Comparing the effectiveness of non-synthetic remedies to commercially produced antacids in combating acid reflux

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ABSTRACT

Acid reflux is a result of the backflow of digestive acid into the esophagus, causing discomfort and sensations of heartburn (Badillo & Francis, 2014; Schneider et al., 2010). Antacids offer temporary relief from the pain caused by acid reflux. While commercially produced antacids have been in production since the early twentieth century, concerns about their production and potential side effects have led to the widespread use of home remedies made from varying non-synthetic materials (Bierer, 1990). In this study, the effectiveness of seven different non-synthetic materials in increasing the pH of white vinegar, which simulated stomach acid, was tested. The effectiveness of the home remedies was compared to that of commercially produced antacids. The results were analyzed using a one-way ANOVA test and gave a p-value of 0.0068, therefore rejecting the null hypothesis. A post-hoc Tukey's multiple comparison test was performed to determine where the significant differences were found in our results. Altogether, these results indicated that commercially produced antacids, specifically TUMS®, are more effective at neutralizing acid. Our findings provide a statistical perspective on the comparison between commercially produced medicine and home remedies for acid reflux, informing consumer decisions regarding the use of non-traditional medicine.

INTRODUCTION

Acid reflux is one of the characterizing symptoms of gastroesophageal reflux disease (GERD), perhaps the most prevalent condition detected by gastroenterologists (Katz et al., 2013). While GERD is a chronic condition manifesting through acid regurgitation and heartburn, acid reflux, in particular, is primarily caused by transient lower esophageal sphincter relaxations (TLESR), relaxations in the lower esophageal sphincter that take place independently of swallowing (Badillo & Francis, 2014; Schneider et al., 2010; Zhang et al., 2002). Complications with the lower esophageal sphincter, which is located between the esophagus and the stomach, underlies the backflow of digestive acid into the esophagus. Commercially produced antacids work by neutralizing gastric acid that has flowed into the esophagus and any excess gastric acid in the stomach (Jakaria et al., 2015). While well-known brands such as TUMS®, Pepto-Bismol®, and Gaviscon® produce medications that temporarily subside the pain caused by acid reflux, many people turn to their homes to find alternative solutions.

Our non-synthetic samples are examples of suggested home remedies, which are simple means of recovery for minor health problems (Parisius et al., 2014). Home remedies for ailments permeate the internet, offering cost-reducing and natural alternatives to commercially produced prescriptions. While the use of home remedies for the management of symptoms is not widely researched and often anecdotal, it is commonplace among laypeople (Parisius et al., 2014). Through our study, we aim to find whether these widely suggested home remedies for acid reflux satisfy the claims made about them.

The aim of our experiment is to find out whether home remedies are able to neutralize gastric acid and combat acid reflux, and if they work, how they compare to commercialized antacids. If non-synthetic solutions are as effective at countering acid reflux as commercially produced selections, then a resulting neutralized pH of 7.0 should be observed because antacids should bring the pH level of gastric acid to the normal esophageal pH level of about 7.0 (Tutuian & Castell, 2006). Our null hypothesis states that there is no significant difference between the non-synthetic materials and commercially produced antacids in their capability to increase the pH of the simulated stomach acid. Our alternative hypothesis states that there will be a significant difference between the home remedies and store-bought antacids.

We predict that while the non-synthetic ingredients will be able to increase the pH of our solution, the commercially produced antacids will be more effective and neutralize the solution to a greater degree. Understanding the efficacy of these home remedies is important as inadequate treatment for reflux disease can result in worsening conditions and complications in the esophagus (Badillo & Francis, 2014). In more extreme cases, such as GERD, untreated conditions can lead to pulmonary disease and esophageal cancer (Badillo & Francis, 2014; Mirić et al., 2014). Overall, relief from these symptoms can greatly improve the quality of life.

