CHEMISTRY EXTENDED ESSAY

"Determining the acidity levels of certain types of tomato products with the process of titration and to determine which product of tomato is more suitable to the human body"

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Abstract:

The aim of this practical is to determine the acidity levels of certain types of tomato products with the process of titration and to determine which product of tomato is more suitable to the human body. I have chosen to search which product of commercial tomato is more suitable to the human body, because I was curious about this subject. Tomatoes, ketchup and tomato paste are nutrients that are quite common in daily life. I wanted to search the acidity of such product that we use a lot. Therefore I have searched tomato products' pH in order to indicate which product is more suitable to the normal pH level of our blood.

At first, I have searched *what percentage of each tomato products that are tomato juice, ketchup and tomato paste, contain any kind of acid.* Then I have tried to indicate *which one is the most harmless to the human body.* For reaching a conclusion I focused on the normal blood pH of human body and I have tried to obtain the best commercial tomato product for normal regulation of acidity in human body.

I have chosen to use the method titration in the experiment. The reason why I choose titration is that, both qualitative and quantitave results could be obtained from it. I have predicted that tomato paste is going to be the less harmless. In fact, the pH values were close to each other, but most suitable tomato product is tomato paste according to my experiment. Therefore my predicted result proven.

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Research Question:

Tomato is an acidic substance but what percentage of each tomato products that are tomato juice, ketchup and tomato paste, contain any kind of acid? And which one is the most harmless to the human body?

Background Information:

During the experiment my aim was to determine the percentage of the acids in tomato products, so properties of the acids is the main deal of my essay. Therefore it is needed to give some information about acids.

According to the modern acid definition, which is known according to the Lewis definition is that; acids are the substances that accepts electron, and bases give electron.

Substance's being an acid is mentioned, but this information is not enough to define a molecule as acid. Acid character could be observed when a molecule has H-X bonds, it should ionize to form positive +1 ion which is not enough because of the fact that H does not ionize, and molecules with non polar bonds can not be acids. In addition, acids could be strong and weak. As tomato products are composed of weak acids, the properties of weak acids are important for the information of the experiment. A weak acid is an acid that dissociates incompletely and does not release all of its hydrogen in a solution. It does not completely donate all of its protons. The properties of acids and character of acids are mentioned above. However the information about the regulation of blood pH in human body is necessary as I am trying to dedicate the most harmless tomato product to the human body. Therefore, acidity of human body is important to find the answer of my research question.

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Normal Blood pH

In order to reach the information of blood pH of the humankind, it is important to give information about regulation of blood pH. And acid-base balance of blood is necessary in order to survive. Therefore, it should be between 7.35 and 7.45 in order to protect the brain from losing its ability to function normally. Therefore, regulation of blood pH is necessary for human to continue his/ her standard body conditions.

The control of arterial CO_2 tension by the central nervous system and the control of the plasma bicarbonate by the kidneys stabilize the arterial pH by excreation of acid. Under many circumstances, CO_2 tension is 40 mmHg, however when this balance is failed, then excreation provides the balance again. Therefore, it can be said that blood pH could be stabilized by respiratory factors.

On the other hand, the kidneys regulate plasma; HCO_3^- by reabsorbtion of filtered HCO_3^- , formation of titratable acid and excreation of NH_4^+ in urine. Kidneys dealing with the process as; distal nephron reabsorbs the remainder and secretes protons in order to stabilize the blood pH. These secreted protons are represented in the urine as titratableacid and NH_4^+.

To sum up , regulatory responses which include chemical buffering, control of CO_2 tension by respiratory system and providing the balance of pH by the mechanism of kidneys are in order to maintain pH between 7.35 and 7.45.

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← Buffer taking up excess H^+		Buffer releasing H^+→
H-Hb	↔	$Hb^- + H^+$
Prot-H	↔	$Prot^- + H^+$
$H_2PO_4^-$	↔	$HPO_4^{2-} + H^+$

Table 1 : demonstration of pH regulation mechanism of buffers in human blood.

