INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME

Affect of lemon juice on digestion of proteins in the stomach

How does the increasing amount of freshly squeezed citrus limon juice affect the rate of digestion of proteins in stomach, when digestion is monitored using a pH meter?

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Abstract

This paper explores the claims that lemon helps lose weight by facilitating digestion.The effect of varying volumes of lemon juice on the rate of digestion was investigated through series of controlled experiments as “How does the increasing amount of freshly squeezed *citrus limon* juice affect the rate of digestion of proteins in stomach, when digestion is monitored using a pH meter?” is the topic of investigation concerning this essay.The digestion of proteins in the stomach is characterized by the decrease in pH as aciditiy increases with the hydrolysis of proteins.To be able to evaluate the rate of digestion, the change in pH of the stomach was observed on a model resembling the digestive qualities of the stomach, such that the width of the gap between the initial and final pH is directly proportional with the rate of digestion. Identical solutions of gastric juices composed of pepsin and HCl, were added differing volumes of lemon juice to monitor the digestion of chewed lamb meat. While the beakers were kept in a water bath set to stabilize the temperature at 36.5◦C, the homeostatic temperature of a healthy human body.

Experiments revealed that solutions containing higher volumes of lemon juice tend to show a greater change in pH. Although the mean change in pH was observed to be constant for sets containing 2 and 3 ml of lemon juice, Anova single factor test revealed that the overall variations between sets were significant. White residue was observed on digestive solutions containing more than 3 ml of lemon juice. Although the results of the experiment are not enough to evaluate the effect of lemon juice on weight loss, the awareness that lemon juice increases the rate of digestion can pave the way for other investigations as the topic concerns a wide spectrum of biological phenomena. (Word Count: 300)

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Introduction

You can never lose too much weight, or so they say. If you were to walk out of your house this instant, you would find yourself surrounded by perfectly skinny Barbies and Kens. In a world where being paper thin is not only encouraged, but is mandatory millions of women, men and even children are victimized by the miracle pills that will make you "lose 5 pounds in a week without ever visiting the gym". Although I am among those conforming to the societys definition of perfect, I was deeply moved by the tragic stories of weight loss pill victims.

As a little girl, I was known for my ability to eat, so my grandmother would make me drink warm lemony water, hoping this would keep me from becoming the Yogi Bear of our family. As I dug deeper into the "warm lemon water" phenomena I found out that, among many other benefits, it is believed to aid in digestion and claimed to help lose weight.

Botanically, lemon belongs to the family of *Rutaceae* of the genus, *Citrus* ,whereas its scientific name is *Citrus limon*.[1]Its acidic taste can be accounted for by citric acid, which is present up to 8% in its juice. Citric acid ,2-hydroxy-1,2,3-propanetricar-boxylic acid as shown in figure 1, is a weak tricarboxylic acid that is a natural preservative[2] which is believed to aid in digestion. When considering the properties of lemon juice, which make it an essential part of every diet, it should be noted that an ion is part of a molecule con-atom or a group of atoms that carry an electrical charge due to the ratio of protons to electrons in its molecules. Ions which carry positive charges are known as cations. Lemons are

[1] Rudrappa, Umesh. "Lemon Nutrition Facts and Health Benefits." *Nutrition And You.com*. N.p., n.d. Web. 22 Feb. 2014.
[2] "Quantitative Assessment of Citric Acid in Lemon Juice, Lime Juice, and Commercially-Available Fruit Juice Products." *US National Library of Medicine National Institutes of Health Search TermSearch Database*. N.p., n.d. Web. 10 Feb. 2014.

considered to be anionic, meaning having more electrons ,negatively charged ions, of energy as compared to cations which are positively charged ions in their atomic structure. Saliva, hydrochloric acid, bile and the stomach's other digestive juices are also anionic.Lemon is one of the only foods on the planet that has more anions than cations in its atomic structure.Whilst reviewing the electromagnetic properties of food, Dr. A.F. Beddoe points out that all food is considered cationic with the exception of fresh, raw lemon juice.However, it should be noted that pasteurized and packaged lemon juice is cationic and, therefore, ineffective as a health remedy. On the other hand, some have suggested that the reason fresh lemon juice is similar to digestive enzymes is due to the low amount of sulfur in lemons[3].However, it is known that as most organic acids, citric acid has weaker acidic character when compared to the hydrochloric acid in stomach, which raises the question that " can a weak acid such that is present in lemon juice interfere with the functioning of a strong acid such as HCl in stomach?". I was intrigued by this contradiction between scientific data before I realised that I could be the one to solve the mystery.

