CHEMISTRY EXTENDED ESSAY

“Measuring the fatty acid percentage of the reused sunflower oil after numerous times of potato frying and determining the effects of it on human health.”

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Session: May 2010

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Change in Fatty Acid Percentage of Oil After Frying Potatoes

Measuring the fatty acid percentage of the reused sunflower oil after numerous times of potato frying.

Introduction:

In the 21st century that we are living in, most of the people changed their habit of nutrients. Fast foods became popular and take the place of main meals because of the faster life which does not let people eat their meals at home. We became addictive to those foods which do not really feed us. The faster the people started to eat, the faster the restaurants became to work. So fast food restaurants found new ways to get used to this hectic life-style. Many companies started to use trans-fats in their foods because they're easy to use, inexpensive to produce and last a long time. These kinds of fats give foods a desirable taste and texture. So they can make more money with less spending and also be delicious. Trans-fats (or trans fatty acids) are created in an industrial process that adds hydrogen to liquid vegetable oils to make them more solid. As they do not exist naturally, trans-fats are difficult to metabolize and so they accumulate in the fatty tissues of the body. They also cause an increase in the levels of LDL (bad) cholesterol and a decrease in the levels of HDL (good) cholesterol, which can lead to atherosclerosis (narrowing of the arteries) and a resultant increase in the probability of strokes and heart problems. LDL is low-density lipoprotein; HDL is high-density lipoprotein. Their density is determined by the amount of proteins present in the molecule. As HDLs have a much higher percentage of proteins as LDLs, they can prevent the build-up of cholesterol in the arteries. The lower percentage of lipids in HDLs means these can absorb more cholesterol and hence carry it from the arteries.

Many restaurants and fast-food outlets use trans-fats to deep-fry foods because oils with trans fats can also be used many times in commercial fryers. Trans means that H-atoms are on the opposite side of the carbon chain. The polarity of the molecules determines the forces of attraction between the molecules in the liquid state. Polar molecules are attracted by the opposite charge effect (the positive end of a molecule is attracted to the negative end of another molecule). As a result *trans*-unsaturated oils have high melting points. And the higher melting point increases the number of frying that can be made by using trans-oils. So it can be seen that another property apart from taste and cheapness is being reusable. As a contrast, poly-unsaturated oils (containing more than one C=C) such as sunflower oil and corn oil have lower melting points.

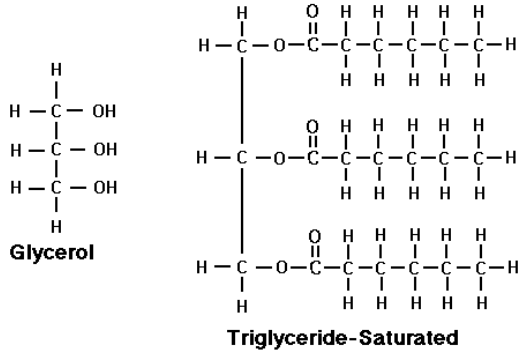
When you fry your potatoes in deep-fryer with normal sunflower oil many times, you may think that this oil can make no harm because it is not a trans-fat. But is it totally safe to fry the potatoes with the same oil even if this oil does not have a trans fat structure? Thus my research question is: ***Can lots of fries increase the free fatty acid percentage in the vegetable oil and harm us or this increase is a benefit?***

These questions are not so far from our lives. My life is also hectic between the roads of my school and my house. Every day, at lunch I eat my meals at school. And my menu mostly has potato fries in it because of the limited time I have for lunch and it is faster to eat fried potatoes. So when I started to read some news at the newspaper about the oils that companies use in frying, I started to question my meals and wanted to learn the reality about the potato frying which I eat everyday with my thousands of friends at school. Because of this, I chose free fatty acid percentage in frying oil as an extended essay subject and my aim in this experiment was t*o "prove the harmful effects*

of reused vegetable oil in potato frying and to find out the consequences of aggregate in numbers of frying, on free fatty acid percentage of the oil used".