METHODS

For this experiment, a simulation of the conditions of a human stomach was attempted. To do so, 33 separate clear plastic cups were filled with 100 mL of white vinegar each. Each cup was labeled with the test ingredient with 3 replicates for each of the 7 non-synthetic remedy ingredients (ginger, spinach, almond milk, papaya, banana, vanilla yogurt, and aloe vera), 3 drugstore antacids [sodium alginate (SA, commonly known as Gaviscon), bismuth subsalicylate (BSL, commonly known as Pepto Bismol), and TUMS® tablet], and 1 control of just white vinegar, for a total of 33 labels. The next step was to prepare the ingredients before putting them into their cups. In terms of preparation, the ginger, spinach, papaya, banana, aloe vera, and TUMS® tablets needed to be modified for this experiment. For ginger, the root was cut into slices, and for spinach, the leaves were chopped up, before being placed in boiling water to make a tea mixture and then left to settle. In terms of the banana and papaya, they were cut up into small pieces before being mashed up into their own aqueous solutions. For the aloe vera, the plant was cut up and the juices and pieces were scraped straight off the plant and into a small container and set aside. For the TUMS® tablets, the tablets were completely crushed up and the three proportions were set aside.

After the two tea mixtures settled, everything was ready to be placed in their cups. For the following solutions, ¼ of a cup was poured into their respective cups: ginger, spinach, almond milk, papaya, and aloe vera. For the commercially produced antacids, the recommended doses were put in each cup, which was 2 tablespoons for bismuth subsalicylate, 2 crushed up tablets for TUMS®, and 15 mL for sodium alginate. For yogurt, the full container (15 mL) was used for each cup. Finally, for the banana, the aqueous solution was split into 3 portions (25mL) and poured into the cup. Each of these cups was then left to rest for 30 minutes (Figure 1).

Figure 1. The experimental setup, with 3 replicates of each test ingredient placed in white vinegar. Each cup was labelled with the test ingredient and replicate number. All the ingredients were left in the cups for 30 minutes after mixing with white vinegar.

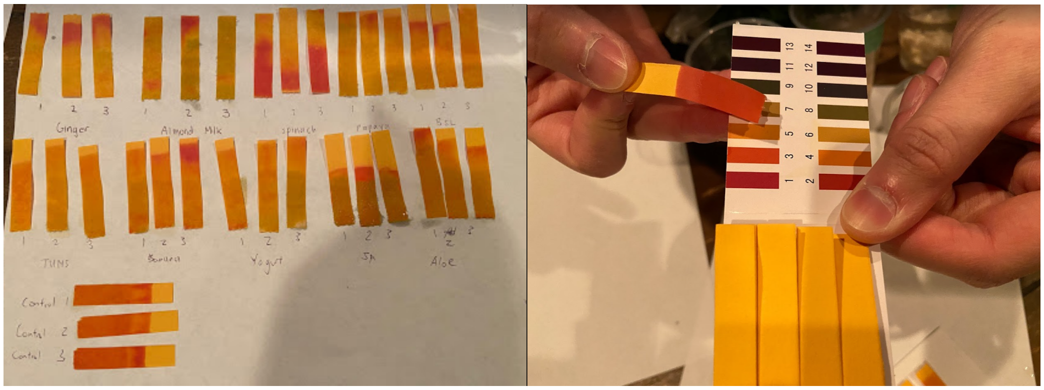

Figure 2. On the left, the pH test strips used for each sample were displayed after all pH levels were measured. The test strips lost their colour over time so the image does not reflect the colours that were used to determine the pH. On the right, an example of comparing a pH test strip to the provided colour chart immediately after dipping the test strip into the solution.

After 30 minutes, each cup was stirred thoroughly before the pH of each solution was measured. The stir stick was washed, or a new stir stick was used each time a cup was stirred to avoid cross-contamination. To determine the pH of each solution, a pH strip was dipped into the solution and the colour of the pH strip was immediately compared to the pH strip colour chart (Figure 2). The pH of each of the 33 cups was measured and recorded immediately after the pH strip was removed from the solution.

For the statistical analysis, a one-way ANOVA test was performed on Google sheets. On Google Sheets, the p-value was calculated, which was compared to an alpha value of 0.05 so it could determine if the data falls within the 95% confidence interval. This gives a low probability of 5% of incorrectly rejecting the null hypothesis. Subsequently, a post-hoc Tukey’s multiple comparison test was conducted on R Studio.

RESULTS

Overall, 7 non-synthetic remedies were tested and 3 commercially produced remedies were tested across 3 trials. As observed, the non-synthetic remedies did not particularly affect the pH levels of the vinegar as the average resulting pH was 3.12 (Figures 3 and 4). However, the store-bought remedies resulted in a much higher average pH of 3.72 (Figures 3 and 4).