While pursuing this curiosity of mine, I hope to find out that warm lemon water does help in digestion of proteins. To put this to a test, some amount of freshly squeezed warm lemon juice will be placed in a beaker with some hydrochloric acid, activated pepsin and boiled, chewed meat as the change in pH is monitored while mimicing the activity of the stomach. A decrease in the pH will indicate the digestion of proteins.To be fully able to comment on the effect, the experiment will be repeated with different amounts of lemon juice.In addition, the natural digestive pathway

[3] Penniston, Kristina L., et al. "Quantitative assessment of citric acid in lemon juice, lime juice, and commercially-available fruit juice products." *Journal of Endourology* 22.3 (2008): 567-570.

without the lemon juice will be included in the trials to be able to compare the data while minimizing the effect of laboratory conditions.

In this experiment, I will focus on " How does the increasing amount of freshly squeezed *citrus limon* juice affect the rate of digestion of proteins in stomach, when digestion is monitored using a pH meter?" My existing knowledge and understanding of biology leads me to believe that the atomic structure and acidic character of lemon juice will aid in the digestion of proteins, and allow the gastric juices to digest more meat when compared to digestion observed under natural conditions of the stomach.

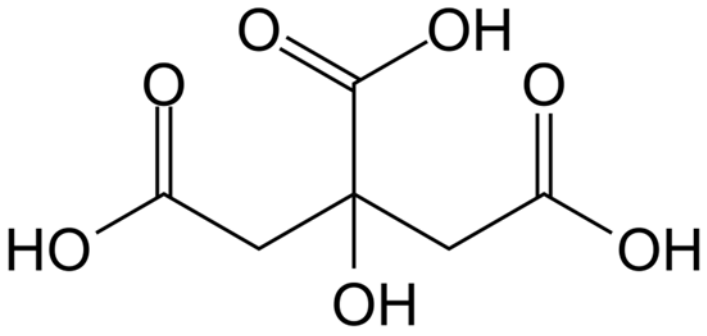


Figure 1, chemical structure of citric acid.

Hypothesis

Whilst the question concerning the weak acidic character of the citric acid in lemon remained, a further look into the functioning of the HCl in the digestive system served as a tool supporting the thesis that lemon juice does aid in digestion. Although HCl does not break apart nutrient bonds, in other words, digest anything; it specifically does the following to become an integral part of digestion;[4](Sherwood 607)

1. It activates the enzyme precursor pepsinogen to an active enzyme, pepsin, by providing an acidic medium that is optimal for pepsin activity.
2. It aids in the breakdown of connective tissue and muscle fibers, reducing large food particles into smaller ones.
3. It denaturates protein; that is; it uncoils proteins from their highly folded final form, thus exposing more of the peptide bonds for enzymatic attack.
4. Along with salivary lysozyme, HCl kills most of the microorganisms ingested with food, although some do escape and continue to grow and multiply in the large intestine.

Since HCl, does not actively digest proteins but instead aids in digestion by activating pepsinogen and denaturating proteins to increase substrate surface for enzymatic activity, it can be deduced that the weak acidic character of citric acid can not play a prominent role as to digest the proteins, as HCl does not digest proteins either. Another evidence indicating that there might be a harmonic coherence pattern between the gastric juices and citric acid is the clinical trials suggesting that dietary citric acids enhances absorption of aluminum in

[4] Sherwood, Lauralee. Human Physiology From Cells to Systems Seventh Edition, Canada: Brooks/ Cole Cengage Learning, 2010. Print.

antacids[5].This may indicate that citric acid interferes with the functionning of the stomach as a digestive organ.Also bearing in mind the resemblances between the digestive medium and the lemon juice in terms of cationic properties and amounts of sulphur as mentioned in the introduction, the lemon juice is expected to aid in digestion of proteins.

My understanding of chemistry and biology lead me to believe that the increasing volume of lemon juice will increase the rate of digestion of proteins. The highest difference between final and initial pH is expected to be observed in the solution containing 5 ml of lemon juice, indicating a rapid digestion process. However, since the independent variables differ from each other by 1 ml, the change in concentration may not be significant enough to be observed.

[5] Slanina, P., et al. "Dietary citric acid enhances absorption of aluminum in antacids." *Clinical chemistry* 32.3 (1986): 539-541.