A fatty acid is a long hydrocarbon chain carboxylic acid which has an acid group at one end and a methyl group at the other end. Hydrolysis is the splitting of a covalent bond by reaction with water. Fatty acids are produced by the hydrolysis of the ester linkages which are the bonding between fatty acids and glycerol that characterizes true fats, in a fat or biological oil (both of which are triglycerides), with the removal of glycerol. A triglyceride is formed from one molecule of glycerol (propan-1,2,3-triol, $CH_2(OH)CH(OH)CH_2OH$) and three fatty aliphatic acids (R-COOH).

Structures are shown in the figure below:



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1 Taken from < http://www.raw-milk-facts.com/images/GlycerolTrigly.gif>

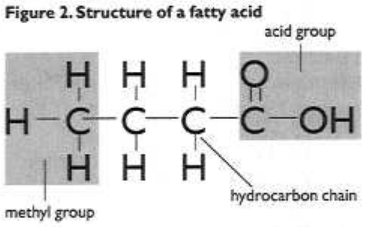


Figure 1: Structures of glycerol and triglyceride-saturated.

The human body is able to synthesize most of the fatty acids it requires, saturated or unsaturated. Saturated fat is the fat which has the hydrocarbon chain without double bonds present between carbon atoms. This kind of oils is mostly animal fat based oils like butter which can stay solid at room temperature. The oil that we experimented is unsaturated fatty acids. That fatty acids have one or more double bonds ("-CH=CH-") formed by the removal of hydrogen atoms. These include vegetable oils and are found to be liquids at around room temperature because of their low melting points. Here is an example of fatty acid structure.[2]

Figure 2: Structure of a fatty acid

Fatty acids can be bound or attached to other molecules, such as in triglycerides or phospholipids. When they are not attached to other molecules, they are known as "free" fatty acids.

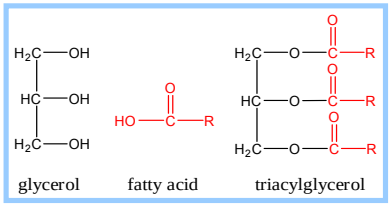


Figure 3: Structures of glycerol, free fatty acid and triacylglycerol which the free fatty acid had binded.

[3] Free fatty acids are an important source of fuel for many tissues in human body since

2 Taken and modified from < ://www.nutrition.org.uk/upload/structure%20of%20a%20fatty%20acid.jpg

3Taken from < www.rpi.edu/dept/bcbp/molbiochem/MBWeb/mb2/.../17-faoxid.ppt>

they can yield relatively large quantities of ATP by getting into a biological process called Kreb's cycle which yields energy by oxidizing the fatty acid molecule. Many cell types can use either glucose or fatty acids for this purpose. In particular, heart and skeletal muscle prefer fatty acids. Although this information can lead to a thought that an increase in fatty acids may be beneficial for human body, during the process of lipolysis which is the breakdown of fat stored in fat cells, free fatty acids released into the bloodstream and if the person is obese, these free fatty acids can block the circulation of blood because of the larger reservoirs of fat cells.

The unsaturated oil that is going to be used in this experiment is refined sunflower oil. After the refinery which is essential to ensure removal of gums, waxes, phosphatides and free fatty acid from the oil; to plant which has a 39-45 impart uniform colour by removal of colouring pigments and to get rid of unpleasant smell from the oil by removal of odiferous matter, oil takes the appearance which we see while using it in our foods. Sunflower oil includes approximately 85% unsaturated fatty acid and 14-43% of oleic acid, 45-75% of linoleic acid and 0.7% of linolenic acid forms this unsaturated fatty acids. And it has one of the greatest smoke points among vegetable oils. The smoke point of oil is the temperature at which the oil begins to decompose and give off visible fumes (smoke). If the oil's smoke point is just above 190 ^{0}C (375 ^{0}F), which is the normal deep-frying temperature, after frying its smoke point will drop below 190 ^{0}C (375 ^{0}F) after its first use, making it useless. And the oil begins to breakdown creating acrolein (systematic name: propenal) which is the simplest unsaturated aldehyde as an obnoxious-smelling compound. Thus oil has to have a high smoke point If it is going to be used many times.

VEGETABLE OILS	**SMOKE POINTS (± 0.5^{o}C)**
Safflower	265.0
Sunflower	246.0
Soybean	241.0
Canola	238.0
Corn	236.0

VEGETABLE OILS	SMOKE POINTS (± 0.5°C)
Peanut	231.0
Sesame	215.0
Olive	190.0

[4]

Table 1: Smoke points of some vegetable oils in C degree.