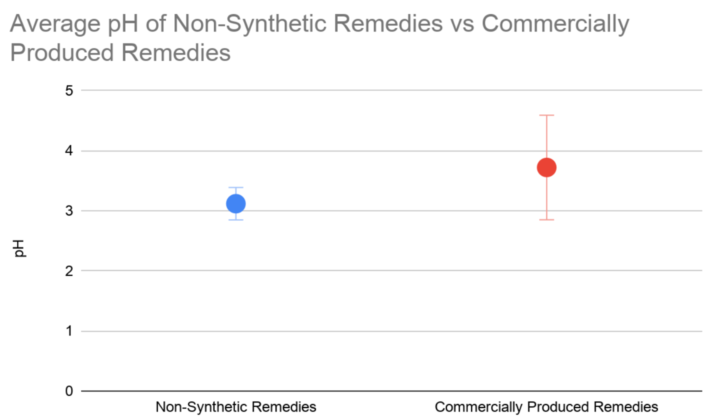

Figure 3. Average pH of Non-Synthetic Remedies vs Commercially Produced Remedies. Natural Remedies had an average pH of 3.12 ± 0.27 whereas the commercially produced remedies had an average pH of 3.72 ± 0.87. Error bars represent standard deviation over a 95% confidence across pH levels observed. The sample size of Non-Synthetic Remedies was 21 and the sample size of Commercially Produced Remedies 9.

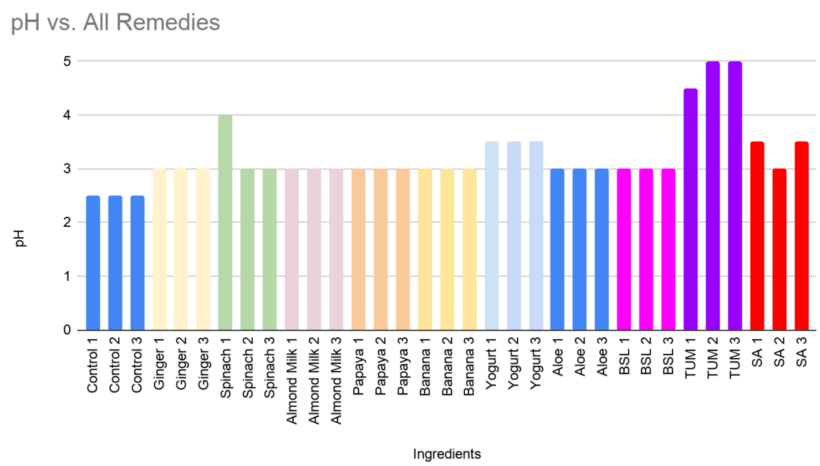

Figure 4. pH level of 7 Non-Synthetic remedies (pale-coloured bars) and 3 Commercially Produced remedies (high contrast coloured bars) after mixing in vinegar. The pH level was recorded after 30 minutes over 3 trials.

The ANOVA test for all remedies indicated that the p-value was 0.0068 which is less than 0.05. This means that the two types of remedies were statistically significantly different in their capacity to neutralize pH. The ANOVA test was performed with an alpha value of 0.05. Therefore, our ANOVA test result was within the 95% confidence interval. The ANOVA results can be found in Table 2 of the Appendix. The standard error of the pH that was measured across all the remedies calculated was measured to be 0.10 pH. Our calculations can be found in Appendix B.

For the post-hoc Tukey's multiple comparison test, the following pairs had a p-value below 0.05, meaning they showed a significant difference between each other: TUMS®-Almond Milk, TUMS®-Aloe, TUMS®-Banana, TUMS®-BSL, SA-Control, Spinach-Control, TUMS®-Control, Yogurt-Control, TUMS®-Ginger, TUMS®-Papaya, TUMS®-SA, TUMS®-Spinach, and Yogurt-TUMS® (Appendix Table 3).