Method Development and Planning

The human body is a complex organisation of systems, thus mimicing it's activity poses several problems. The initial question manifested itself when the resources providing information for the outline of the experiment did not suffice. There is little scientific data available on the internet and in academic resources that suggest a link between digestion and lemon juice. However, a simple Google search provides one with an endless sea of claims as to how lemon juice aids digestion, without no solid proof. My understanding of biology combined with several gastrointestinal specialists, led to an idea of an experiment with proteins rather than carbohydrates and lipids. Bearing in mind the similarities between the humanly gastric juices and citric acid in lemon, I deduced it would be best to experiment on proteins, since their initial site of digestion is the stomach unlike other organic coompounds.

Choosing to work with proteins was merely the beginning, as experimenting on proteins in their purest form became an issue since all nutritional materials contain various amounts of organic compounds. To maximize the accuracy of the data, I decided to use animal flesh which is a natural source of protein. According to most butchers, the upper leg of a lamb ,which is referred to as the hind or fore shank, is the part containing the least amount of fat. And also, the fat surrounding the meat is clearly visible and distinguishable because of its white colour. So, to obtain proteins in its purest form I preferred lamb meat. To prevent the proteins form denaturating, rather than frying, boiling the meat presented a better way of preserving the nature of the proteins and yet mimicing the humanly eating habits.

Later on, determining a method for monitoring the process of digestion became an issue, how could it be said that the protein was digested, or was digested more? The solution lied in the acidic character of proteins. When partially digested to be broken down into peptons in the stomach, proteins decrease the pH. So in less scientific terms the lower the pH, the better the digestion. To observe the time it would take for the pH to show a meaningful deviation, initial trials were carried out in which the pH would be measured each 5 minutes by a pH meter in a solution devoid of lemon juice, resembling only the gastric juices of the stomach. The research revealed that 45 minutes would be enough to observe a sufficent change in pH, as after 44 minutes white residue was observed on the set of solutions containing 4 ml of lemon juice. In solutions of 5 ml of lemon juice, the residue appears as early as the thirty seventh minute.

However, despite all the resemblances in the chemical processes the experiment still lacked some vital qualities of the human digestive system. Originally, a piece of meat is mechanically broken down into smaller particles with the help of our teeth and becomes a substrate for the stomach acids to bind to by the salivary enzymes. This effect is impossible to mimic under laboratory conditions. So, the food had to be chewed and processed by an individual before it was spit out into the digestive solution.

Determining the substrate enzyme ratio, and the amount of HCl and pepsin that would suffice became tricky since there were no previous experiments to refer to. Initially my understanding of biology led me to believe that the excessive usage of enzymes would not inhibit digestion, in addition the increased substarate surface for the enzymes to bind to would increase the rate of the reaction. So the

substarate enzyme ratio would not affect the terminal pH value as long as enough time is given. During the initial trials, several concentrations of HCl and pepsin were experimented with. It is known that the original pH of the stomach is about 2.5, initially 2.5 pH was trying to be obtained by the varying concentrations. However when the pH seemed to vary about 0.60 another method had to be determined. Qualitative observations concerning the interactions between the meat and the solution by the experimenter were used to determine the concentrations. In the final trials, white residue were observed on the meat indicating a successful digestion process.The research trials also helped the experimenter to observe qualitative differences in the beaker.

Providing a stomach like environment for the experiment required many methods of controlling variables. Initially, the temperature of the system had to be 36.5◦C since it is the optimum temperature of the human body. The research trials were carried out in a water bath to be able to observe the change in pH, however the original trials to obtain data were conducted using an electronic water bath which would stabilize the temperature and minimize the possibility of random and systamtic errors. For each trial, to control the quality of the lemon juice, lemons originating from the same batch would be freshly squeezed beforehand. Although the lemon did not present any issue, controlling the quality of the meat was a challenge because of the presence of fat on the surface. Although the chopped meat were shaped to resemble each others dimensions to approximation while the visible fat was removed, nothing could be done about the fat among the layers of meat. However, the non visible fat embeded into the meat, if such a thing exists, would not affect the digestion process since it would not be activated by the gastric juices or inhibit the surface area of the substrate on a distinguishable scale.

