THE EFFECT OF pH ON THE DECOMPOSITION OF PORK RIBS

by

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The purpose of this research is to test the effect that acidic liquids, such as soft drinks, have on the decomposition of soft tissue and bone, specifically pork ribs, and to determine if more acidic sodas do more to the samples of rib than less acidic sodas. Based on previous research, it was believed that pH of soda would not have a notable effect on tooth enamel; however, because bone is composed of much different materials than tooth enamel, as well as being much softer and more porous, it was expected that a more acidic environment created by soda will cause significant degradation to the pork rib as a whole. It was also expected that along with the decomposition, the pH of each soft drink would become less acidic than it was originally. Pork ribs were left to decompose in soft drinks, and each sample’s data was collected at 10 days, 20 days, and 50 days. While the pH of each liquid sample did follow the expected rising trend, the results ultimately showed that more acidic solutions do not necessarily affect the rate of decomposition. To be able to provide further support to the following experiment, more testing would need to be done with longer experimental time spans.
INTRODUCTION

Research Question

How do varying acidic aqueous conditions, such as different brands of soda, affect the decomposition of pork ribs when enclosed in an airtight container for a period of 30 days?

Research Purpose

The purpose of this research is to test the effect that acidic liquids, like soda, have on the decomposition of meat and bone, specifically pork ribs. The types of soda tested will include Coca Cola, Diet Coca Cola, Mountain Dew, Sprite, Pepsi, and Root Beer. Dental studies have shown no notable correlation between degradation of tooth enamel and the pH of soft drinks (Von Fraunhofer & Rogers, 2004), but because teeth are composed of different materials than bone, this experiment will test to see if this result also applies to the meat and bone found on pork ribs. Information such as this can be important to the forensic science community because of the lack of existing research regarding this topic. While soda may not be a common degradation agent, research surrounding degradation in aqueous environments with low pH could be useful to apply to existing knowledge about the decomposition process.
Background Information

The Pepsi Company has had many customer claims made against it over the years regarding foreign objects being found in their canned soft drinks. In the summer of 1993 alone, the company received over 200 complaints. To the Food and Drug Administration (FDA), as well as national media outlets, this string of cases became known as the “Pepsi Crisis,” and each case was thoroughly analyzed by FDA officials. Case reports claimed to have found things inside such as various machine parts, medical syringes, unfired bullets, and even rodents (Platek, Ranieri, & Wolnik, 1997). The Pepsi Company then conducted their own research to investigate the claims made about rodents. They brought in “a veterinary surgeon, [named] Lawrence McGill, to conduct a detailed post mortem…noting the high acidity of the drink, the vet argued that after 30 days…the rodent would have ‘disintegrated’ into a ‘jelly-like substance’” (Adams, 2012). While all cases of the “Pepsi Crisis” were disproven, except for one involving a mechanical screw off of the manufacturing line, the experiment conducted by The Pepsi Company about the probability of finding an entire rodent in a soft drink led to a larger question surrounding the true acidic strength of soft drinks.

Soda in Regards to Health

Beyond the manufacturing line, soft drinks have been raising eyebrows among medical professionals for decades. Physicians and dentists often recommend to keep soft drink intake at a minimum, not only because of their sugar content, but also because of
the proven harmful effects to the inside of the body, including an increase in insulin levels as a result of hyperglycemia followed by the conversion of blood sugar to fat (McClellan, 2015). Soft drinks are also proven to have negative effects on oral health. Many studies have shown “a positive relationship between caries [cavities] and dental erosion and the consumption of soft drinks” (Pallavi & Rajkumar, 2012). While some dentists may claim that one kind of soda is more abrasive to teeth than another, official studies have shown that the differing pH levels of soda have “no correlation between enamel dissolution and beverage pH” (Von Fraunhofer & Rogers, 2004).