An Introduction about Acids and Titration:

As my ambition is to determine which product of tomato is more suitable to the human body, the acidity of those products will be obtained and compared to the normal blood pH. Thus the method that is going to be used in the experiment is important. Titration is one of the most understandable and useful method for dedicating the acidity of solutions. Therefore it is needed to explain titration before hand to obtain more comprehensible experiment.

In an acid-base titration is the process that weak acids react with bases. During the reaction equivalence occurs; which is actually shows that moles of acid and base become equal. Therefore, at the end there is an acid and its conjugate base in the Erlenmeyer flask. And the process is called titration.

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As my experiment is dealing with organic substances and organic acids in those substances too, the points about organic acids in fruits and vegetables is important. Organic acids are acids that their structures based on carbon skeletons. Formic acid, acetic acid, propionic acid, butyric acid, Fumaric acid, sorbic acid, citric acid and their salts are the major organic acids.

"Organic acids are of great significance in plants. As intermediates in the metabolic processes of the fruit, these acids are directly involved in growth, maturation, and senescence. Fruit juices have a low pH, because they contain high levels of organic acids. The total acid content varies widely, from approximately 0.2% in pear juice to 0.8% in lime. Organic acids also influence the growth of microorganisms in fruit and vegetable juices and therefore affect the keeping quality of the product. At proper levels certain acids are inhibitory to most bacteria as Enterobacter, Proteus, and Pseudomonas. Another aspect of organic acids is their influence on the sensory properties of juice and vegetable products. As acids have a characteristic sour taste, they are responsible for the fresh, tart taste of fresh fruits and their processed products. Color is also related to the type and level of acids present in the product."

(Dr. James Gallander, Department of Horticulture, Ohio State University
Resource: The Science Workbook: Student Research Projects in Food-Agriculture-Natural Resources, 1985 Edition, College of Agriculture, Ohio State University)

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Facts about Tomato:

Related to the statistical data which is given in the appendix, it could be concluded that the most abundant acids are aspartic acid and glutamic acid in 'Lycopersicon Esculentum'.

Aspartic acid and glutamic acid are amino acids and they have the pKa 4.0. Thus, in the process of titration, the potassium hydroxide will be used as an indicator.

Experiment:

Potassium hydroxide is a compound which is very basic substance. Its property is that they could form alkaline which are strong. Because of this, it is easier to observe changes in the titration by using KOH as a titrant. Therefore KOH will be used as a base in the titration.

Bromothymol blue acts as a weak acid in solution. Therefore it will be used as an indicator. And in the process of titration the solution color will turn into green because of bromothymol blue.

Hypothesis:

As Lycopersicon Esculentum includes glutamic and aspartic acid in the grams of 0.313 grams and 0.118 grams, the Lycopersicon Esculentum products sold in groceries and supermarkets have acidic features.

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Prediction:

Due to Lycopersicon Esculentum's acidic properties, if solutions of Lycopersicon Esculentum products are neutralized with KOH by titration, they will give green color with the indicator bromthymol blue.

Materials:

- A variety of commercial Lycopersicon Esculentum products

Tomato juice

Ketchup (*TAT Ketcap*)

Tomato paste (*TAT Domates Salcası*)

- Bromthymol blue (100 mL± 1)
- 1 M KOH (100 mL ± 1)
- Test tubes (50 mL ± 1) x 10
- Beaker (500mL ± 1) x 3
- Erlenmeyer (50 mL ± 1) x 2
- Burettes (50 mL ± 1) x 5
- Burette Stand
- Thermometer (0.0 – 100.0 °C ± 0.1)
- Hygrometer
- Pressure-meter

Variables:

Dependent variables: Acid amount in commercial tomato products (*Lycopersicon Esculentum* products)

Independent variables: *Lycopersicon Esculentum* products sold in groceries and supermarkets

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Constant variables:

1. Amount of water which is used to prepare solutions from *Lycopersicon Esculentum* products ; by using a graduated cylinder. Because solutions are needed in order to make titration, so materials should be aqueous.
2. Humidity; by measuring the humidity of the air regularly with a hygrometer.
3. Temperature; by measuring the temperature of the environment regularly with a thermometer. And also water bath is used in order to provide the constant temperature during titration. Because change in temperature may change the validity of chemical reaction.
4. The amount of the indicator, same amount of indicator (4 drops) is used for each trial.
5. In order to prepare solutions, same amount of Lycopersicon Esculentum products is used (approximately 10 grams).
6. Pressure is going to be constant as the laboratory used is same; so there is not any difference of altitude.

