The Effects of Gastric Mucous with Chemically Raised pHs on Lumen Model Mass Retention After Acid Exposure

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Introduction

What is gastric mucous and why is it important?

- The lumen (cavity of the stomach) protects itself from being broken down by the highly acidic gastric acid by coating itself in a thick, protective layer called gastric mucous (Hsu et al., 1987).
- The pH of the gastric mucous at the epithelial layer (closest to the lumen) is 7, or neutral (Dworken et al., n.d.)
- Prostaglandins (lipid compounds that strengthen the mucosa) and bicarbonate (a chemical that locally neutralizes acid) also work to shield the gastric mucosa from corrosion (Golden, 2017). In the mucous model in this experiment, lipid-heavy vegetable oil was used, modeling the prostaglandins.

What is peptic ulcer disease?

- Commonly called an "ulcer"; the lining of their stomach is breached, allowing the tissue to be painfully corroded by gastric acid (Golden, 2017).
- Patients of Zollinger-Ellison (Z-E) syndrome develop gastrinomas, or "rare tumor[s] of non-beta (gastrin secreting) cells of the pancreas," which secrete too much gastric acid for the gastric mucous to keep up with, and "severe ulcers" result (Golden, 2017, Huang et al., 2000, and Ellison et al., 1964).

How is Zollinger-Ellison syndrome treated today?

- With difficulty! Occasionally the gastrinoma can be removed by surgery, but often this is not possible and chemotherapy must be used. (Golden, 2017.)

What are acids and bases, and how do they react?

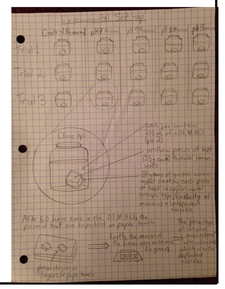
- All substances can be ranked on a logarithmic pH scale from 0 to 14 (0 = most acidic; 14 = most basic) (Bell, n.d.)
- When acids and bases combine, "one or more hydrogen ions, H+ [are exchanged]" and the acid and base are neutralized (Bell, n.d.).

This project investigated whether or not gastric mucous with chemically raised pHs would better protect the stomach's lining from gastric acid damage and mass loss, as a potential surgery-free treatment of Z-E syndrome.The prediction was that if uniform pieces of beef were coated with mucous models chemically enhanced with sodium hydroxide to have a range of basic pHs, then the piece of meat with the most basic mucous would experience the least corrosion/retain the most mass, as the extremely basic pH of the gastric mucous would neutralize the acidic pH of the hydrochloric acid as it attempted to break down the pieces of meat (Bell, n.d.).

Materials and Methods

- USDA organic beef chuck "for stew," cut into pieces of uniform appearance and surface area (15 x 23 g)
- .001 M NaOH (100 mL) [pH 9, used in "pH 9 mucous"]
- .01 M NaOH (100 mL) [pH 11, used in "pH 11 mucous"]
- .1 M NaOH (100 mL) [pH 13, used in "pH 13 mucous"]

1. The mucouses were prepared: To prepare the neutral, pH 7 mucous, 100 mL of filtered water were heated to a simmer and blended with 11.6 grams of unflavored gelatin, 100 mL of glucose-fructose syrup, and 10 mL of canola oil. To prepare each batch of the chemically enhanced mucouses, 100 mL of the corresponding NaOH solutions with the appropriate molarity were substituted for the 100 mL of water.
2. The fifteen 23 g pieces of beef were divided into 5 groups of 3 pieces each. The control group was not coated in any mucous. Each piece in the rest of the groups was dipped and coated in 3 g of the corresponding mucous (pH 9 group coated in pH 9 mucous, etc.)
3. Each of the pieces was stored in an airtight glass jar of 200 mL of .01 M HCl to model the acidity of the human stomach for 50 hours. Next, the pieces of beef drip dried for 20 hours.
4. Each piece of beef was then massed,
5. using the electronic gram scale.



Above: Gastric mucous model and uncoated pieces of beef (lumen wall model)

Right: Experimental Setup

Results

Lumen Wall Model Mass Retention: Raw Data														
Control [No mucous] (Mass retained g)			pH 7 Mucous (Mass retained g)			pH 9 Mucous (Mass retained g)			pH 11 Mucous (Mass retained g)			pH 13 Mucous (Mass retained g)		
Trial #1	Trial #2	Trial #3	Trial #1	Trial #2	Trial #3	Trial #1	Tria l #2	Trial #3	Trial #1	Trial #2	Trial #3	Trial #1	Trial #2	Trial #3
15.35	12.55	13.09	16.38	16.14	16.64	18.88	19.82	18.66	19.52	17.68	17.43	20.21	19.77	18.51

Table 1: Lumen Wall Model Mass Retention: Raw Data

This table displays the raw data exactly as I collected it: the masses, in grams, of the pieces of lumen model after being soaked in a gastric acid environment for 50 hours and drip drying for 20 hours.

