# Low-Cost Ascorbic Acid Sensor Using Photographic Paper

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## Objective

Produce a sensor to aid Dr. Warren's research that is—

- Low cost
- Lightproof
- Accurate
- Easy to assemble and clean
- Usable outside of a darkroom

## Background

Ascorbic acid (vitamin C) is an FDA-regulated additive in pharmaceuticals and processed foods. Current methods to test concentration include titrimetry and spectrophotometry, requiring technical equipment and expertise.[1]

Dr. Roseanne Warren is developing a low-cost alternative to measure ascorbic acid concentration using photographic paper. As a reducing agent, ascorbic acid works as a photographic developer. Tests were run in the Film and Media Arts darkroom, shown in Figure 1. Experiments took several hours and had to be scheduled around class times, preventing timely testing. Researchers needed a solution to continue in Dr. Warren's lab.

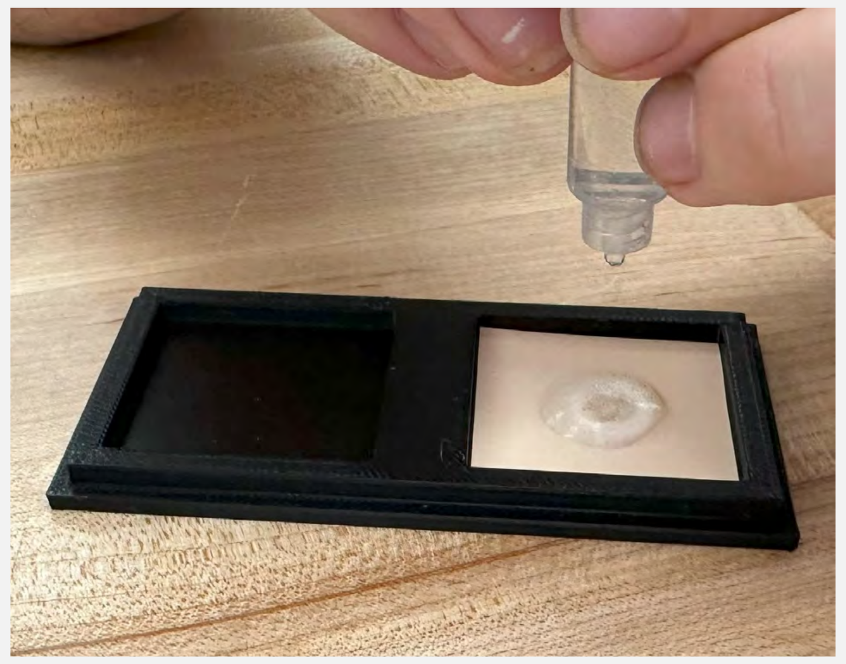

**Figure 1** Researchers applied ascorbic acid to 1 inch x 1 inch pieces of photo paper. The reaction took between 2 and 8 hours for optimal results. Samples were fixed with sodium thiosulfate, photographed, then analyzed in ImageJ. Analysts used the 8-bit grayscale value to correlate the resulting darkness to ascorbic acid concentration.

## Design Evolution

We first developed a device in which to run tests. The housing had three major revisions, each focusing on a critical function:

1. Ability to block ambient light
2. Consistent and accurate fluid application
3. Loading paper outside of a darkroom

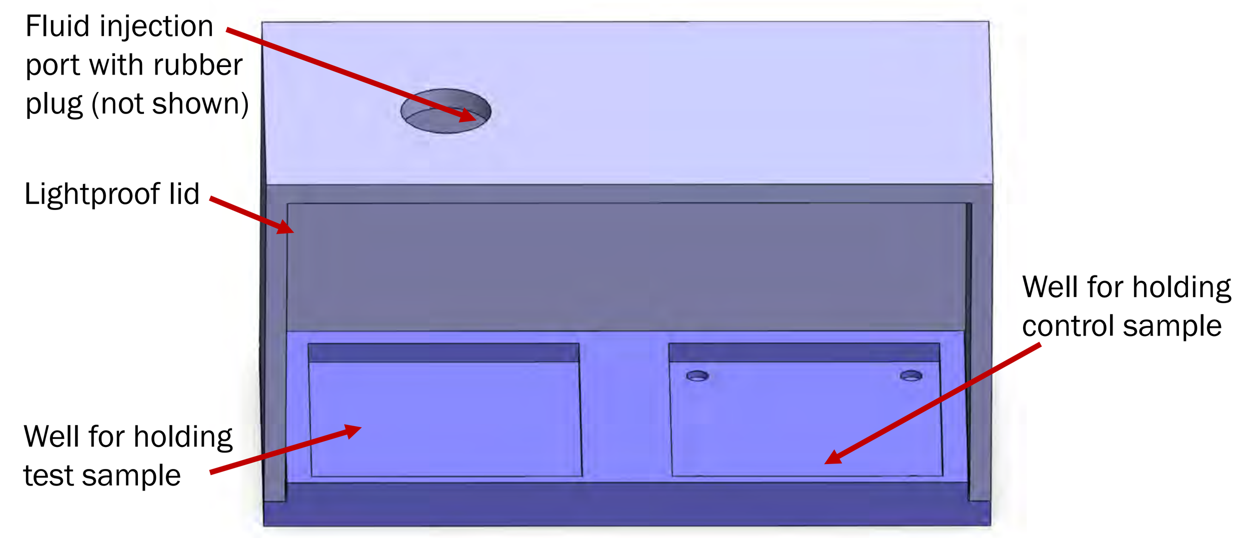


**Figure 2.1** Initial prototype focusing on its ability to block light. We found black PLA at 0.12 inches thick was lightproof up to 800 lux (using a cell phone flashlight). Typical office lighting is 500 lux. Analyte was injected through the port using a hypodermic needle. It had to be loaded in a darkroom.

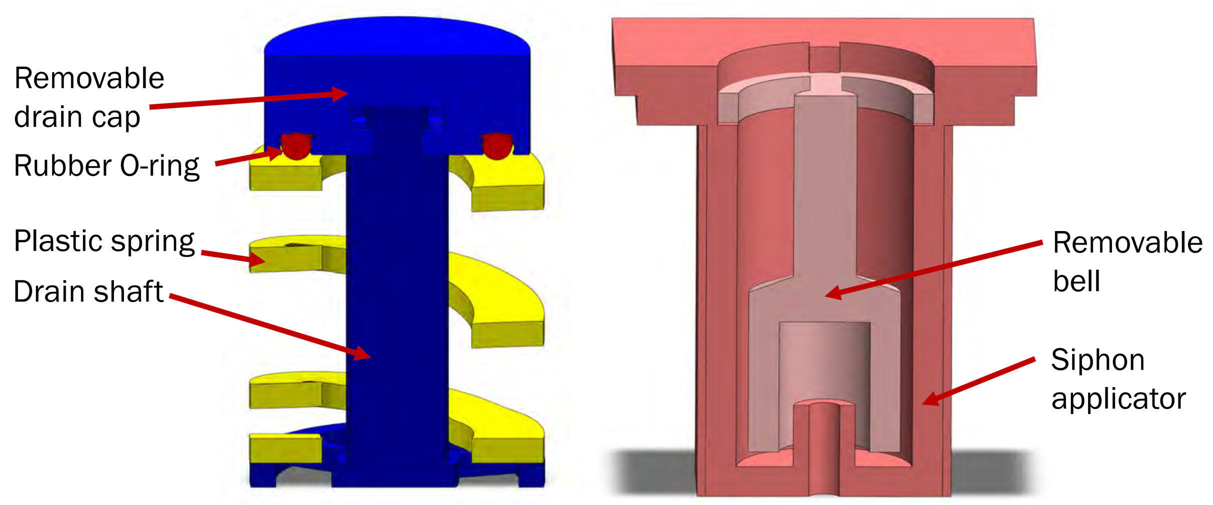


**Figure 2.2** Second prototype with a spring-loaded drain (left) and a bell siphon (right) to apply analyte into a bath. Fluid application was consistent, but the design needed over a dozen parts and ¼ cup of analyte to work properly. The drain was difficult to disassemble and clean.