In this experiment the free fatty acids in the refined sunflower oil which is used before many times for potato frying is going to be observed, and by writing down the free acid percentage as oleic acid percentage the experimental results will be understood more easily and the increase or the decrease can be plotted more efficiently. And my hypothesis is that after many 25 frying the sunflower oil which is used to fry the potatoes will have an increase in its free fatty acid percentation as a harmful effect.

KEY VARIABLES:

Independent Variable: Amount of frying (5, 10, 15, 20, 25 times)

Dependent Variable: Fatty acid percentage of the sunflower oil.

Constant Variables: Time, temperature, amount of oil, pressure, brand of oil, concentration of the solutions (phenolphthalein and KOH), amount of the indicator, amount of the alcohol for each sample, amount of oil samples.

MATERIALS:

► 0.01 M, 1000.0 ± 1,0 ml KOH (which is prepared with ethyl alcohol)

4 Taken and modified from < http://www.culinary-yours.com/frying_oil>

► Phenolphthalein (which is made a 0.5% solution with 95% ethyl alcohol)

► Ethyl alcohol (100.0 ± 1.0 ml for each trial)

► Sunflower oil samples which are used in potato frying with different numbers of frying with same oil (5, 10, 15, 20, 25 frying)

► 1, 100.0 ± 1.0 ml Erlenmeyer flask

► 5, 100.0 ± 0.5 ml glass measuring tubes

► 5, 100.0 ± 1.0 ml glass volumetric flasks

► Thermometer (± 0.5 ^{0}C)

► Bunsen burner

► Electronic balance (± 0.001 g)

► Tripod

► 5 droppers

► 5 burettes

Preparation of KOH and phenolphthalein:

Firstly it was needed to prepare a 0.01 M potassium hydroxide (KOH). To prepare a litre of the solution 1L volumetric flask, KOH and ethyl alcohol is needed as it is going to be

$$Molarity = \frac{number\ of\ moles}{volume} \qquad M = \frac{n}{V}$$

alcoholic.

For 0.01M:

$$0.01 = \frac{number\ of\ moles}{1L} \qquad n = 0.01 \pm 0.01\ moles$$

$$\frac{0.01\ moles\ of\ KOH}{1}\ x\ \frac{56.109\ g\ KOH}{1\ mole\ of\ KOH} = 0.561 \pm 0.001\ grams\ of\ KOH$$

must be used for 0.01M solution.

In order to prepare the solution, 0.561 grams of NaOH is added in 1L volumetric flask. Then, the flask is slowly filled with ethyl alcohol and waited for KOH to dissolve in alcohol.

For 0.5% alcoholic phenolphthalein solution; weigh out 0.5g of phenolphthalein powder. Prepare a 95% ethanol (ethyl alcohol) solution consisting 95 ml ethanol and 5 ml water. Dissolve the phenolphthalein thoroughly in the 95% ethanol solution. This indicator is chosen because of the visible colour during the neutralization which helps to observe the changes clearly.

METHOD:

1) I put 100 mL of ethyl alcohol into an Erlenmeyer flask and heat it on the Bunsen burner until 70 ^{0}C.
2) I added 1-2 drops of phenolphthalein indicator into the boiling alcohol and a faint colour of pink is observed.
3) I measured the temperature while boiling by a thermometer and all trials of the investigation is done in the same room and nearly at the same period of the same day to stable the pressure and the temperature.
4) When the thermometer reaches 70°C, I neutralized the solution with potassium hydroxide by adding alcoholic KOH by the help of a dropper until the pink colour as a sign of neutralized solution is seen and I tried to stabilize the temperature by the help of burner.
5) I dissolved 5 grams of 5 times fried oil sample which is measured with the electronic balance, in this solution. If the oil does not dissolve in the solution

totally, strain the solution (take the homogeneous part) and continue to the experiment with this solution.

6) If the pink colour is seen when the sample is dissolved in the solution, it means that there are no free fatty acids in the sample.

7) When the colour pink is not seen or disappeared, this time I titrated the solution with alcoholic KOH which is the process adding KOH with a burette into the solution until the colour pink stays for 30 seconds.