The most important aspect determining the accuracy and precision of the experiment is how the control variables were controlled. Several factors which were most likely to affect the rate of digestion were controlled such as room temperature, amounts of chemicals in the solution, the amount of substrate put into the solution, the freshness of the lemon juice, the quality of the protein to be digested, the temperature of the solutions among many others mentioned in the method section. The temperature of the solution was kept constant at 36.5 °C to resemble the homeostatic body conditions with the help of a water bath. The lemons were freshly squeezed just before each trial and for the gastric juice soluion to maintain it's acidic character the experiment was directly initiated after each time that the solution was prepared. The HCl, pepsin, substrate, lemon juice and water was placed inside the beaker simultaneously to prevent any undesired reaction among the reagents. Between sucsessive trials the amounts of reactants, excluding the lemon juice, were kept constant. Identical devices of measurement were utilised to minimize random errors.

Phototgraphs

Figure 2, shows the change in composition of meat during boiling as the lipids inside the meat are extracted and become visible on the surface.

Figure 3, is a photograph of the system set up for the test trials. The beakers inside water contain meat chewed by the experimenter.

Figure 4, shows the interior of the water bath used while collecting data.

Method

Materials and Apparatus

Şimşek Laborteknik® SBD-312 Water bath

Merck® Pepsin from porcine gastric mucosa

1 M HCl

Thermometer of range 0˚C – 100 ˚C

500 grams of chopped lamb hind shank

Kitchen Knife

Erikli® Natural Spring Water

Kitchen Oven

Tupperware® Vet'N Serve 2 piece Medium Set

25 lemons from the same batch

Vernier® pH probes

Vernier® datalogger

An electronic weigher

A Chronometer

Tefal® 24 cm stainless steel Dutch Oven with tempered glass lid

A graduated cylinder of 10 ml

5 beakers of 500 ml

500 grams of chopped lamb hind shank was rid of its visible fat which would occupy an area on the surface and appear white in contrast to the red meat. After the meat becomes fat free, 75 pieces of 2x2x2 cm lamb chops are obtained. On a kitchen oven, 2 litres of tap water is placed in a pot ,while the lid is kept closed,to heat up the chops until the water boils. The meat is put in a tupperware container and maintained under room conditions for 2 hours. One lemon is freshly squeezed and x ml of lemon juice is placed in a 500 ml beaker. The beaker is then placed inside the water bath set to stabilize the temperature at 36.5 °C.3 pieces of lamb chops are chewed until they are ready to be swallowed. The chewed meat is spit on a paper to be weighed. 3 grams of chewed meat is put inside the beaker. Without wasting any time , 100 ml of drinking water,10 ml of HCl and 50 grams of pepsin is placed inside the same beaker simultaneously.The initial pH is measured and until the 45 minute digesting time has elapsed, the solution is kept inside the closed water bath. Then the terminal pH is noted down for further investigation. This process is repeated 5 times for each value of independent variable denoted by x, when 0,2,3,4 and 5 is substituted for x.

Data Collection and Processing

Volume of lemon juice V_L/ml ΔV_L= ±0.5ml	**Trial**	**Volume of HCl V_{HCl}/ml** ΔV_{HCl}= ±0.5ml	**Volume of H_2O V_H/ml** ΔV_H= ±0.5 ml	**Mass of pepsin** M_p / g ΔM_p = ±0.005 g	**Mass of substrate** M_s / g ΔM_s = ±0.005 g	**Temperature of the system** T/ ˚C ΔT= ±0.5/ ˚C	**Initial pH** $P_İ$	**pH after 45 minutes** P_T	**The Change in pH** ΔP
0.0	1	10.0	100.0	50.000	3.000	36.5	0.94	0.88	0.06
0.0	2	10.0	100.0	50.000	3.000	36.5	0.90	0.85	0.05
0.0	3	10.0	100.0	50.000	3.000	36.5	0.88	0.79	0.09
0.0	4	10.0	100.0	50.000	3.000	36.5	0.88	0.83	0.05
0.0	5	10.0	100.0	50.000	3.000	36.5	0.88	0.80	0.08
2.0	1	10.0	100.0	50.000	3.000	36.5	0.85	0.70	0.15
2.0	2	10.0	100.0	50.000	3.000	36.5	0.85	0.71	0.14
2.0	3	10.0	100.0	50.000	3.000	36.5	0.83	0.68	0.15
2.0	4	10.0	100.0	50.000	3.000	36.5	0.79	0.67	0.12
2.0	5	10.0	100.0	50.000	3.000	36.5	0.79	0.69	0.10
3.0	1	10.0	100.0	50.000	3.000	36.5	0.76	0.54	0.22
3.0	2	10.0	100.0	50.000	3.000	36.5	0.72	0.57	0.15
3.0	3	10.0	100.0	50.000	3.000	36.5	0.71	0.61	0.10
3.0	4	10.0	100.0	50.000	3.000	36.5	0.70	0.58	0.12
3.0	5	10.0	100.0	50.000	3.000	36.5	0.70	0.63	0.07
4.0	1	10.0	100.0	50.000	3.000	36.5	0.72	0.50	0.22
4.0	2	10.0	100.0	50.000	3.000	36.5	0.70	0.53	0.17
4.0	3	10.0	100.0	50.000	3.000	36.5	0.70	0.57	0.13
4.0	4	10.0	100.0	50.000	3.000	36.5	0.68	0.59	0.09
4.0	5	10.0	100.0	50.000	3.000	36.5	0.68	0.49	0.19
5.0	1	10.0	100.0	50.000	3.000	36.5	0.66	0.43	0.23
5.0	2	10.0	100.0	50.000	3.000	36.5	0.64	0.48	0.16
5.0	3	10.0	100.0	50.000	3.000	36.5	0.63	0.39	0.24
5.0	4	10.0	100.0	50.000	3.000	36.5	0.61	0.45	0.16
5.0	5	10.0	100.0	50.000	3.000	36.5	0.61	0.40	0.21