DISCUSSION

In this experiment, we sought to determine whether there was a difference in the effectiveness between non-synthetic antacids and commercially produced antacids in relieving and neutralizing acid reflux experienced in the stomach. A remedy would be classified as effective by its ability in reducing the acidity of the simulated stomach acid via measuring the pH level of the treated solution (Bradley, 2017). Based on the results of the one-way ANOVA test, we reject our null hypothesis, indicating that there is a significant difference between the home remedies and store-bought antacids. The results from the ANOVA and post-hoc Tukey's analysis supported our prediction that drugstore selections would be more efficient in reducing acidity than the home remedies, specifically pointing out TUMS® as significantly different from all other remedies. We noticed that the standard deviation in the observed pH was much higher when treated with commercially produced antacids in comparison to non-synthetic antacids, a result that is similarly reflected in another study testing the effectiveness of antacids in raising the pH of gastric acid (Bradley, 2017).

Furthermore, since our F-value was 8.55, which is significantly larger than our F-crit value of 4.20, this suggests that the variance between the non-synthetic remedies and the commercially produced remedies was greater than the variance within each group itself. Since the pH of our treated solutions experienced the most significant increase when treated with TUMS® and sodium alginate, this suggests that the commercially produced antacids could play a larger role in relieving acid reflux in comparison to non-synthetic antacids.

A post-hoc Tukey's multiple comparison analysis revealed that the pH of the solution, when treated with TUMS®, sodium alginate, spinach, or yogurt, was significantly different from the control pH of 2.5. Among these, the pH level resulting from TUMS® was significantly different from the pH levels resulting from all other remedies. As a result, the remaining remedies were not significantly different from each other. Of the non-synthetic remedies, yogurt resulted in a statistically significant difference to the control pH, indicating its usefulness in neutralizing acidity.

Possible sources of variation that may have impacted our results include differences in the amounts of antacids that were added to each acidic solution. For instance, ¼ of a cup was typically added for each non-synthetic antacid whereas, for the commercially produced antacid, there was more variation observed in how much was added (whether this was a few mL or a few tablespoons). The amounts of each antacid that was added in the trials were determined by following the recommended dosage written on commercially labeled products or through research suggestions for non-synthetic material. Since we were trying to simulate the conditions of the human stomach, the amounts chosen were reflective of what a patient would consume when experiencing acid reflux. However, because of the limitation in the cup size used to mimic the stomach, we were unable to simulate the changes in expansion noticed in the stomach upon consumption of substances (Bornhorst & Paul Singh, 2014), thereby limiting us in the amount of substance we can introduce to each of our acidic solutions without it overflowing. As a result, we were limited in the amount of substance that could be added to each cup, specifically for the non-synthetic remedies. This may have contributed to a lower resulting pH in the solutions treated with non-synthetic remedies whereas if we had used the appropriate amount, it could have led to a higher pH. Additionally, due to the arbitrary nature of home remedies from our research (Parisius et al., 2014), it was difficult to gauge the appropriate amount to use. For example, one article would say 2 pieces of ginger and another would say ginger tea without a specific dosage.

Notably, the largest limitation was the difficulty of imitating the human condition. As acid reflux is a condition that afflicts humans (Katz et al., 2013), an essential part of an investigation on the condition would involve emulation of human physiology and understanding whether treatments provide relief for patients. In our experiment, we were unable to simulate the peristaltic contractions noticed in the stomach during consumption of material (Bornhorst & Paul Singh, 2014). Although we attempted to mimic the wave-like motions responsible for mixing substances in the stomach via stirring each solution prior to measuring its pH, it was difficult to simulate the bodily functions of a human. Furthermore, the white vinegar that we used has a pH of 2.5 whereas stomach acid ranges from a pH of 1.5-3.5 (MedlinePlus, 2018). Due to this discrepancy in pH, our results may not have accurately portrayed the true strength or effects elicited by our chosen remedies in raising pH levels. This is demonstrated by the resulting pH levels of the solutions with commercially produced antacids, which were much lower than the expected effect of antacids, involving the increase of pH towards normal esophageal pH levels of 7.0 (Tutuian & Castell, 2006). Moreover, the effectiveness of an antacid is associated with the relief it provides (Earnest et al., 2000). The inusitation of human subjects in our experiment meant that the results do not give any information on the relief that a human can receive after consuming the remedy because pain and relief are subjective to an individual (Coghill, 2011).

In the future, further testing can be performed to evaluate the effectiveness of antacid remedies by timing how quickly certain substances act in raising the pH levels of the acid.