Procedure:

I have determined the molarity of an acid by finding out exactly how much base which is KOH of known concentration is required to neutralize it. As neutralization point is that the color of the solution turns into green from reddish. In order to do this,

- I have measured the acid which is the solutions of tomato products that was prepared with equal mass of pure water, into an Erlenmeyer flask.
- Then, I have added the KOH from a burette until it has reacted with the acid and neutralized it.
- I have used burettes as they measures volumes with great precision.

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- I have used the indicator bromthymol blue as its color has changed when acidity changes and reaches the equivalence point where the acid and KOH are neutralized.

1. Clean and DRY beaker.
2. Put about 100 mL of tomato product into the beaker.
3. Clean burette with detergent and a long brush.
4. Pour about 5 mL KOH solution into the burette.
5. Rinse some of the acid through the tip, then hold the burette horizontally and allow the acid to rinse all sections of the burette. Drain and discard the base.
6. Fill the burette with KOH to above the graduations at the top. Drain some so the tip is filled with base.
7. Clean an Erlenmeyer flask and rinse it with distilled water.
8. Read the burette to find the place where the meniscus of the KOH solution is found and record this as the initial reading of KOH. (All measurements should be recorded to the nearest 0.1 mL.)
9. Add approximately 15 mL of acid to your flask. Subtracting the initial reading from the final reading will give you the volume of KOH added to your flask.
10. Add 2 or 3 drops of bromthymol blue indicator to the acid in the flask. In this process ne change in color will appear.
11. Titrate by adding the base to the acid until one drop turns the solution green for at least 10 seconds.

12. The faintest shade of green color that persists indicates the end point. Be sure to swirl the flask while adding the base. It is in order to rinse the sides of the flask down with distilled water shortly before the end point.
13. Record the burette reading of the base.
14. Subtracting initial from final readings will give you the volume of base added. And the molarity of base is known which is 1.0 M.
15. Calculate the molarity of the acid with the equation; Volume of base added x Molarity of base added = Volume of acid solution x Molarity of H^+
16. Repeat the processes 1-15 for 4 trials and for other solutions.

Data Collection:

	Tomato product / Trial #	Tomato juice	Ketchup	Tomato paste
Volume of KOH used per trial (± 0.1) ml	1	11.0	9.0	8.0
	2	8.0	12.0	10.0
	3	10.0	11.0	11.0
	4	12.0	10.0	9.0

Table 1: Volume of KOH used (± 0.1) ml per each trial for different solution of tomato products.

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Data Processing:

When I have added enough base to neutralize the acid and then just one more drop to make the solution basic, the Bromthymol blue turns green, alerting that neutralization has been accomplished. This point, called the equivalence point, the number of moles of base I have added is equivalent to the number of moles of acid in the flask. At this point I record the volume of base added. Once I know this volume, I multiply it by the base molarity to calculate the moles of base required for neutralization;

Volume of base added x Molarity of base added = Volume of acid solution x Molarity of H^+

Tomato juice:

Calculations for Tomato Juice are stated in Appendix.