**Aspartame**

Aspartame, “also known under the market names of Nutrasweet, Assugrin, and Canderel,” is the most commonly used low-calorie sweetener that is approximately 200 times sweeter than sugar (“Aspartame,” 2008). It was accidentally discovered by a chemist named James M. Schlatter in 1965 while he was working on an “anti-ulcer drug”. His drug mixture included both aspartic acid and phenylalanine, which are two amino acid building blocks of the aspartame molecule (Nill, 2000).

When broken down into separate components, aspartame becomes aspartic acid, phenylalanine, and methanol (which can become toxic to the human body at high concentrations). In the digestive system, aspartame will “never enter the bloodstream as aspartame, because it is so rapidly broken down to its constituent parts” (Magnuson, 2011). Because of aspartame’s excessive use in diet soft drinks, studies have been
conducted regarding how aspartame degrades in the presence of caramel coloring.

“Aside from water, caramel coloring is the predominant ingredient in diet cola beverages, and diet cola is typically formulated to contain around 1400 ppm [parts per million] caramel coloring ingredient” (Wang & Schroeder, 2000). According to the previous statement, it is expected that Diet Coke, one of the aqueous samples in this experiment, will contain approximately 1400 ppm caramel coloring. The final finding in this study claimed that caramel coloring’s properties along with a pH of 3.1 “can account for the enhanced degradation of α-APM [aspartame] in a cola beverage” (Wang & Schroeder, 2000). Diet Coke, for the purposes of this experiment, measured at a pH of approximately 3.38. Being the closest soft drink in pH to Wang and Schroeder’s experimental “cola”, it is reasonable to believe that the aspartame in Diet Coke will have degraded into its component parts as well.

**Soil in a Forensic Application**

Aside from soft drinks, for the purposes of this experiment, it is important to investigate soil and its variation in moisture and pH from a forensic science perspective. One study showed that the presence of moisture in soils from different regions in Australia seemed to have a significant effect on mass loss in cadavers during the period of decomposition (Carter, Yellowlees, & Tibbett, 2010). This study, however, tested the effect of moisture in different types of soil (sand, loamy sand, clay) that was measured
prior to the experiment. This experiment showed that the most moist, clay-based soil, as
seen in Figure 1 from Pallarenda, yielded the greatest mass loss.

Figure 1:

![Figure 1: Cadaver mass loss (% wet weight)](Source: Haslam and Tibbett, 2009)

Moisture in soil can simply be explained by lack of use, shade coverage, or
geographical features rather than “decompositional events”; however, the organic
content of soil, including “the combination of all plant and animal residues and
indigenous soil organisms in various stages of decomposition”, can appropriately be
linked to a correlation with soil moisture (Damann, Tanittaisong, & Carter, 2012). A
separate study that tested how the presence of moisture detected and measured prior to
burial in one type of soil changed as a result of swine carcass decomposition, found that
“no significant differences in moisture content were observed between gravesoil and
control soil” (Benninger, Carter, & Forbes, 2008). These findings are significant to this
study because if the carcasses decomposed more efficiently in moist soil, then there is a
good chance that they will decompose well in aqueous solution. This study doesn’t take pH into account prior to burial, but the findings regarding moisture remain applicable.

While moisture’s effect on decomposition is generally consistent, studies about the relationship between soil pH and decomposition have produced interesting results. “Changes in soil pH exhibited a sigmoidal characteristic in all soils” (Haslam and Tibbett, 2009). This result is also found in a similar study regarding the pH of soil surrounding a burial site for swine carcasses. The soil pH increased from the original sample in the first three weeks, decreased in the following two weeks, and then had increased again by the end of the experimental time span (Benninger, Carter, & Forbes, 2008). A study from the University of Tennessee’s Anthropology Research Facility (ARF) found that soil pH levels outside of the facility are “lower on average” than those inside the facility’s perimeter. The basicity of the soil inside the ARF “may be explained by increased ammonification of soil” which pulls excess Hydrogen (H\(^+\)) ions from the soil and binds them with an NH\(_3\), creating NH\(_4^+\), and removes the H\(^+\) ion’s “contribution to acidic conditions” (Damann, Tanittaisong, & Carter, 2012).