Specifically, it would signify the presence of fast-acting antacids, allowing for individuals in pain to experience quick relief of acid reflux symptoms. Another improvement that can be made would be to try different amounts of the non-synthetic antacids to get a better picture of which quantity is sufficient to relieve acid reflux symptoms.

CONCLUSION

From our results, the two types of remedies were statistically significantly different in their capacity to neutralize pH. Specifically, we found that TUMS® was significantly different from the other remedies. Furthermore, our prediction was correct because we predicted that while the non-synthetic ingredients will be able to increase the pH of our solution, the commercially produced antacids will be more effective and neutralize the solution to a greater degree, which was observed. These results could help individuals who suffer from acid reflux decide whether they want to use non-synthetic materials, or commercially produced antacids with potential side effects, to reduce their acid reflux symptoms.

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APPENDIX A

Data Analysis

Table 1. The inputs of the one-way ANOVA test that was performed, which included 7 (x3 trials) non-synthetic remedies and 3 (x3 trials) commercially produced remedies that were used in the experiment.

Non-Synthetic pH	Comercially Produced pH
3	3.5
3	3
3	3.5
4	3
3	3
3	3
3	4.5
3	5
3	5
3	
3	
3	
3	
3	
3	
3	
3	
3	
3.5	
3.5	
3.5	

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Non-Synthetic pH	21	65.5	3.119047619	0.07261904762
Comercially Produced pH	9	33.5	3.722222222	0.7569444444

Table 2. The results of a one-way ANOVA test performed with an alpha value of 0.05 for 7 (x3 trials) non-synthetic remedies and 3 (x3 trials) commercially produced remedies. A p-value of 0.0068 was observed, indicating statistical significance.

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.292063492	1	2.292063492	8.547991543	0.006778438858	4.195971708
Within Groups	7.507936508	28	0.2681405896			
Total	9.8	29				

Table 3. The results of a post-hoc Tukey's multiple comparison test conducted on R studio for each pair. A p-value below 0.05 (as shown in the column "Ingredient.p.adj"), indicating significance, was observed for the following pairs: TUMS®-Almond Milk, TUMS®-Aloe, TUMS®-Banana, TUMS®-BSL, SA-Control, Spinach-Control, TUMS®-Control, Yogurt-Control, TUMS®-Ginger, TUMS®-Papaya, TUMS®-SA, TUMS®-Spinach, and Yogurt-TUMS®.