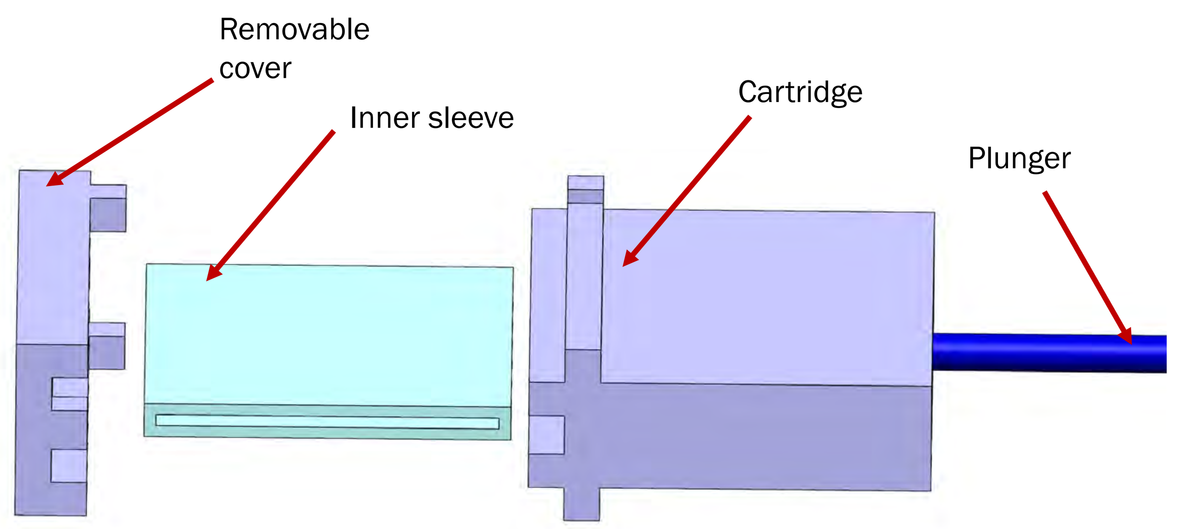


**Figure 2.3** Third prototype to insert paper into the housing. The cartridge was loaded with photo paper inside a film changing bag, then pushed into the housing. The inner sleeve with paper would drop into the bath. The addition needed more fluid and added points that light could enter.

## Final Prototype

The final sensor includes a simplified housing, camera stand, and image analysis program. The user loads and tests samples in the housing, photographs samples inside the camera stand, and analyzes the results with the program.

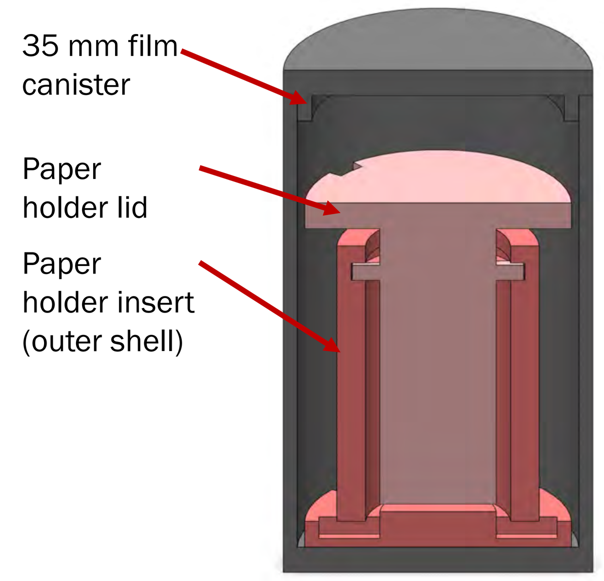


**Figure 3.1** The final housing uses a 35 mm film canister and 3D-printed paper holder. The user loads paper into the holder inside a film changing bag, then stores and tests the samples inside the canister. The design is simple, low cost, and light tight. It works with only 0.5 ounces of analyte.

