Milk Spoilage Detection Using Ion-Sensitive Field-Effect Transistors

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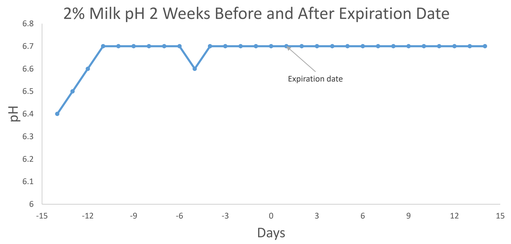
Background

- Americans throw away roughly 3.9 billion gallons of milk annually [1].
- Over 30 million tons of CO2 was emitted to produce this wasted milk [2].
- Much of this waste is the result of consumer reliance on inaccurate or misleading expiration labels [3].
- Manufacturers label milk with expiration dates prior to actual spoilage times to avoid lawsuits related to food poisoning.

Problem Statement

- Expiration dates provided to consumers are unreliable. Currently, there are no consumer products that assist consumers in determining actual spoilage of milk.



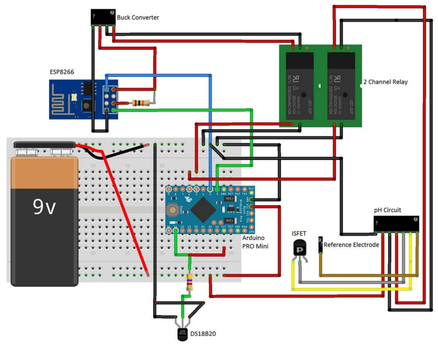
Planned Solution

- Develop an apparatus to accurately and reliably measure pH of the milk to determine the spoilage date.
- Develop pH circuit for accurate measurement of pH.
- Provide user with notification when milk has spoiled.

Developed Prototype

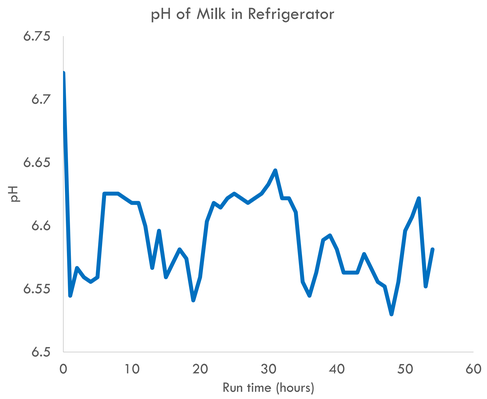
Device Operation

1. Device is turned on.
2. Arduino turns on CH 1 of the relay.
3. The pH is measured by the ISFET and collected by the Arduino as a raw input directly proportional to the voltage.
4. The Arduino turns off CH 1 of relay and turns on CH 2.
5. The Arduino sends data to the ESP8266.
6. ESP8266 sends data to server-side application.
7. Arduino goes into power conserve mode for 1 hour then repeats steps 2-7.



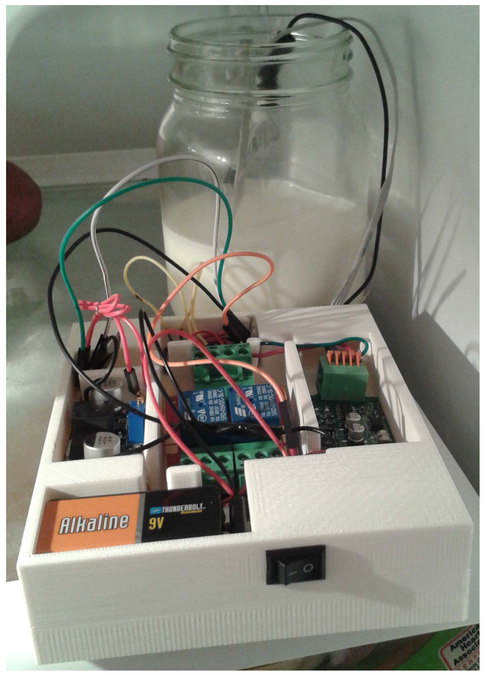
Server Side Application

1. Server side application receives “GET” request with data appended.
2. Application adds a timestamp and logs data in Google sheet.
3. Raw pH input is converted to an actual pH value that is logged in the sheet.
4. The program analyzes the data and determines if the milk is spoiled by comparing the pH against a spoilage threshold pH.
5. If the milk is spoiled, a text message or email is sent to the device user.



Prototype Testing

Below is a picture of the device in operation. The housing was 3D printed from ABS plastic.



Evaluation of Device against Original Design Criteria

The Table below summarizes the original design criteria and compares the current device against the criteria.

Criteria	Criteria met
Portion of the device that is inside the container fits through 1-5/8 diameter hole.	Yes
The product must be able to be used repeatedly.	Yes
Cost of all of the parts needed to manufacture product must be less than or equal to $25.00.	No, current prototype cost is $139.66.
All food contact surfaces must be made of FDA approved food grade materials, and the device must not adulterate the product in any way.	Yes
The product must be able to read pH levels accurately within a tenth of a pH level (±0.1).	Yes
The operation of the product must be able to be explained in one diagram and no more than a page of instructions.	No, current setup of product is too complicated for consumer.

Conclusions

Preliminary data confirmed the inaccuracy of manufacturer issued expiration dates. A working prototype was developed that fulfilled many of the requirements of the original criteria proposed. The prototype was advanced enough to run on multiple cycles via battery. Although the prototype functioned properly, the cost and size prohibit the practicality of the device. Further development of the circuit and probe would reduce size and cost.

Literature cited

[1] S. A. K. Mary K Muth, “Consumer-Level Food Loss Estimates and Their Use in the ERS Loss-Adjusted Food Availability Data,” 2011.

[2] “Greenhouse Gas Emissions from the Dairy Sector A Life Cycle Assessment,” FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Animal Production and Health Division, 2010.

[3] R. Newsome et al., “Applications and Perceptions of Date Labeling of Food,” Compr. Rev. Food Sci. Food Saf., vol. 13, no. 4, pp. 745–769, Jul. 2014.

Acknowledgments

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