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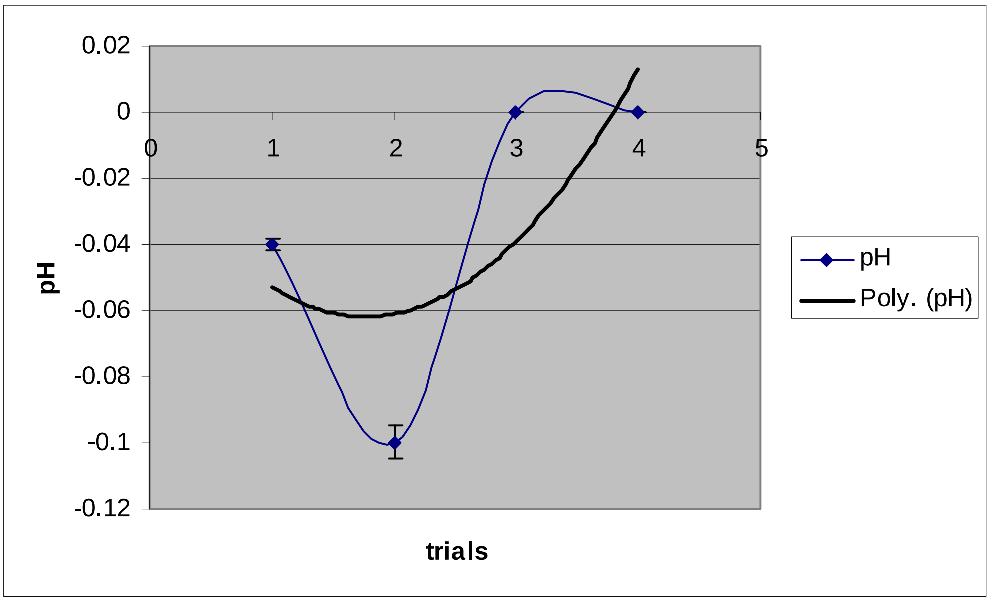
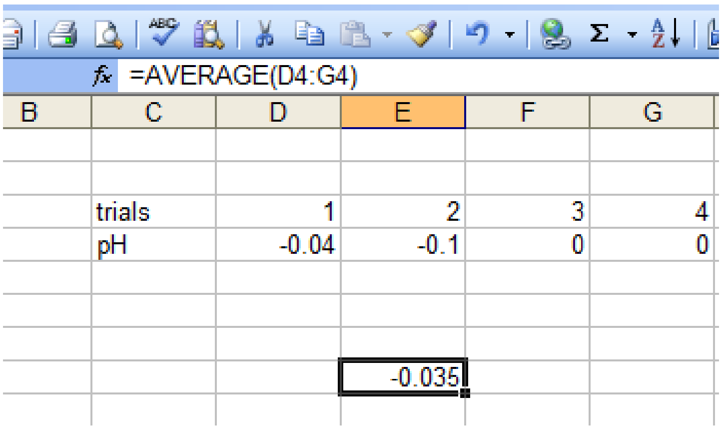


Graph1: Graph shows the calculated pH values of tomato juice.



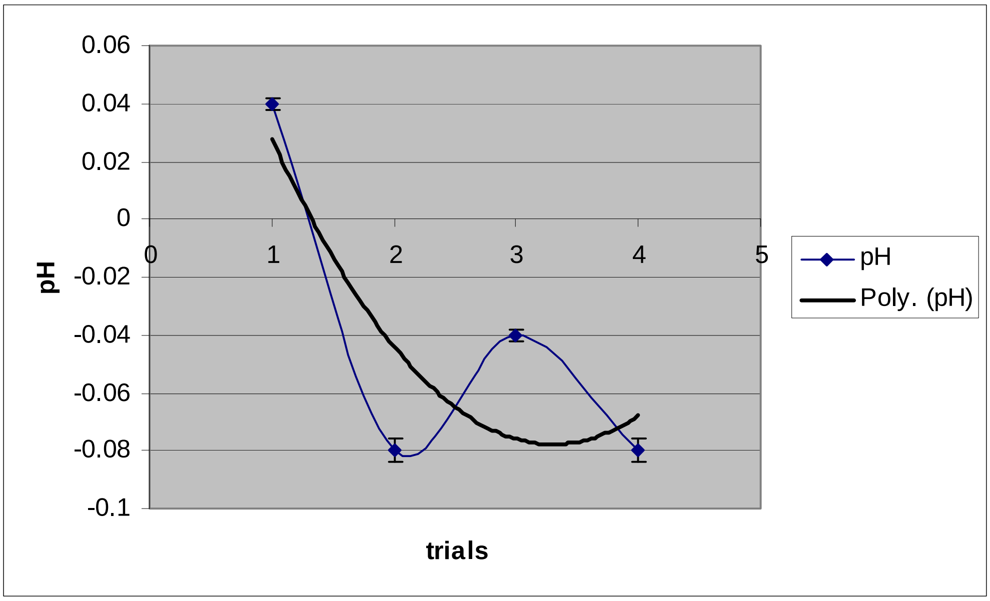
=AVERAGE(D4:G4)