**Hypothesis**

Based on the above research regarding teeth in soda, it is believed that pH of soda will not have a notable effect on tooth enamel; however, because bone is composed of much different materials than tooth enamel, as well as being much softer and more porous, it is expected that the acidic environment created by soda will cause significant
degradation to the pork rib as a whole. Also noted in the research above is the acceleration effect that moisture has on decomposition. According to a source regarding pH of soil in an archaeological site, mass loss in soil-exposed rib bone was “much greater at pH 1, compared to pH 3” (High, Milner, Panter, & Penkman, 2015). Based on the expert testimony of Dr. Lawrence McGill from the Pepsi Company’s lawsuit, along with the archaeological site experiment, it is reasonable to expect decomposition to be greater in more acidic soft drinks, as compared to less acidic, therefore providing support to the hypothesis.
**METHODOLOGY**

**Apparatus and Materials**

To begin the experiment, pork ribs were purchased from a grocery store and weighed with an electronic scale before use in order to ensure that the mass of each sample is similar enough for comparison. Each sample was placed in a quart-sized glass jar with an airtight seal to prevent contamination or tampering with the sample throughout the experimental process.

The liquids used include Coca Cola, Diet Coke, Mountain Dew, Sprite, Pepsi, Root Beer and distilled water. The pH level of each liquid was tested using a pH probe. While the pH levels of soft drinks do not generally vary by much, the differing acidic environments created by these sodas allowed a valid comparison. Distilled water was used as a neutral liquid control, while another control jar contained no liquid at all.

Following extraction from the jars, the ribs were weighed again with an electronic scale. The pH probe was used again to test for any change in pH over the time the pork ribs were left in the jars. The change in mass (percent mass loss and/or gain) was then calculated using the original mass as compared to the new mass.

To begin the mouse experiment, frozen “pinky” (feeder) mice were purchased from a pet store. The four liquids used in this experiment included Coca Cola, Pepsi, Mountain Dew, and distilled water. Quart-sized, glass jars were again used in order to allow ample liquid sample size. The pH of each soda tested was taken using the same pH probe.
probe from the pork rib experiment, and the weight of each mouse was recorded using an electronic scale.

Following extraction, the mice were weighed using the same electronic scale from the original experimental setup. Unlike the pork rib experiment, the mice were weighed before and after being allowed to “drain.” The pH of each liquid sample was recorded to detect any change from the experimental period.

**Procedure**

Pork ribs of varying masses were placed into quart-sized, glass, canning-style jars, with seals and screw on lids. The remaining open space in the jars was filled to the 24 ounce line (marked on the outside of the jar) with their respective liquid in order to have consistency of jar volume between samples. Each soft drink was assigned three of its own glass jars. The masses of each sample and acidities of each liquid were recorded for later comparison.

**Figure 2:**

<table>
<thead>
<tr>
<th>TYPE OF LIQUID</th>
<th>10 DAYS</th>
<th>20 DAYS</th>
<th>50 DAYS</th>
<th>STARTING pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>COKE</td>
<td>69.2g</td>
<td>82.9g</td>
<td>73.3g</td>
<td>2.69</td>
</tr>
<tr>
<td>DIET COKE</td>
<td>76.2g</td>
<td>83.9g</td>
<td>84.7g</td>
<td>3.38</td>
</tr>
<tr>
<td>PEPSI</td>
<td>77.3g</td>
<td>73.6g</td>
<td>75.4g</td>
<td>2.7</td>
</tr>
<tr>
<td>SPRITE</td>
<td>69.1g</td>
<td>49.5g</td>
<td>71.5g</td>
<td>3.45</td>
</tr>
<tr>
<td>ROOT BEER</td>
<td>72.2g</td>
<td>89.4g</td>
<td>62.0g</td>
<td>4.1</td>
</tr>
<tr>
<td>MOUNTAIN DEW</td>
<td>77.8g</td>
<td>64.5g</td>
<td>74.7g</td>
<td>3.42</td>
</tr>
<tr>
<td>WATER</td>
<td>69.6g</td>
<td>70.5g</td>
<td>65.2g</td>
<td>6.97</td>
</tr>
<tr>
<td>NO LIQUID</td>
<td>50.7g</td>
<td>46.6g</td>
<td>60.2g</td>
<td>N/A</td>
</tr>
</tbody>
</table>
The jars containing the samples were all filled to the 24 ounce mark and sealed on the same day. The jars were left in a climate-controlled (72°F or 22.2°C), dark room over the entire experimental time span. One jar of each type of soft drink was opened and examined after ten days, another after twenty days, and the last after fifty days. Pictures were taken of each glass jar immediately after being sealed and right before opening. Pictures of each sample were collected following extraction from their respective jars. The weight of each sample was collected after being removed from the jars and the percent mass loss was calculated by comparing mass before and after the time left in the solution. The pH of the remaining liquid is also collected with a pH probe and compared to see if any variation of acidity occurred throughout the experimental period.
**RESULTS**