Table 1. provides unprocessed data and processed data concerning the dependent, independent and control variables. The initial and final pH is presented along with the difference between them to be used as a norm while determining the rate of digestion according to the difering volumes of lemon juice. The volumes of digestive agents are presented in addition to the constant temperature of the system.The uncertainties for volumes and temperatures were accepted to be half the smallest unit on the beaker, while for mass it is presented as half the smallest significant figure visible on the electronic weigher. However an uncertainty for pH is not available as all data concerning pH was obtained through electronic devices eliminating the effect of the experimente. The reason as to why mass was presented with uncertainties in spite of the electronic device is due to the measurements of mass being easily disturbed by sudden movements of air.

Qualitative Observations: Figure 5, shows the colour of digestive solutions containing 3 ml of lemon juice after 45 minutes in test trials.The change in shape of the substrate can be observed when figures 2 and 5 are compared.

Figure 5

Figure 6, shows white residue formed by solutions reacting with 5 ml of lemon juice.

During the cleaning up process following the experiment, it was observed that solutions containing 4 and 5 ml of lemon juice have produced white particles.

Volume of lemon juice V_L/ml $\Delta V_L = \pm 0.5$ml	**Mean**	**Standard Error**	**Standard Deviation**	**Confidence Level (95,0%)**
0.0	0.066	0.008124038	0.018165902	0.022555947
2.0	0.132	0.00969536	0.021679483	0.026918634
3.0	0.132	0.025573424	0.057183914	0.0710003207
4.0	0.16	0.022803509	0.050990195	0.06331269
5.0	0.2	0.017029386	0.038078866	0.047281156

Table 2. presents the obtained data when the pH difference values are analyzed using descriptive statistical techniques. The mean, standard error, standard deviation and confidence level concerning each value of independent variable is calculated using excel. These data will then be used to determine whether the change in volume of lemon juice supplies a significant variation among the pH values.

The following tables are formed by naming each group according to the volume of lemon juice it receives, for instance the group marked 4 has reacted with 4 ml of lemon juice.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0	5	0,33	0,066	0,00033
2	5	0,66	0,132	0,00047
3	5	0,66	0,132	0,00327
4	5	0,8	0,16	0,0026
5	5	1	0,2	0,00145

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,04792	4	0,01198	7,376847	**0,000806**	2,866081
Within Groups	0,03248	20	0,001624			
Total	0,0804	24				

Table 3. presents data undergone anova single factor test.