B	C	D	E	F	G
	trials	1	2	3	4
	pH	-0.04	-0.1	0	0
			-0.035		

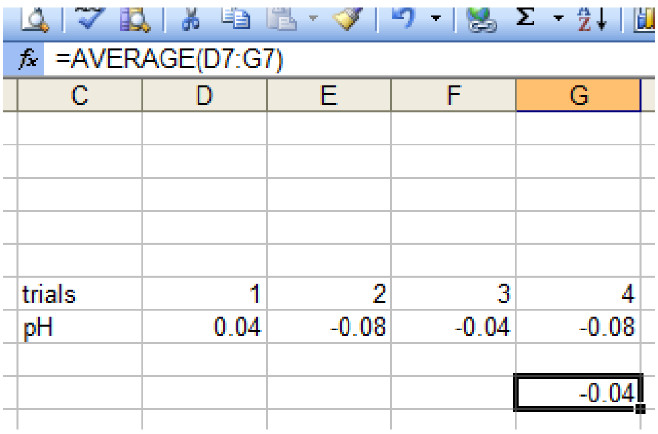
<u>Picture 1:</u> Calculation of average pH value of tomato juice in Microsoft Excel.

<u>Ketchup:</u>

Calculations for Ketchup are stated in Appendix.



Graph 2: Graph shows the calculated pH values of ketchup and the best line of the pH values calculated.



=AVERAGE(D7:G7)

C	D	E	F	G
trials	1	2	3	4
pH	0.04	-0.08	-0.04	-0.08
				-0.04

Picture 2: Calculation of average pH value of ketchup in Microsoft Excel.

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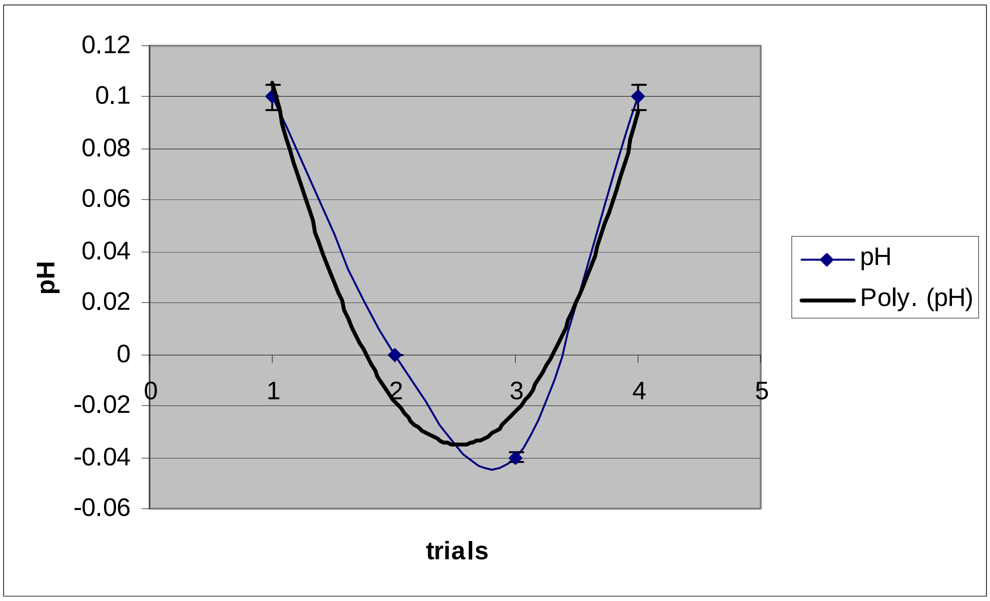
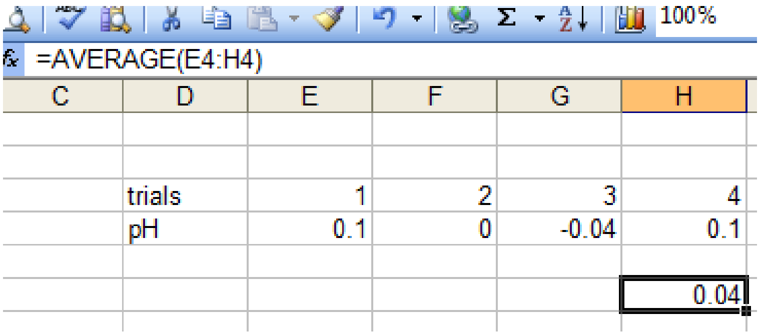
<u>Tomato Paste:</u>