8) I measured the volume of alcoholic KOH which I used to titrate the solution at the end of the titration which means 30 seconds stable colour of pink.

9) I repeated the steps from 1 to 9 for other trials of the sample and for the 10, 15, 20 and 25 times fried samples.

10) Use the results of the investigation to determine the effect of frying on fatty acid percentage by the help of calculations.

1) <u>Preparing the sunflower oil:</u>

In this investigation the experiment is based on sunflower oil which has had numerous potato frying. So it is also important to prepare fine samples for experiment. Firstly the oil which is going to be used in frying must be unused and the potatoes must be renewed for each frying. Secondly the force of the fire or the owen must be stable to not to create more percentage errors during the experiment. So I used a gas owen which I have set to a constant power before the frying process. Also the amount of potatoes must stay the same in each trial if the frying is made by using new oil for different numbers of frying. Like using the oil only for 5 times frying then renewing the oil for 10 times frying and doing this for others. This method may spend a lot of oil and also make the investigation longer. So it is recommended to use the same oil for all trials. But the potato – oil ratio must be the same. For example if 500 ml oil is used to fry 1000 g potatoes for 5 times then this ratio must be the same after taking a sample from the fried oil and continuing with the rest of the oil for 10 times (by frying the potatoes 5 times more). It is also

important to not to fry the potatoes more than it needs, if they get closer to burning, they may decrease the quality of the oil which means an error in the results. Thus the time for each frying must be equal. Take 3 minutes for each frying by the help of a chronometer. Be careful while taking the samples from the main frying oil, try to take at least 15 g (at the beginning of the frying process, measure 5 grams of oil and put it into a graded burette and write down the value in ml to be able to take the same amount while taking samples) for the 3 trials but also do not take too much sample because the rest of the oil may not be able to complete the rest of the frying. Shortly, fry the potatoes in a frying pan on a gas owen for 3 minutes. At the end of 3 minutes take the fried potatoes and put the new potatoes into the same oil for 3 minutes frying. Take a sample after 5, 10, 15, 20 and 25 times of frying while decreasing the amount of potatoes due to the sunflower oil that left after taking samples.

2) Determining the percentage of free fatty acids in the sunflower oil by acid-base titration:

This kind of titration mechanism is a neutralizing process which helps to find the acid amount by the base amount which is used for its neutralization. Neutralization process is the reaction which acidic and basic substances are given out as water and salts which are neutral substances with pH border near seven. In this experiment KOH is used as a base and the acid is the free fatty acids in the fried sunflower oil. At the beginning of the experiment, boiling oil which has phenolphthalein indicator in, mixed with alcoholic potassium hydroxide and this adding goes on until a faint pink colour is seen which means the neutralization of free fatty acids that are found in the fried sunflower oil by the solution of KOH. Dissolving a sample makes the mixture colourless because free fatty acids in the oil causes the solution to be acidic which means it's no longer neutralized so no colour can be seen. After these steps 0.01 M alcoholic potassium hydroxide started to add to this solution. And when 30 seconds stable pink colour is seen, used potassium hydroxide will be equal to the free fatty acid volume. After that, free fatty acids which are found in the experimented sample will be transformed into oleic acid as data by the calculations to be able to use the formula to calculate fatty acid percentage. And for these calculations the following equation is used due to the information below:

DATA COLLECTION AND PROCESSING:

%A = (V x 0.0028 x 100) / m

A: free fatty acids

V: volume of the used alcoholic KOH solution

m: mass of the sample

0.0028: mass for the 0.01 M, 1 ml oleic acid

$$Molarity = \frac{number\ of\ moles}{volume} \qquad M = \frac{n}{V}$$

Mass of 1 mole oleic acid ($(CH_2)_7CH=CH(CH_2)_7COOH$): 282.4614 g

$$0.01 = \frac{number\ of\ moles}{0.001L}$$

For 0.01 M :

$$10^{-5}\ moles\ of\ oleic\ \frac{acid}{1}\ x\ \frac{282.4614\ g\ oleic\ acid}{1\ mole\ of\ oleic\ acid} = 0.0028\ g \qquad n = 10^{-5} moles$$

