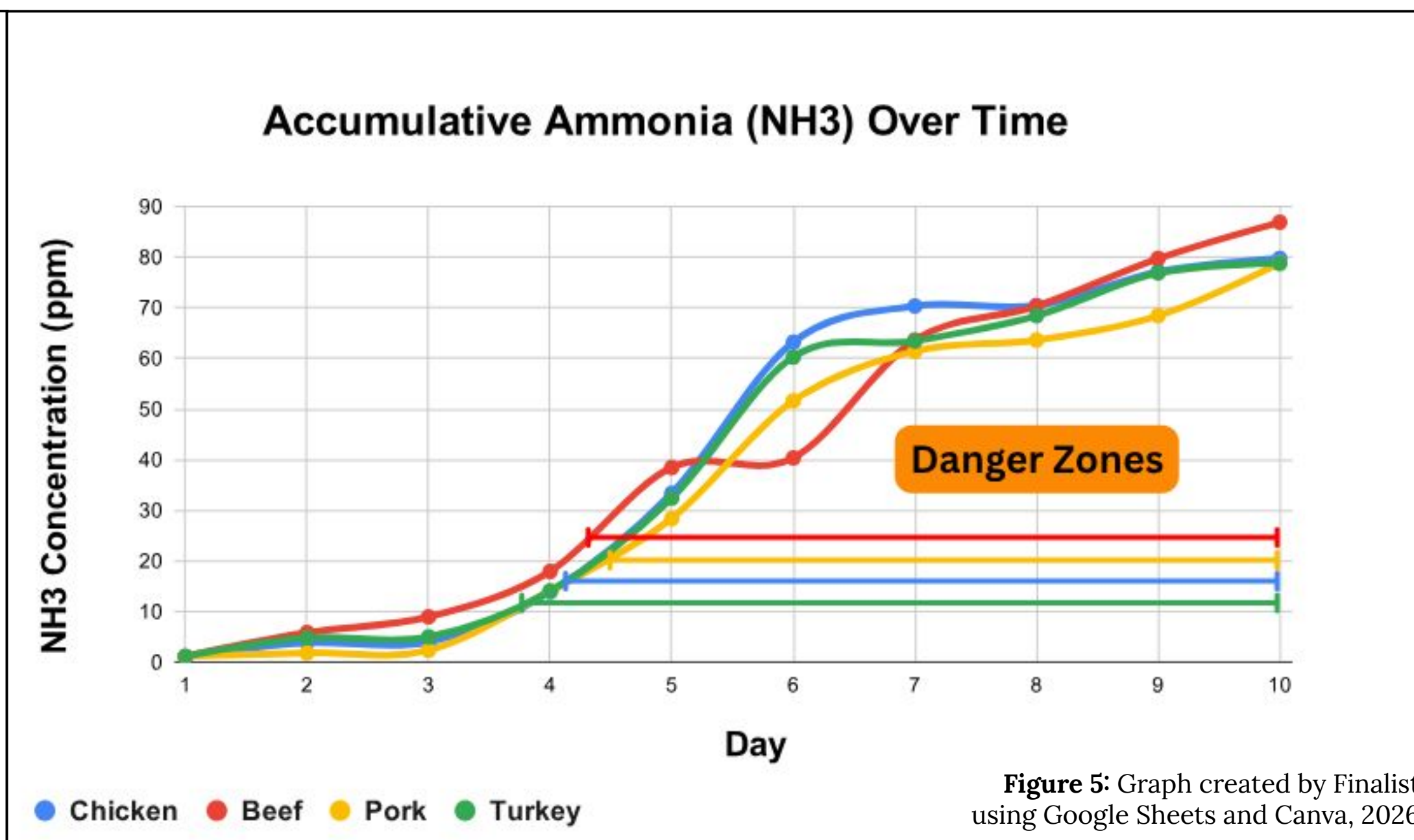
Research Question: Can a low-cost wireless sensor utilizing targeted gas sensing and microcontroller architecture accurately detect early spoilage in food based on ammonia level changes?

Statistical Analysis

Daily ammonia production for all meat types peaks significantly between Day 5 and Day 7