Calculations for Tomato Paste are stated in Appendix.



<u>Graph3:</u> Graph shows the calculated pH values of tomato paste.

Average pH value for tomato paste solution = 0.04 ± 1.18%



C	D	E	F	G	H
	trials	1	2	3	4
	pH	0.1	0	-0.04	0.1
					0.04

<u>Picture 3:</u> Calculation of average pH value of tomato paste in Microsoft Excel.

Error Propagation:

All of the tomato samples used in the experiment has the same percent composition of glutamic acid on their labels, which is 0.3 %. The average experimental values of each different kinds of vinegar will be compared to the theoretical value of 0.3 %.

$$Random\ Error = \frac{|Observed\ Value - Theoretical\ Value|}{Theoratical\ Value} \times 100$$

- For tomato juice: -111.2 %

- For ketchup: -112.8 %

- For tomato paste: -87.2

Table 2: Calculated results in the experiment.

Commercial tomato product	Trials	Volume of KOH used (±0.1 ml)	Molarity of KOH used (±0.1 M)	Volume of commercial tomato product used(±0.1 ml)	Temperature of the medium (±0.1°C)	pH (±0.01)	Mean	Percentage error %
Tomato juice	1	11.0	1.0	10.0	23.0	-0.04	0.040	-87.2
	2	8.0	1.0	10.0	23.0	0.10		
	3	10.0	1.0	10.0	23.0	0.00		
	4	12.0	1.0	10.0	23.0	0.00		
Ketchup	1	9.0	1.0	10.0	23.0	0.04	-0.035	-111.2
	2	12.0	1.0	10.0	23.0	-0.08		
	3	11.0	1.0	10.0	23.0	-0.04		

	4	10.0	1.0	10.0	23.0	-0.08		
Tomato Paste	1	8.0	1.0	10.0	23.0	0.10	-0.040	-112.8
	2	10.0	1.0	10.0	23.0	0.00		
	3	11.0	1.0	10.0	23.0	-0.04		
	4	9.0	1.0	10.0	23.0	0.10		

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Conclusion and Evaluation:

In the experiment, my aim was to determine the acidity levels of certain types of tomato products with the process of titration and to determine which product of tomato is more suitable to the human body. Thus, I have done titration with the Lycopersicon esculentum products and calculated their pH in order to find out which Lycopersicon esculentum product is more suitable to the human body in case of being appropriate to the blood pH level.

In the titration, both titrant and analyte are required to be aqueous, or in a solution form. If the sample is not a liquid or solution, the samples must be dissolved. If the analyte is very concentrated in the sample, it might be useful to dilute the sample. The reason is that; in titration, the samples used should be aqueous in order to maintain the method work with less error. Therefore, I have added 50 mL of pure water into the Lycopersicon Esculentum products.

I took an Erlenmeyer flask and I put 50 mL of Lycopersicon esculentum product solution and three drops of indicator bromthymol blue. Then I put 1M KOH into the burette until it is full of KOH. I have controlled the quantity of KOH which I have added to the Erlenmeyer flask, so I indicated the equivalence point as the color of the Lycopersicon Esculentum product turned to green from red. This also showed me that it is the neutralization point of the KOH and Lycopersicon esculentum product. Then I have read the change in the volume of KOH by reading the scale on the burette. As I knew that the concentration of KOH is 1M, I have used the equation Volume of tomato paste solution x Molarity of H^+= Volume of KOH x Molarity of KOH in order to calculate the molarity of the Lycopersicon esculentum product and its pH.