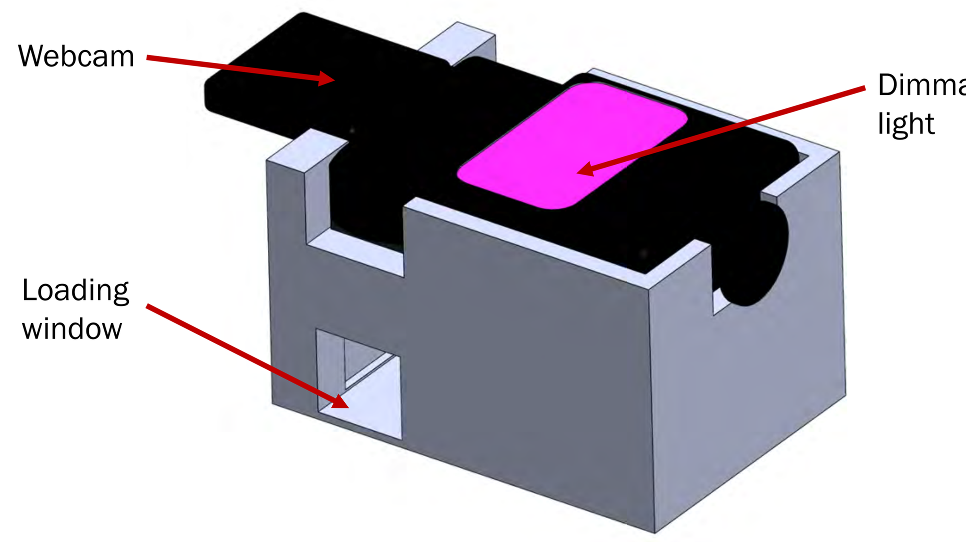


**Figure 3.2** 3D-printed camera stand. It holds a USB webcam and dimmable light. The users inserts the developed sample in the bottom window. The design permits consistent exposure by blocking most ambient light. The image analysis software reads the sample from the webcam.