Lumen Wall Model Percentage Mass Retention																			
Control [No mucous] (% mass retained)				pH 7 Mucous (% mass retained)				pH 9 Mucous (% mass retained)				pH 11 Mucous (% mass retained)				pH 13 Mucous (% mass retained)			
T1	T2	T3	A	T1	T2	T3	A	T1	T2	T3	A	T1	T2	T3	A	T1	T2	T3	A
66.7	54.6	56.9	59.4	71.2	70.2	72.3	71.3	82.1	86.2	81.1	81.3	84.9	76.9	75.8	79.2	87.9	86.0	80.5	84.8

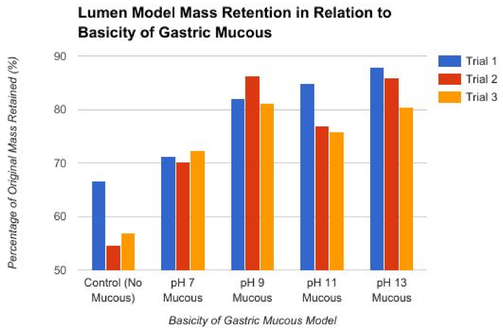
Code of Symbols: T1 = Trial #1; T2 = Trial #2; T3 = Trial #3; A = Average

Table 2: Lumen Wall Model Percentage Mass Retention

This table displays the percentage of mass retained per each group, by trial and on average. The average were reached by finding the arithmetic mean of the masses of all three trials and dividing that sum by three; lastly, this quotient was divided by the original mass of each piece, which was 23 g. The result was the percentage of mass retained per group on average.

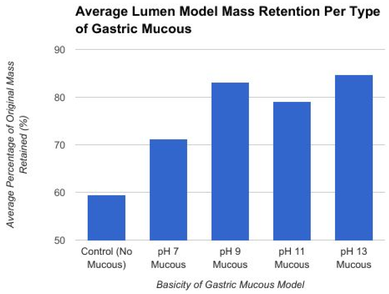
Here is a sample calculation for the control group.

Average percent of original mass retained = 15.35g + 12.55g + 13.09g = 40.99g/3 = 13.663g → 13.663 g/23 g = .59404... = 59.4%



Graph 1: Lumen Mass Retention in Relation to Basicity of Gastric Mucous

Graph 1 demonstrates the percentage of mass retained in all three trials of each group. The similarity in the heights of the bars indicates that the amount of mass retained in each of the groups was fairly consistent across the trials. The group with the most notably inconsistent trials was the control group, with a range of 12.1%.



Graph 2: Average Mass Retention Per Type of Gastric Mucous

Graph 2 presents the percentage of mass retained on average per mucous group. (The values were reached by finding the arithmetic mean of the data for the three trials in every group.) Evidently, the pieces of meat in the pH 13 mucous group retained highest percentage of their original mass, followed by the pH 9 mucous. Oddly, the pH 11 mucous group did not follow the trend indicated by the graph (Gastric mucous has a higher pH greater mass retention); the percentage mass retention of the pH 11 mucous group was in fact *less* than the percentage mass retention of pH 9. Had it followed the pattern, the value would have fallen between the values of the pH 9 mucous group and the pH 13 group.

Figure 1: Coated Pieces Lumen Wall Model Before Acid Corrosion

Note the vivid color of the tissue and thick, shiny coating of the mucous. →

Figure 2a: Control (No Mucous)

Figure 2b: pH 7 Mucous

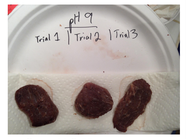


Figure 2c: pH 9 Mucous

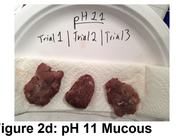


Figure 2d: pH 11 Mucous

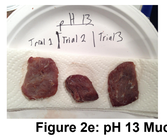


Figure 2e: pH 13 Mucous

Figure 2: State of Lumen Wall Model Pieces After 50 Hours in "Gastric" Acid and 20 Hours of Drip Drying

Since the time at which the previous photograph had been taken, the lumen wall model pieces had been pressed with paper towels and then left to drip dry on beds of paper towels for 20 hours. The paper towel pressing flattened them all a little, but I observed that the pieces in the pH 13 group retained their original shape better than the rest. On the other hand, the pieces without mucous in the control group had shriveled up and lost their original shape. I noticed that the coloring on all the pieces, especially the pieces in the pH 9 group, darkened considerably; it was unclear whether or not this development was relevant to the data collection.