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As I mentioned 'And acid-base balance of blood is necessary in order to survive. Therefore, it should be between 7.35 and 7.45 in order to protect the brain from losing its ability to function normally.' according to my research. Then I could conclude which Lycopersicon esculentum product is more suitable to the human body. As the average acidity of tomato juice is -0.035, ketchup is -0.040 and tomato paste is 0.040. Then it is obvious that the pH value of tomato paste is the closest pH value to the normal blood pH of human being. Therefore it could be less harmful to the human body in the aspect of acidity.

However, there could be some failures in the experiment that affect the validity of data. One of them could be time failure could cause the failure as there is a reflex time for stopping the chronometer. The solution could be to repeat the treatments.

In addition, temperature of the medium could change because of the heat loss. In order to prevent this happening, water bath should be used. Therefore heat loss could be at minimum level.

Besides, there could be some differences between tomatoes chosen and also tomatoes in the tomato products used, originated from the structure of the plant.

Also, intensity of light changes during the eight hour period, therefore all trials should have the same conditions, as they should be next to the window, each next to the another one.

On the other hand, there could be a CO_2 yield during the titration in test Erlenmeyer flask. CO_2 yield affects the pH of the medium, so the controlled variable

could not be stable. Therefore, the reaction's pH should be recorded for a fixed period of time and buffer solution should be added to the solutions in the test tubes.
Amount of pure water added to the solutions, I order to dilute them should be a same amount. On the other hand, choosing another type of Lycopersicon esculentum product can eliminate this source of error. • Before hand, it is possible that the conditions during growth of all tomatoes could not be exactly same. Therefore, their quality may change by the means of their minerals and chemicals.

By doing this experiment I have helped people in the case that we are using the products of tomato in daily life. From now, we know that the most suitable product of tomato to our normal body conditions is TAT tomato paste. Therefore, it could be the commercial tomato product we choose to consume. The aim of the experiment is eliminated, then results could be more accurate. However, aim of the experiment is achieved and the hypothesis 'As Lycopersicon Esculentum includes glutamic and aspartic acid in the grams of 0.313 grams and 0.118 grams, the Lycopersicon Esculentum products sold in groceries and supermarkets have acidic features.' is proven to be correct.

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Appendix:

<u>Table:</u> Nutrients of ***Lycopersicon Esculentum.***

Nutrient	Units	Value per 100 grams of edible portion	Sample Count	Std. Error
Amino acids				
Tryptophan	g	0.006	0	
Threonine	g	0.021	0	
Isoleucine	g	0.020	0	
Leucine	g	0.031	0	
Lysine	g	0.031	0	
Methionine	g	0.007	0	
Cystine	g	0.011	0	
Phenylalanine	g	0.022	0	
Tyrosine	g	0.015	0	
Valine	g	0.022	0	
Arginine	g	0.021	0	
Histidine	g	0.013	0	
Alanine	g	0.024	0	
Aspartic acid	**g**	**0.118**	**0**	
Glutamic acid	**g**	**0.313**	**0**	
Glycine	g	0.021	0	
Proline	g	0.016	0	
Serine	g	0.023	0	

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Calculations:

Calculations of Tomato Juice:

Trial #1:

Volume of tomato juice: 10.0 (± 0.1) ml

Volume of KOH: 11.0 (± 0.1) ml

Molarity of KOH: 1.0 (± 0.1) M

Molarity of H^+ is unknown

Volume of tomato juice x Molarity of H^+= Volume of KOH x Molarity of KOH

(10.0 ± 1.0%) x Molarity of H^+= (11.0 ± 0.9%) x 1

Molarity of H^+= 1.1 ± 1.9% M

-log (molarity of H^+) = pH

pH= -0.04 ± 0.28%

Trial #2:

Volume of tomato juice: 10.0 (± 0.1) ml

Volume of KOH: 8.0 (± 0.1) ml

Molarity of KOH: 1 M

Molarity of H^+ is unknown

Volume of tomato juice x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (8.0 ± 1%) x 1

Molarity of H^+= 8.0 ± 2% M

-log (molarity of H^+) = pH

pH= 0.10 ± 0.3%

Trial #3:

Volume of tomato juice: 10.0 (± 0.1) ml
Volume of KOH: 10.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of tomato juice x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (10 ± 1%) x 1

Molarity of H^+= 1 ± 2% M

-log (molarity of H^+) = pH

pH= 0.0 ± 0.3

Trial #4:

Volume of tomato juice: 10.0 (± 0.1) ml

Volume of KOH: 10 (± 0.1) ml

Molarity of KOH: 1 M

Molarity of H^+ is unknown

Volume of tomato juice x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (10 ± 1%) x 1

Molarity of H^+= 1± 2% M

-log (molarity of H^+) = pH

pH= 0.0 ± 0.3%

Average pH value for Tomato Juice= -0.035 ± 1.18%

Calculations of Ketchup:

Trial #1:

Volume of ketchup solution: 10.0 (± 0.1) ml

Volume of KOH: 9.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of ketchup solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (9 ± 1%) x 1

Molarity of H^+= 0.9 ± 2% M

-log (molarity of H^+) = pH

pH= 0.04 ± 0.30%

Trial #2:

Volume of ketchup solution: 10.0 (± 0.1) ml
Volume of KOH: 12.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of ketchup solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (12 ± 0.8%) x 1

Molarity of H^+= 1.2 ± 1.8% M

-log (molarity of H^+) = pH

pH= -0.08 ± 0.26%

Trial #3:

Volume of ketchup solution: 10.0 (± 0.1) ml
Volume of KOH: 11.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of ketchup solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (11 ± 0.9%) x 1

Molarity of H^+= 1.1 ± 1.9% M

-log (molarity of H^+) = pH

pH= -0.04 ± 0.28%

Trial #4:

Volume of ketchup solution: 10.0 (± 0.1) ml
Volume of KOH: 12.0 (± 0.1) ml

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Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of ketchup solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (12 ± 0.8%) x 1

Molarity of H^+= 1.2 ± 1.8% M

-log (molarity of H^+) = pH

pH= -0.08 ± 0.26%

Average pH value for ketchup solution= -0.04 ± 1.10%

<u>Calculations of Tomato Paste:</u>

Trial #1:

Volume of tomato paste solution: 10.0 (± 0.1) ml
Volume of KOH: 8.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of tomato paste solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (8 ± 1%) x 1

Molarity of H^+= 0.8 ± 2% M

-log (molarity of H^+) = pH

pH= 0.10 ± 0.30%

Trial #2:

Volume of tomato paste solution: 10.0 (± 0.1) ml
Volume of KOH: 10.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of tomato paste solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (10 ± 1%) x 1

Molarity of H^+= 1 ± 2% M

-log (molarity of H^+) = pH

pH= 0.0 ± 0.30%

Trial #3:

Volume of tomato paste solution: 10.0 (± 0.1) ml
Volume of KOH: 11.0 (± 0.1) ml
Molarity of KOH: 1

Molarity of H^+ is unknown

Volume of tomato paste solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (11 ± 0.9%) x 1

Molarity of H^+= 1.1 ± 1.9% M

-log (molarity of H^+) = pH

pH= -0.04 ± 0.28%

Trial #4:

Volume of tomato paste solution: 10.0 (± 0.1) ml
Volume of KOH: 8.0 (± 0.1) ml
Molarity of KOH: 1 M
Molarity of H^+ is unknown

Volume of tomato paste solution x Molarity of H^+= Volume of KOH x Molarity of KOH

(10 ± 1.0%) x Molarity of H^+= (8 ± 1%) x 1

Molarity of H^+= 0.8 ± 2% M

-log (molarity of H^+) = pH

pH= 0.10 ± 0.30%

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