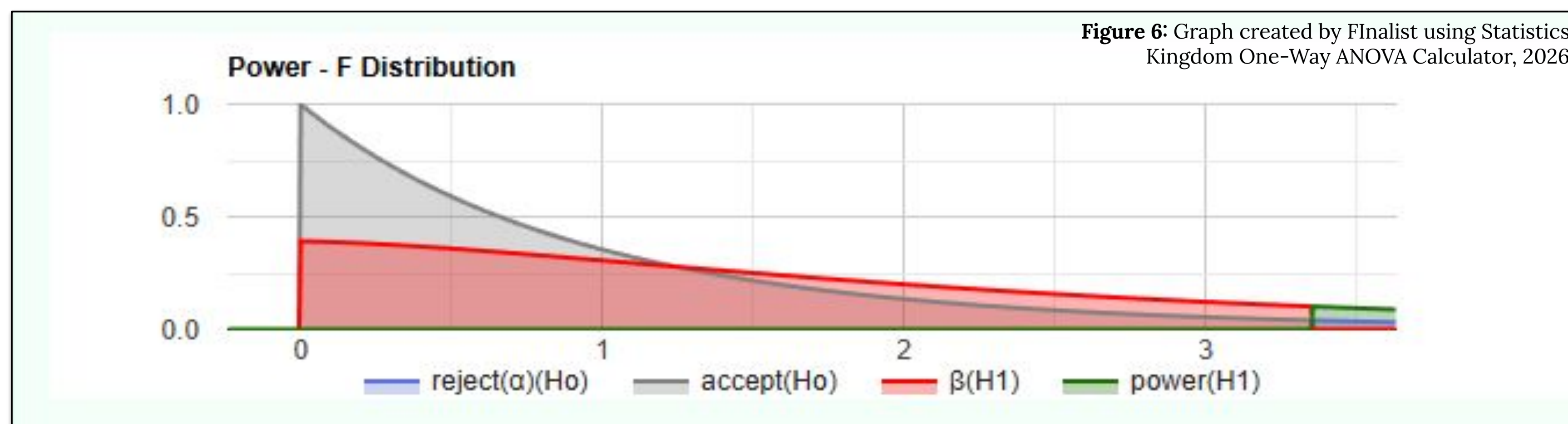


Total ammonia accumulation follows a consistent upward trajectory across all biological replicates, crossing the critical spoilage threshold midway through testing.



One Way ANOVA Test Results: A mathematical calculation to find the variance and significance of data.

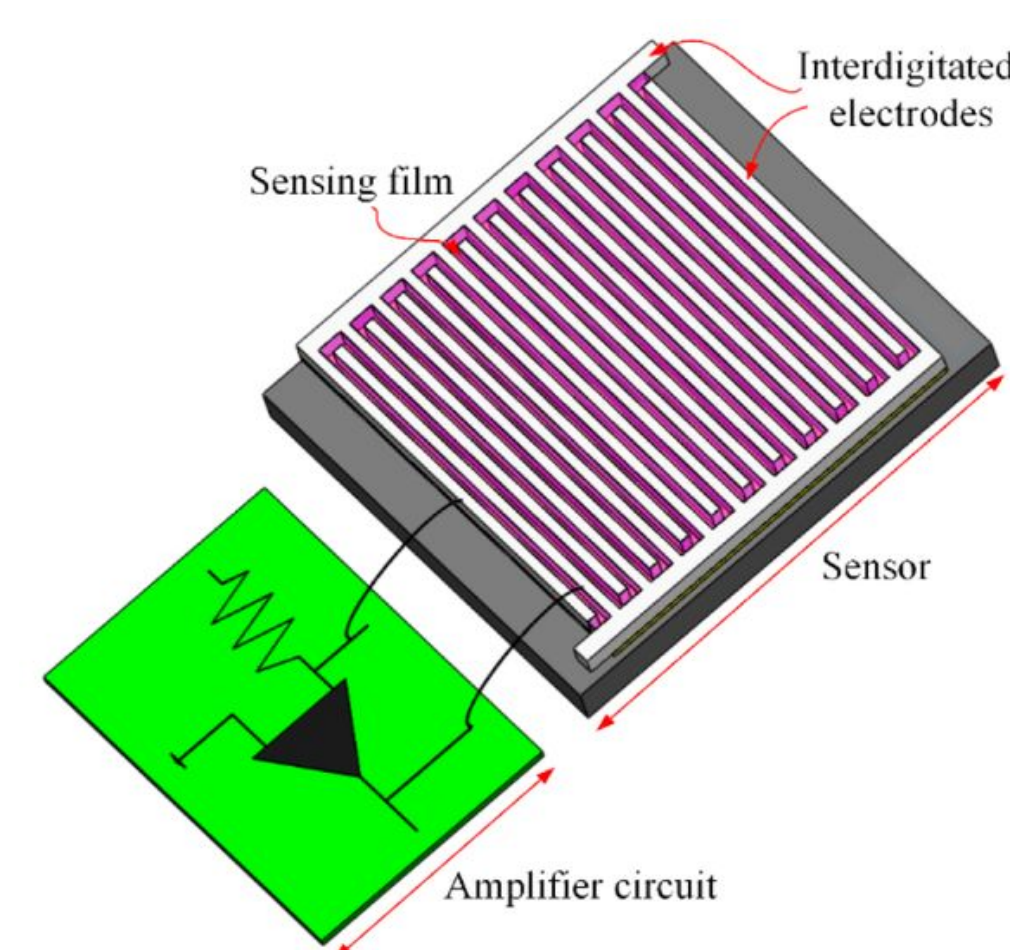
- P-value:** p-value equals 0.02, $[p(x \leq F) = 0.906986]$. It means that if we would reject H_0 , the chance of type 1 error (rejecting a correct H_0) would be too low: 0.009301 (0.93%)
 - This means that **each meat is different**.
- Effect size:** The observed effect size, "f" is small (0.19). That indicates that the magnitude of the **difference between the averages is low**.
 - The η^2 equals 0.16. It means that the group explains **16.1% of the variance** from the average