Total# of frying	**Trial #**	**Amount of the fried sunflower oil sample (g)(±0.001)**	**Amount of KOH used for titration (ml) (±0.05)**
5	1	5.433	71.50
5	2	5.249	67.00
5	3	5.109	65.50
10	1	5.150	61.00
10	2	5.195	62.00
10	3	5.665	65.50

15	1	5.253	54.50
15	2	5.141	48.50
15	3	5.479	53.00
20	1	5.002	19.00
20	2	5.107	25.00
20	3	5.238	27.50
25	1	5.005	10.00
25	2	5.120	15.50
25	3	5.096	12.50

Table 2: Amount of sunflower oil samples with different total frying numbers and the volume of alcoholic KOH that is used to titrate this sample

From this table the raw data show a decrease in the amount of KOH solution which has used for titration. So before some calculations it can be stated that the aggregation in frying numbers decreases the free fatty acids in sunflower oil. Thus this decrease will cause health problems which occur in the absence of free fatty acids. For a more scientific comment see Graphic 1 which is the graphic of percentage of free fatty acids in the numerous times fried sunflower oil after the calculations and for more clear information about the problems that the decreasing of free fatty acids can cause see conclusion.

Calculations to find the free fatty acid percentage:

Samples:

Sample 1: 5 times fried sunflower oil

Sample 2: 10 times fried sunflower oil

Sample 3: 15 times fried sunflower oil

Sample 4: 20 times fried sunflower oil

Sample 5: 25 times fried sunflower oil

For the neutralization of the solution with fried sunflower oil the following equation is used to calculate the percentage of free fatty acids in ml/grams due to the following chemical reaction:

$C\text{-}O\text{-}CO\text{-}R + KOH_{(aq)} \rightarrow \quad + H_2O_{(aq)}$

Oil/fat $+ KOH_{(aq)} \rightarrow$ +water

The datum with uncertainty is: $A \pm \Delta A$

The relative uncertainty is: $\varepsilon = \frac{\Delta A}{A} \times 100$

Calculations for trial 1 of sample 1:

Data collected: 71.5 ± 0.1 ml KOH

5.433 ± 0.001 g fried sunflower oil sample

V = 71.5 ± 0.1 ml → Vε = 71.5 ± 0.1% ml

m = 5.433 ± 0.001 g → mε = 5.433 ± 0.018% g

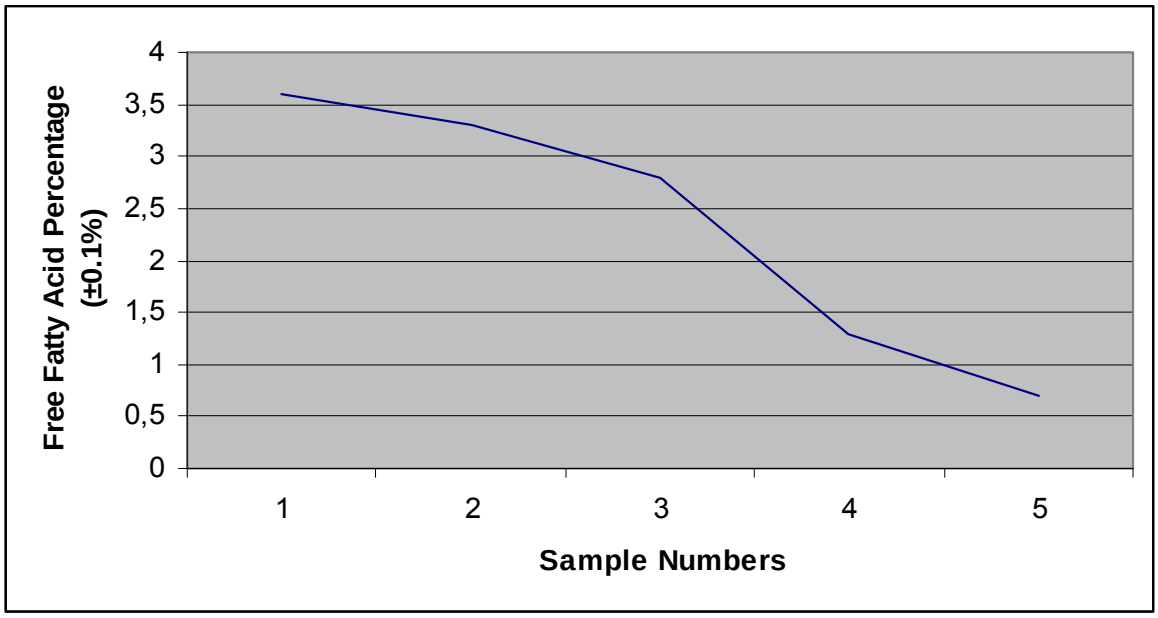
$$A\% = \frac{(71.5 \pm 0.1\% \times 0.0028 \times 100)}{5.433 \pm 0.018\%}$$