	Ingredient.diff	Ingredient.lwr	Ingredient.upr	Ingredient.p.adj
Aloe-Almond Milk	0	-0.622295022145099	0.622295022145099	1
Banana-Almond Milk	0	-0.622295022145099	0.622295022145099	1
BSL-Almond Milk	0	-0.622295022145099	0.622295022145099	1
Control-Almond Milk	-0.5	-1.1222950221451	0.122295022145099	0.19522261224465
Ginger-Almond Milk	1.77635683940025e-15	-0.622295022145097	0.6222950221451	1
Papaya-Almond Milk	-4.44089209850063e-16	-0.622295022145099	0.622295022145098	1
SA-Almond Milk	0.333333333333333	-0.288961688811765	0.955628355478432	0.702448977493821
Spinach-Almond Milk	0.333333333333334	-0.288961688811765	0.955628355478433	0.702448977493819
TUMS-Almond Milk	1.83333333333333	1.21103831118823	2.45562835547843	2.25217386962129e-08
Yogurt-Almond Milk	0.5	-0.122295022145099	1.1222950221451	0.19522261224465
Banana-Aloe	0	-0.622295022145099	0.622295022145099	1
BSL-Aloe	0	-0.622295022145099	0.622295022145099	1
Control-Aloe	-0.5	-1.1222950221451	0.122295022145099	0.19522261224465
Ginger-Aloe	1.77635683940025e-15	-0.622295022145097	0.6222950221451	1
Papaya-Aloe	-4.44089209850063e-16	-0.622295022145099	0.622295022145098	1
SA-Aloe	0.333333333333333	-0.288961688811765	0.955628355478432	0.702448977493821
Spinach-Aloe	0.333333333333334	-0.288961688811765	0.955628355478433	0.702448977493819
TUMS-Aloe	1.83333333333333	1.21103831118823	2.45562835547843	2.25217386962129e-08
Yogurt-Aloe	0.5	-0.122295022145099	1.1222950221451	0.19522261224465
BSL-Banana	0	-0.622295022145099	0.622295022145099	1
Control-Banana	-0.5	-1.1222950221451	0.122295022145099	0.19522261224465
Ginger-Banana	1.77635683940025e-15	-0.622295022145097	0.6222950221451	1
Papaya-Banana	-4.44089209850063e-16	-0.622295022145099	0.622295022145098	1
SA-Banana	0.333333333333333	-0.288961688811765	0.955628355478432	0.702448977493821
Spinach-Banana	0.333333333333334	-0.288961688811765	0.955628355478433	0.702448977493819
TUMS-Banana	1.83333333333333	1.21103831118823	2.45562835547843	2.25217386962129e-08
Yogurt-Banana	0.5	-0.122295022145099	1.1222950221451	0.19522261224465
Control-BSL	-0.5	-1.1222950221451	0.122295022145099	0.19522261224465
Ginger-BSL	1.77635683940025e-15	-0.622295022145097	0.6222950221451	1
Papaya-BSL	-4.44089209850063e-16	-0.622295022145099	0.622295022145098	1
SA-BSL	0.333333333333333	-0.288961688811765	0.955628355478432	0.702448977493821
Spinach-BSL	0.333333333333334	-0.288961688811765	0.955628355478433	0.702448977493819
TUMS-BSL	1.83333333333333	1.21103831118823	2.45562835547843	2.25217386962129e-08
Yogurt-BSL	0.5	-0.122295022145099	1.1222950221451	0.19522261224465
Ginger-Control	0.500000000000002	-0.122295022145097	1.1222950221451	0.195222612244647
Papaya-Control	0.5	-0.122295022145099	1.1222950221451	0.195222612244652
SA-Control	0.833333333333333	0.211038311188235	1.45562835547843	0.00336322827451119
Spinach-Control	0.833333333333334	0.211038311188235	1.45562835547843	0.00336322827451119
TUMS-Control	2.33333333333333	1.71103831118823	2.95562835547843	2.25054197500185e-10
Yogurt-Control	1	0.377704977854901	1.6222950221451	0.000371951604406728
Papaya-Ginger	-2.22044604925031e-15	-0.622295022145101	0.622295022145096	1
SA-Ginger	0.333333333333332	-0.288961688811767	0.95562835547843	0.702448977493827
Spinach-Ginger	0.333333333333332	-0.288961688811767	0.955628355478431	0.702448977493826
TUMS-Ginger	1.83333333333333	1.21103831118823	2.45562835547843	2.25217386962129e-08
Yogurt-Ginger	0.499999999999998	-0.1222950221451	1.1222950221451	0.195222612244654
SA-Papaya	0.333333333333334	-0.288961688811765	0.955628355478433	0.702448977493819
Spinach-Papaya	0.333333333333334	-0.288961688811764	0.955628355478433	0.702448977493818
TUMS-Papaya	1.83333333333333	1.21103831118823	2.45562835547843	2.25217386962129e-08
Yogurt-Papaya	0.5	-0.122295022145098	1.1222950221451	0.19522261224465
Spinach-SA	4.44089209850063e-16	-0.622295022145098	0.622295022145099	1
TUMS-SA	1.5	0.877704977854901	2.1222950221451	7.90463013045084e-07
Yogurt-SA	0.166666666666667	-0.455628355478432	0.788961688811765	0.995326277083652
TUMS-Spinach	1.5	0.8777049778549	2.1222950221451	7.90463013045084e-07
Yogurt-Spinach	0.166666666666666	-0.455628355478433	0.788961688811765	0.995326277083652
Yogurt-TUMS	-1.33333333333333	-1.95562835547843	-0.711038311188234	5.53599832753271e-06

APPENDIX B

Calculations

The calculations that were performed to obtain the standard error for the observed pH measurements for both non-synthetic and synthetic remedies, including control. The number of samples was 33. The standard error calculated was 0.10 pH.

$$SE = \frac{\sigma}{\sqrt{n}}$$

Standard deviation

Number of samples

Where standard deviation $\sigma = 0.5813$ and number of samples is 33 so:

$$0.581318359/\sqrt{33} = 0.10119 \sim 0.10 \text{ pH}$$