Figure 3:

![P-Value Chart]

The chart above contains the p-values that correlate to the comparison between two different types of liquids at any time. The green-coded values are those that the ANOVA program found to be significant (p < 0.05 or p < 0.01). The red-coded values are those found to be not statistically significant (p > 0.05).

Figure 4:

![10 DAY CHECK]

The chart above shows the original mass and pH of each sample’s components (pork rib and liquid), as well as the ending mass and pH of each to numerically represent the change that occurred over the 10 day period.
Figure 4a (graph of Figure 4 data):

The graph above shows the increase (or decrease) in mass during the first 10 days of the experiment.

Figure 5:

<table>
<thead>
<tr>
<th>TYPE OF LIQUID</th>
<th>ORIGINAL MASS</th>
<th>ENDING MASS</th>
<th>STARTING pH</th>
<th>pH at 20 DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>COKE</td>
<td>82.9g</td>
<td>101.4g</td>
<td>2.69</td>
<td>3.68</td>
</tr>
<tr>
<td>DIET COKE</td>
<td>83.9g</td>
<td>83.7g</td>
<td>3.38</td>
<td>4.75</td>
</tr>
<tr>
<td>PEPSI</td>
<td>73.6g</td>
<td>105.8g</td>
<td>2.7</td>
<td>3.58</td>
</tr>
<tr>
<td>SPRITE</td>
<td>49.5g</td>
<td>56.8g</td>
<td>3.45</td>
<td>3.78</td>
</tr>
<tr>
<td>ROOT BEER</td>
<td>89.4g</td>
<td>98.1g</td>
<td>4.1</td>
<td>3.95</td>
</tr>
<tr>
<td>MOUNTAIN DEW</td>
<td>64.5g</td>
<td>74.8g</td>
<td>3.42</td>
<td>3.94</td>
</tr>
<tr>
<td>WATER</td>
<td>70.5g</td>
<td>72.2g</td>
<td>6.97</td>
<td>5.84</td>
</tr>
<tr>
<td>NO LIQUID</td>
<td>46.6g</td>
<td>45.5g</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The chart above shows the original mass and pH of each sample’s components (pork rib and liquid), as well as the ending mass and pH of each to numerically represent the change that occurred over the 20 day period.
Figure 5a (graph of Figure 5 data):

The graph above shows the increase (or decrease) in mass during the 20 day experiment.

Figure 6:

<table>
<thead>
<tr>
<th>TYPE OF LIQUID</th>
<th>ORIGINAL MASS</th>
<th>ENDING MASS</th>
<th>STARTING pH</th>
<th>pH at 50 DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>COKE</td>
<td>73.3g</td>
<td>88.3g</td>
<td>2.69</td>
<td>4.05</td>
</tr>
<tr>
<td>DIET COKE</td>
<td>84.7g</td>
<td>82.1g</td>
<td>3.38</td>
<td>5.11</td>
</tr>
<tr>
<td>PEPSI</td>
<td>75.4g</td>
<td>101.1g</td>
<td>2.7</td>
<td>3.91</td>
</tr>
<tr>
<td>SPRITE</td>
<td>71.5g</td>
<td>79.6g</td>
<td>3.45</td>
<td>4.22</td>
</tr>
<tr>
<td>ROOT BEER</td>
<td>62.0g</td>
<td>77.2g</td>
<td>4.1</td>
<td>4.05</td>
</tr>
<tr>
<td>MOUNTAIN DEW</td>
<td>74.7g</td>
<td>89.1g</td>
<td>3.42</td>
<td>4.02</td>
</tr>
<tr>
<td>WATER</td>
<td>65.2g</td>
<td>66.3g</td>
<td>6.97</td>
<td>5.51</td>
</tr>
<tr>
<td>NO LIQUID</td>
<td>60.2g</td>
<td>57.2g</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The chart above shows the original mass and pH of each sample’s components (pork rib and liquid), as well as the ending mass and pH of each to numerically represent the change that occurred over the 50 day period.
**Figure 6a (graph of Figure 6 data):**

The graph above shows the increase (or decrease) in mass following the 50 day experiment.

**Figure 7:**

The graph above shows the change in pH from original setup to the end of each experimental time span. The second, third, and fourth points on each line represent the ending pH of each separate experiment (10 days, 20 days, 50 days).
DISCUSSION

Do more acidic aqueous solutions cause more degradation to meat and bone of pork ribs than those that are less acidic? Based on previous research, it is known that mass loss is greater in more acidic soil conditions than in less acidic conditions (High, Milner, Panter, & Penkman, 2015). Because of this research, it was expected that liquids with a lower acidity (Coca Cola and Pepsi) to cause a greater a mass loss to pork ribs than those with higher acidities or more neutral pH levels (root beer and distilled water); however, after conducting my own research, the hypothesis was not supported. The only sample that gave expected results was the Diet Coke sample. That being said, Diet Coke was the only sample to contain aspartame, which is one type of artificial sweetener. While it is not known whether that was the ultimate factor in the pork rib samples’ decomposition, further testing could prove or disprove this finding.

Analysis of Data

Contrary to the hypothesis, none of the liquids, except for Diet Coke, followed an increase in pH along with a decrease in mass. Coca Cola, Pepsi, Sprite, A&W Root Beer, Mountain Dew, and distilled water all showed an increase in mass. The mass gain in each sample could most likely be attributed to absorption of water from the soda. All liquids, except distilled water, followed the expected pH trend by increasing to be less acidic. Distilled water, which originally had a pH of 6.97, experienced a drop in pH to
5.86 at 10 days, 5.84 at 20 days, and 5.51 at 50 days. Analysis of mass loss showed significant differences (p < 0.01) between Coca Cola and Diet Coke, Coca Cola and distilled water, and Pepsi with Diet Coke, Sprite, A&W Root Beer, Mountain Dew, and distilled water as well as a less significant, but still notable, difference (p < 0.05) between Coca Cola and Pepsi. The rest of the sodas showed no significant correlation in mass loss (p > 0.05). Figure 3 shows all values collected from an online ANOVA program. The green values are those that were found to be statistically significant (p < 0.05), while the red values are those that were not statistically significant (p > 0.05). All of the data regarding pH and mass can be seen graphically above in Figures 4 through 7.

**Follow-up Experiment**

Following the extraction of the 20-day samples, but before the 50-day samples were opened, a new experiment was conducted with feeder mice that weighed approximately 3.0 grams each. This experiment was to challenge the claim that the mouse in the Pepsi Company experiment would have a “jelly-like substance” after month-long exposure to Mountain Dew. The experiment was done with 4 of the 7 liquids tested in the original pork rib experiment. 24 ounces of Coca Cola, Pepsi, Mountain Dew, and water were poured into separate, quart-sized, canning-style jars with seals and screw on lids. The pH of each liquid was tested with a pH probe before the mice were added into the jars. One small “pinky” mouse was placed in each jar and left
for 35 days in a dark, climate-controlled (22.2°C) room. At the end of the 35 day period, the mice were extracted from the jars and weighed. First, each was weighed immediately after being pulled from the jars (wet mass as seen in Figures 8 and 8a). Next, they were set on a paper towel and allowed to “drain” for a moment before a second weight measurement was taken for a more accurate idea of mass loss (dry mass as seen in Figures 8 and 8a).