Discussion

- The data collected supported the original hypothesis, as the experimental group with the most basic mucous, pH 13, retained the most mass, and besides the group with no mucous, the group with a chemically neutral mucous (pH 7) retained the least.
- The original hypothesis implied the trend that a more basic mucous results in greater mass retention; All of the groups followed this trend except for the pH 9 and pH 11 mucous groups. The average mass retention in the pH 9 group, 83.1%, was *greater* than the average mass retention of the pH 11 group, 79.2%. This value interrupted the surfacing pattern, preventing the emergence of a conclusive trend. So the final ranking of the groups in order of greatest mass retention to least was the following: 1.) pH 13 mucous, 2.) pH 9 mucous, 3.) pH 11 mucous, 4.) pH 7/neutral mucous, 5.) Control (no mucous)
- No pre-existing research could be referred to for corroboration or refutation, as this experiment implemented an entirely new method of addressing lumen corrosion as a symptom of Zollinger-Ellison syndrome. Like the chemotherapy/radiation solution, the method investigated in this experiment would not actually remove the gastrinoma; rather, it would help ameliorate the symptoms (Golden, 2017).
- Ideally, the experiment could be conducted in vivo, or on living tissue, that had blood flow and functional cells. Even though the results were logical and the experiment was carefully controlled, it would be a big leap to base conclusions about the human stomach on an experiment conducted in vitro.
- The results inspire a fairly high degree of confidence due to the logical data trend and the careful, controlled environment in which the experiment was held. For instance, while slicing the beef for the lumen wall model, extreme caution was taken to ensure as best one could that the pieces were uniform (similar surface area, fat content, etc.). Nevertheless, conducting more than three trials would have led to greater confidence in the results.
- The concept of chemically enhanced gastric mucous is one worth serious thought and exploration; it would allow the excruciating lumen corrosion experienced by Z-E syndrome patients to be cured without surgery or chemotherapy. Investigations should be made to explore alternative, safer methods of raising the pH of one's gastric mucous that would be realistic and feasible in the medical world.

Works Consulted

"Acids and Bases." Science of Everyday Things . Retrieved March 30, 2017 from Encyclopedia.com: http://www.encyclopedia.com/science/news-wires-white-papers-and-books/acids-and-bases

Bell, R. P. (n.d.) Acid-base reaction. In *Encyclopædia Britannica*. Retrieved March 27, 2017, from https://www.britannica.com/science/acid-base-reaction

Dworken, H. J., Hightower, N. C., Sircus, W., & Keeton, W. T. (n.d.). Gastric mucosa. In *Encyclopædia Britannica*. Retrieved March 25, 2017, from https://www.britannica.com/science/human-digestive-system/Gastric-mucosa

Ellison, E. H., Zollinger, R. M., Wilson, S. D., & Dragstedt, L. R. (1964). The *Zollinger-Ellison Syndrome: re-appraisal and evaluation of 260 registered cases. Annals of Surgery*, 512-528. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1408784/pdf/annsurg00937-0184.pdf

Frank, D. V. (2006). *Focus on California physical science*. Boston, MA: Pearson prentice hall.

Feinstein, L. B., Holman, R. C., Yorita Christensen, K. L., Steiner, C. A., & Swerdlow, D. L. (2010, September). Trends in *hospitalizations for peptic ulcer disease, United States, 1998-2005*. Retrieved April 2, 2017, from Center for Disease Control and Prevention: Emerging Infectious Diseases website: https://wwwnc.cdc.gov/eid/article/16/9/09-1126_article

Golden, C. F., M.D., M.P.H. (2017, January 25). [Personal interview by A. Golden].

Golden, J. S., M.D. (2017, March 26). [E-mail interview by the author].

How does the stomach work? (2016, August 21). In *U.S. national library of medicine*. Retrieved February 1, 2017, from https://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0072488/

Hsu, B., Tadlock, C. H., Assef, S., & Percelay, J. M. (1987). *Physiology: A review with questions and explanations*. Boston, MA: Little, Brown and Company.

Huang, J.-Q., & Hunt, R. H. (2000). *Therapy of Digestive Disorders* (M. M. Wolfe, G. L. Davis, F. A. Farraye, R. A. Giannella, J. Malagelada, & M. L. Steer, Eds.). Saunders.

Periodic Videos, & University of Nottingham. (2010, March 26). *Cheeseburger in hydrochloric acid - periodic table of videos* [Video file]. Retrieved January 30, 2017 from: https://www.youtube.com/watch?v=Nb6Z5fRQb0Q Touchette, B. (2014, September 26). Making fake snot! Retrieved January 30, 2017, from Education.com website: https://www.education.com/science-fair/article/how-to-make-fake-snot/

What is the pH of stomach acid when your stomach is not full of food? How long does food stay in your empty stomach for? (2015). Retrieved February 1, 2017, from UCSB Science Line website: http://scienceline.ucsb.edu/getkey.php?key=275

Acknowledgments

Many thanks to Ms. Taylor and Mr. Schmidt for their endless supply of support and patience. Thanks to Dr. J Stephen Golden, MD, for sharing his knowledge on the human stomach.