Anova single factor test enables us to evaluate the significance of the variation of change in pH due to the concentration of lemon juice. As shown in table 2, the confidence interval was chosen to be 95.0% which would indicate a 5.0% possibility of error. To be able to reject or accept the null hypothesis, which suggests that there is

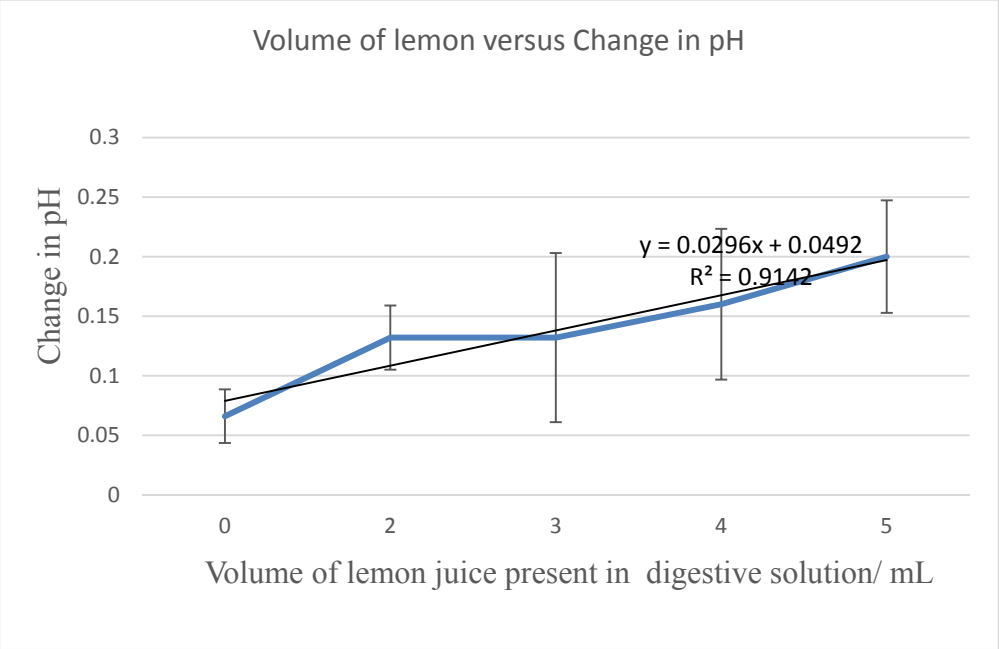
no relation between the volume of lemon juice and change in pH, the P-value is compared with the error percentage.

P-value = 0,000806

Error = 5% = 0.05

P-value < Error

The null hypothesis, denying the relation between volume of lemon juice present in the digestive solution and the change in pH, was rejected.



Graph 1 shows the variation of change in pH due to differing volumes of lemon juice with respective error bars and a best fit line.

Evaluation

The data obtained during the experiment was processed using Anova statistical analysis since the independent variable presented 5 groups of data, and while with 2 groups of data T test is more widespread, Anova is commonly used for experiments with a number of groups exceeding 2.Although the results of the Anova single factor test oppose the null hypothesis, that the rate of digestion reflected through the change in pH is not affected by the volume of lemon juice, the hypothesis should be evaluated using the raw and processed data in hand. To observe how the process of digestion is affected by the independent variable, graph 1 could be used, which shows a correlation among the two variables. However, the graph does not present a straight line, suggesting that the change in pH and the volume of lemon juice are not directly proportional. It could be stated that the increasing volume contributes to the digesting process but how much it deviates the reaction from its original pathway differs irregularly among successive groups.

Another irregularity among data can be seen in Table 2, which shows a variation among the standard deviations of each group so that even the first significant figures of the standard deviation values differ. For example, while the standard deviation for 2 ml of lemon juice is 0.021679483, it is 0.057183914 for 3 ml whilst their means are the same. The difference between the two is almost as much as the standard deviation of the group marked 2. So it could be deduced that the fluctuation of data, expressed through standard deviation is not constant when compared in terms of groups. To be able to further comment on the significance of these fluctuations

among and within groups standard deviations could be analyzed using statistical techniques.

In spite of the fact that the mean change in pH increases with the increasing concentration of lemon juice, some data show resemblance among groups. For instance, while the first trial for the group marked 4 shows a variation of 0.22 on the pH scale, the fifth trial of the batch reacting with 5 ml of lemon juice moves 0.21 points further. This resemblance may indicate that the difference among volumes of lemon juice was not enough to observe distinguishable patterns. To improve the results the independent variables could be 0, 5, 10, 15, 20 ml of lemon juice.

These patterns could also be explained through random errors. One of the main causes of my suspicion as to the irregularity of the data is the uneven distribution of fat and proteins among the layers of meat, which cannot be observed. The presence of fat would have decreased the surface area of the substrate for the enzyme to bind to. To use protein in its purest form, protein pills or shakes could be used but it would not comply with the common dietary habits. However, such an experiment can be carried out to better interpret the data in hand via comparisons. Furthermore, the quality of the lemon juice should not be expected to be constant, since for each trial a different lemon is squeezed and even though the lemon is obtained from the same batch, they may originate from separate trees or may have been harvested at different times. To minimize such a variation, the same lemon could be used to simultaneously initiate one trial for each group.