The mouse experiment ended with interesting results. The mice were still intact at the end of the 35 day time period, and did not resemble anything like a “jelly-like substance” as stated in The Pepsi Company’s experimental report regarding a mouse being discovered in a can of Mountain Dew. The mouse that had been left in the Mountain Dew was stained with the yellow-green coloring from the soda itself, but was still whole and firm as though it had recently died. The only mouse that showed any indication of true decomposition was the mouse in distilled water. This mouse was extremely bloated when first extracted, but almost completely flattened out after being allowed to drain on a paper towel. This mouse also showed the greatest mass loss from original weight to dry mass, losing a total of 1.0 gram. Figures 8 and 8a graphically show the differences between original mass, wet mass, and dry mass of each mouse.

**Figure 8:**

<table>
<thead>
<tr>
<th>TYPE OF SODA</th>
<th>ORIGINAL MASS</th>
<th>WET ENDING MASS</th>
<th>DRY ENDING MASS</th>
<th>STARTING pH</th>
<th>ENDING pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>COKE</td>
<td>2.9g</td>
<td>3.7g</td>
<td>2.8g</td>
<td>2.12</td>
<td>2.97</td>
</tr>
<tr>
<td>PEPSI</td>
<td>2.9g</td>
<td>3.1g</td>
<td>2.8g</td>
<td>2.04</td>
<td>2.15</td>
</tr>
<tr>
<td>MOUNTAIN DEW</td>
<td>3.3g</td>
<td>3.8g</td>
<td>3.7g</td>
<td>2.89</td>
<td>3.72</td>
</tr>
<tr>
<td>WATER</td>
<td>2.6g</td>
<td>2.4g</td>
<td>1.6g</td>
<td>7.05</td>
<td>6</td>
</tr>
</tbody>
</table>
Limitations

There were several limitations to this experiment. First, all of the samples did not weigh exactly the same amount. While each group of samples (10 days, 20 days, 50 days) for each type of liquid were kept within the same general mass range (+/- approximately 10 grams), the masses were not all the same and therefore cannot be compared with 100% confidence that the changes were accurate. Also regarding mass, the jars containing the pork ribs were filled to the 24 ounce line. Because each rib was shaped differently and weighed a different mass, each jar did not contain exactly the same amount of liquid. The 24 ounce line acted as a constant for total jar volume, but did allow variety in the total amount of liquid.
Another limitation in this experiment was the lack of funding for supplies and instruments that would have given more precise measurements. To obtain more exact mass measurements, a microbalance or a higher-end scale with less variance would need to be used to get a better idea of the exact percent mass loss or mass gain. Also, in order to obtain more precise pH measurements, a pH probe of better quality is necessary. Finally, without access to instruments such as a spectrometer or a nuclear magnetic resonance machine to tell exactly what kind of chemical changes occurred within each liquid, it is difficult to qualitatively compare and contrast each sample.
CONCLUSION

This study has shown that the decomposition of pork ribs is not necessarily affected by the acidity of soft drinks. Because none of the soft drinks gave the result expected, except for Diet Coke, it is reasonable to hypothesize that aspartame may have some effect on the rate of decomposition in organic tissue.

If this experiment were to be redone, there would need to be a greater number of samples to test, as well as more consistent measurements of each sample such as mass and volume of liquid added. The samples would need to be tested with a methodology refocused on the study of non-diet soft drinks versus diet soft drinks that contain aspartame and their effects on decomposition over a given time period.
REFERENCES


See Appendix A for Auxiliary Reading References
APPENDIX A

AUXILIARY READING REFERENCES


Retrieved February 20, 2017, from Academic Search Premier.


doi:10.1093/nutrit/nuw032