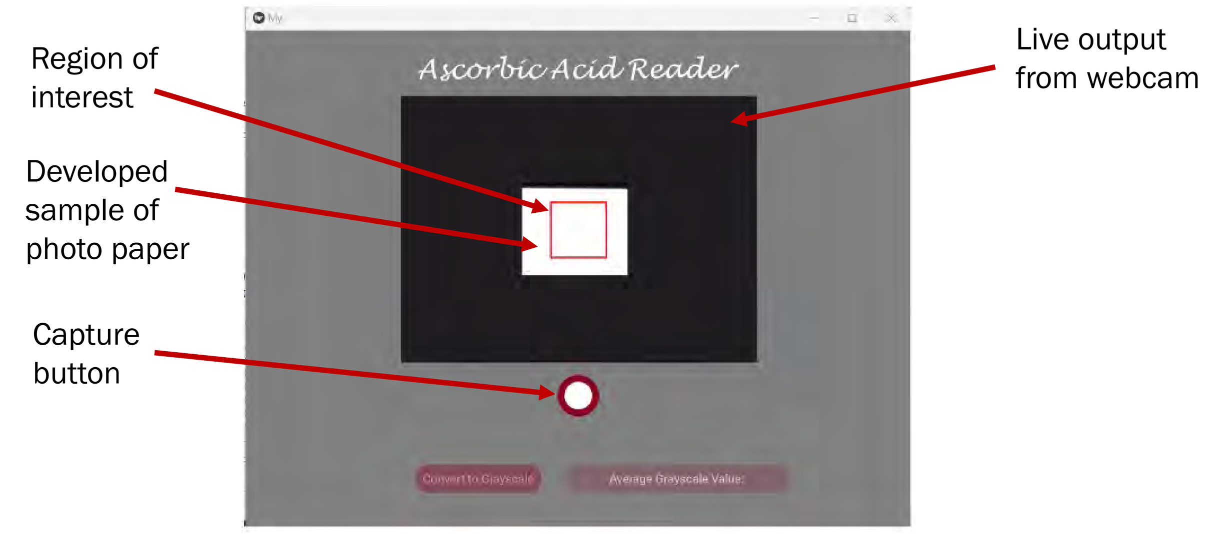


**Figure 3.3** User interface of the image analysis program developed with Python and Kivy. The user can adjust the region of interest. The program displays an average grayscale value and can output a spreadsheet with the values at each pixel.

## Specifications

| Metric | Actual | Required |
|---|---|---|
| Total prototype cost | $131.12 | < $400.00 |
| Total cost per 100 samples* | $1.33 | < $4.02 |
| Rated lighting level | 800 lux | > 500 lux |
| Analyte volume | 0.5 fl oz | < 1.0 fl oz |
| Analysis program accuracy | 97% | > 95% |
| Test sample accuracy** | 91% | > 90% |

* Includes cost of photo paper, ascorbic acid solution, and sodium thiosulfate fixer.
** Compared to samples developed in a darkroom.

## Key Findings

- Sodium thiosulfate and ascorbic acid corrode metal.[2] The leachate may contaminate test samples.
- Samples from the housing were 91% accurate compared to darkroom samples.
- Analysis program accuracy varied based on ambient light exposure and darkness of the photo paper. Performance was worse for dark samples and low lighting.

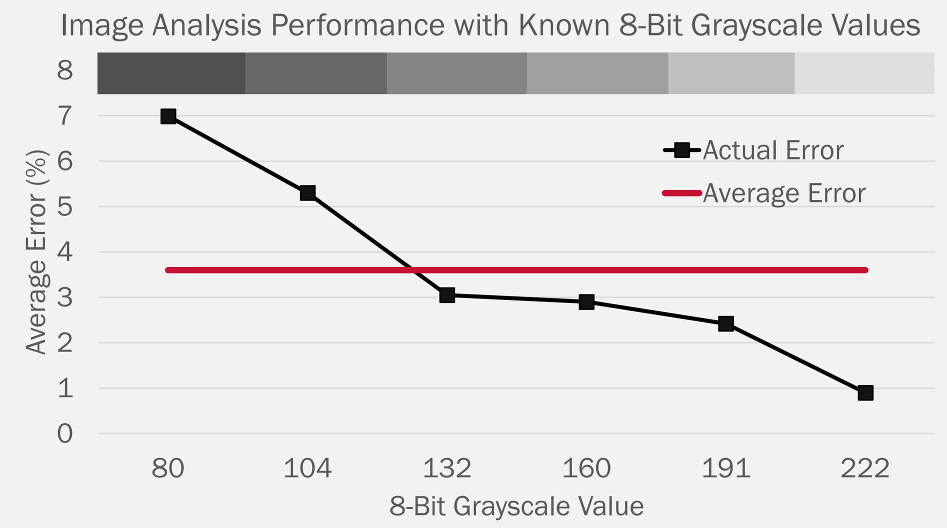


**Figure 4** Performance of image analysis software compared to known 8-bit grayscale values. The mean error was 3.60% and maximum error was 6.99%. The reference bar corresponds to the grayscale values tested.

## Conclusion

Research is ongoing about the relationship between the darkness of photo paper and ascorbic acid concentration. The housing, camera stand, and image analysis program will aid in continuing this research.

**References and Acknowledgments**
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1. J. A. Lopez-Pastor *et. al.* National Institutes of Health. Feb 2020. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7038320
2. E. A. Ashour *et. al.* "Effects of Thiosulfate on Susceptibility of Type 316 Stainless Steel…" *Corrosion* (53). August 1, 1997.