There does not seem to exist any literature value to explain the data in terms of accuracy. However, the digestion process involves bolus of food activated by the experimenter's salivary enzymes, which are unique to each individual as it is a

protein. To eliminate the experimenter's saliva as a factor determining the rate of digestion, synthetic saliva could be utilized.

In the human body, digestion takes place in the stomach where peristaltic movement increases the rate of reactions and the mucosal layer isolates the stomach from the surroundings. In addition, emotions can also alter gastric motility by acting through the autonomic nerves to influence the degree of gastric smooth muscle excitability[6](Sherwood 604).Under these circumstances the effect of lemon juice may be of greater significance in the human body due to factors such as the placebo effect. These conditions could not be modelled under laboratory conditions. The lack of digestive functions must have resulted in the inaccuracy of the data. However the mentioned situation is valid for all the trials so the precision or imprecision of the data is not affected.

The experiment itself does not allow qualitative observations without disturbing the process of digestion. So the significance of the quantitative data becomes more prominent. The observations during the test trials determined the time period allowed by the experimenter to for statistically remarkable digestion to occur. During the test trials of group 4 in 3 beakers out of 5, and 5 out of 5 in the fifth groups trials white residue was observed. The white residue manifested 43 minutes after the initiation in the earliest outcome of group 4 whereas residues became apparent after the thirty seventh minute of group 5. Although the characteristics of the residue, shown in figures , are unknown it was accepted to be an indicator of digestion since the only possible reaction which could produce solid particles of such size inside that solution was digestion . Nonetheless, another method of measurement was not

[6] Sherwood, Lauralee. Human Physiology From Cells to Systems Seventh Edition, Canada: Brooks/ Cole Cengage Learning, 2010. Print.

possible since investigations concerning rate of digestion in humans is very limited and no mean of direct measurement exists. If the increase in the amount of peptons in the solution could be monitored, the data would hold greater credibility as pH is easily affected by the random movements of air, the reactions of hydrogen and hydroxyl ions in water.

The independent variable was determined to be the volume of lemon juice inside the solution, which caused the reactions to take place in different amounts of liquid. The differing volumes of digestive solution would affect the interaction between the substrate surface and the enzymatic medium. Instead of changing the volume of lemon juice between groups of trials, the concentration of lemon juice could be the independent variable defining the rate of reaction.

The most suitable method for this experiment eliminating most errors caused by the differences between the system and the human body is the aspiration of gastric juices using a nasogastric tube. The variations in the pH of the gastric juices could be monitored after the substrate had been ingested with warm lemon water.

Conclusion

As stated in the research question, this experiment does not aim to discover the chemical mechanisms involved in digesting proteins, instead the change in rate of digestion due to volume of lemon juice present in the stomach was investigated. It has been proven by statistical analyses that varying volumes of the independent variable cause deviations from the original path of digestion. The increasing volume has allowed greater change in acidity, which marks the breaking down of proteins into smaller polypeptide fragments known as peptons. The greatest mean change in pH is observed in the set of systems receiving 5 ml of lemon juice. Moreover, Graph 1 presents the trend shaped by the independent variable as to confirm the directly proportional nature of the relation between the increasing volume of lemon juice and the rate of digestion. Per contra, why lemon juice plays such a role is still a mystery to biology. It may be caused by the low amounts of sulfur, the presence of citric acid or the structure of other organic compounds in the lemon. To further challenge the issue, the effect of varying concentrations of sulfuric compounds, citric acid and lemon juice on the rate of digestion could be experimented with in order to obtain a comperative result.

The primary source of beliefs which led to this experiment was the urban tale that lemon juice helped one lose weight while aiding in digestion. Although it could be deduced that it does facilitate digestion, nothing could be said about the vanishing of weight. The rate of digestion alone is not a sufficent criteria to determine the metabolic rate eliminating unnecessary fat tissue in the body. Clinical trials investigating the affect of lemon juice on the human metabolism can be carried out by

monitoring body mass indices of the individuals in a test group . The results of the experiment could allow the utilisation of lemon juice to relieve patients of some symptoms of gastrointestinal diseases.

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