= 3.7% ± 0.1% ml/g of oleic acids

For the rest of the calculations see please Appendix 1.

Table 3: Shows the amount of free fatty acid in the form of oleic acid percentage and the means of the trials' data for each sample of neutralized sunflower oil.

Trial #	# of sunflower oil sample	Amount of free fatty acids by the means of oleic acid (± 0.2) (%ml/g)	Means of the trials of the samples (± 0.3) (%ml/g)
1	1	3.7	3.6
2	1	3.6	
3	1	3.6	
1	2	3.3	3.3
2	2	3.3	
3	2	3.2	
1	3	2.9	2.8
2	3	2.6	
3	3	2.7	
1	4	1.1	1.3
2	4	1.4	
3	4	1.5	
1	5	0.6	0.7
2	5	0.9	
3	5	0.7	



Graph 1: Free fatty acid percentage of sunflower oil samples by the means of oleic acid after numerous frying.

See Appendix 2 for error propagation.

CONCLUSION AND EVALUATION

CONCLUSION OF THE INVESTIGATION

As an overall, the investigation was consisting of two researched questions. Firstly it was investigated whether numerous frying with the same oil will increase the free fatty acid percentage in the oil. And secondly it was questioned if this result has a harmful effect on human health.

The volume of KOH which is used in titration is decreased after each 5 frying. That means the free fatty acid percentage will also get lower and the processed data proves it. It is investigated that first sample which has fried 5 times, has 3.6% free fatty acid in it. The second sample which is has fried 10 times, has 3.3% free fatty acid. The third sample with 15 frying has 2.8% free fatty acid; while the fourth sample with 20 frying has 2.3% free fatty acid. And lastly fifth sample which has fried 25 times has 0.7% free fatty acid. Thus, the more sunflower oil is fried, the more decrease occurs in the fatty acid

percentage. As a result the first part of the hypothesis which has built at the beginning of the investigation proved as wrong and the opposite claim resulted. The opposite claim was: an increase in the number of frying will increase the free fatty acids in the sunflower oil. Then the rest of the hypothesis became wrong. Hence the second part of the hypothesis which claims that an increase in the fatty acid percentage will be harmful should be changed because of the new result. And the reason for that is the well-known harmful effect of repeatedly used vegetable oil. Hence the second part of the hypothesis tries to prove the harmfulness; this claim should has another assessment after the new part.

As the human mechanism needs free fatty acids as an important source of ATP and the heart and skeletal muscle prefer them as an energy source, a decrease in the free fatty acid percentage of a food will not be beneficial for the body because of the food being useless. So when the nutrition has a decrease in its free fatty acid percentage while frying, it also loses its value as nourishment. And because of this, the body will not be able to use it, so the mechanism of the body may break down after awhile because of the lack of needed molecules or its functions may slow down.

As a conclusion, a decrease in the volume of KOH is observed during the investigation which leads the results also to a decrease in the free fatty acid percentation. And the harmful effect which comes from the decrease is the possible breakdown of the mechanism of human body which has some of its parts that prefers free fatty acid for energy. And by this investigation social information can be given to the community. Although people read a lot of articles and see lots of news about the harmful effect of reused frying oil, this investigation will cause a real consciousness because the articles are made by people who are far from our lives; but this investigation will create a serious awareness as I am a member of the community that I live in. And this closeness will make people believe in it and think on it more seriously.

EVALUATION OF THE INVESTIGATION

During the investigation there occurred some limiting and restricting factors which keep the results from being a hundred percent trustful. Some of these factors also happened because of the weakness of the design that has made at the beginning.