Product & Solution

- A **low-cost** container to constantly measure ammonia gas productions to gauge if it is spoiled.
- Targets ammonia gas (NH_3), a reliable biological marker for contamination
- The system uses integrates targeted gas sensing with dedicated microcontroller architecture
- The multi-point calibration algorithm coded via **MicroPython** accurately tracks volatile organic compound trends to evaluate freshness
- By utilizing accessible microcontroller architecture and targeted gas sensing, this device delivers high-accuracy detection at a fraction of the cost of industrial gas analyzers.
- Integrated digital display provides real-time status output

Figure 7: Sensor Circuit Diagram



Conclusion

- Cost-Efficient Innovation:** Successfully developed a compact, automated ammonia detection system at a 75% lower cost than industrial alternatives.
- Rapid, Early Detection:** Integrated targeted sensing and automated microcontroller processing to identify critical ammonia buildup within seconds.
- Versatile Application:** The portable design scales effectively for household refrigerators, restaurants, and global supply chains, while providing a critical safety aid.
- Public Health Impact:** Bridges the gap between engineering and food safety, a blueprint for smarter food storage solutions.



Figure 8: Original Visualization of the Meat Freshness Monitor generated by Sora
Graphic created in 2026 using Open AI

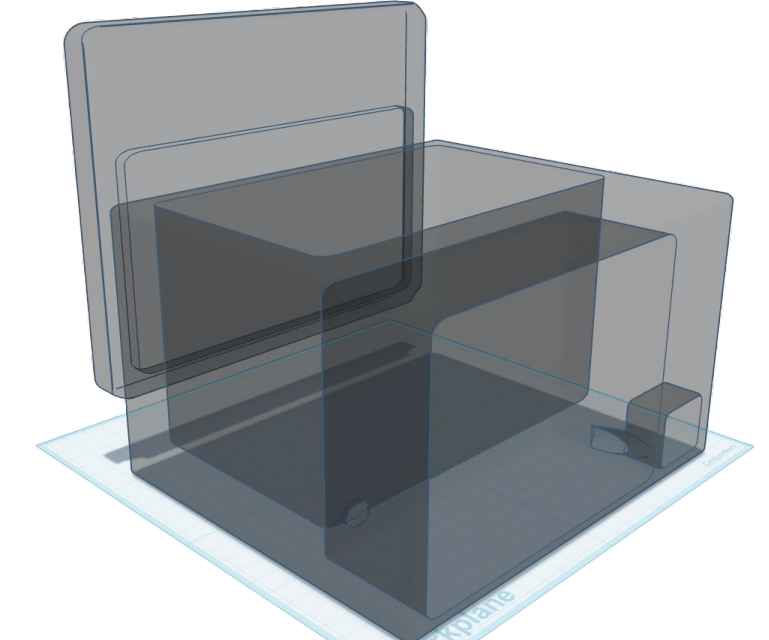


Figure 9: CAD Model of the Final Prototype
Image created by Finalist using Tinkercad, 2026

Future Work

01

Diversify Subjects

- Seafood & Meats

02

Enhance Detection

- Gas & Environment

03

Identify Spoilage

- Proactive Food Safety

04

Compact PCB

- Battery-Powered

05

Smart Integration

- Proactive & Voice-Activated

Figure 10: Future Improvements generated by Sora
Graphic created in 2026 using Open AI

Graphic Reference List

- [1]: Taras. (n.d.). Rotten meat. Stinky food. White insect caterpillars on meal. Health hazard. Cartoon flat illustration. Maggot worms [Vector illustration]. Adobe Stock. Retrieved from <https://stock.adobe.com/no/images/rotten-meat-stinky-food-white-insect-caterpillars-on-meal-health-hazard-cartoon-flat-illustration-maggot-worms/337098036>
- [7]: Shen, W.-C., Shih, P.-J., Tsai, Y.-C., Hsu, C.-C., & Dai, C.-L. (2020). Low-Concentration Ammonia Gas Sensors Manufactured Using the CMOS-MEMS Technique. Micromachines, 11(1), 92. www.mdpi.com/2072-666X/11/1/92#article-metrics-citations