As to start with the design, the temperature which had to be kept stable during the experiment went sometimes under the preferred degree which obligates the one who does the investigation to rise the temperature by Bunsen burner. And this method mostly resulted in the unwanted high temperatures during the experiment. Thus this kind of temperature deviations can affect the results such as less solubility which results in less volume of KOH because of the low temperature. As an improvement to the design, a water bath is used to keep the temperature stable because water will keep the temperature at the same degree longer than air, as water has a greater density than air.

Another weakness of the design is the colour establishing. During the preparation of the investigation and the investigation itself a colour of pink should have to be observed. When the solution which contains oil is being titrated, the point to stop has always designated by the light pink colour. Although the colour can be seen easily, the tint of colour can differ from trial to trial, as the drops are not equal or the line on the droppers that refers ml can't be seen exactly. Thus it will get harder to observe the same colour and stop dropping at the same time as other trials. And as a result, raw data can increase or decrease which will also change the processed data. To improve this weakness a totally white paper can be put behind the Erlenmeyer in a way that doesn't block the colour observation. As the solution doesn't have a colour before the titration white paper can be seen easily. And a change in the colour of the solution during the titration can be observed at the right time and the titrating will stop without adding more or less. Or a control group which is a determined amount of titrated solution with a determined colour of pink can be designed to compare the colour of the solution.

Some limiting factors may have also affected the results of the experiment. As the time for experiment is limited, it was obliged to cut off the experiment in the middle and continue it next day. So the conditions during remaining part of the experiment probably may not the same as the previous one like the pressure which has an effect on the boiling point of liquids or the design may not replaced as properly as the previous one. The evaporation of ethyl alcohol will cause less dissolving of oily solution and the calculations will result in less percentage of oleic acid. So these will cause some small or big deviations while collecting the data. As to prevent big deviations liquid materials or experiment solutions should not be left to be used next day, the investigation trials should not be cut off.

Another limiting factor was using the formula in the design. At the beginning the original design is changed. In the original one 0.1M alcoholic KOH must be used during the experiment and as the numerical results are under 10ml this concentration is changed to 0.01M. The formula contains a constant number which is the gram per millilitre for 0.1 M of oleic acid. As the concentration of alcoholic KOH is changed the constant in the formula also had to change. And this change is made by dividing the constant to 10 which decreases the quality of the processed data; because the constant may differ a little.

Last limiting factor was the preparation of the alcoholic KOH solution and the 0.5% phenolphthalein solution which contains 95% alcohol. As to get the preferred concentration of KOH and the exact percentage of alcohol in the phenolphthalein, the solution has to be prepared by the lab assistant. But the experiment was too long and the solution that has prepared had come to an end after some trials. So the solution must be prepared by the assistant again and naturally the new solution will not be the same when it is compared to the previous one and this may cause another error in the results.

As to get clearer and more trustful results from this kind of experiments, the investigation should be repeated and the trial number trustful ones.per experiment should increase. By only this way the results may come near to the hundred percent

Word Count: 4.464: including tables excluding calculations

4.171: excluding both tables and calculations

Appendix 1: Calculations for Neutralization of Numerous Times Fried Sunflower Oil Samples:

Calculations for sample 1 (5 times frying) :

Trial 1:

V = 71.5 ± 0.1 ml → Vε = 71.5 ± 0.1% ml

m = 5.433 ± 0.001 g → mε = 5.433 ± 0.018% g

$$A\% = \frac{(71.5 \pm 0.1\% \times 0.0028 \times 100)}{5.433 \pm 0.018\%}$$

= 3.7% ± 0.1% ml/g oleic acid

Trial 2:

V = 67.0 ± 0.1 ml → Vε = 67.0 ± 0.1% ml

m = 5.249 ± 0.001 g → mε = 5.249 ± 0.019% g

$$A\% = \frac{(67.0 \pm 0.1\% \times 0.0028 \times 100)}{5.249 \pm 0.018\%}$$

= 3.6% ± 0.1% ml/g oleic acid

Trial 3:

V = 65.5 ± 0.1 ml → Vε = 65.5 ± 0.1% ml

m = 5.109 ± 0.001 g → mε = 5.109 ± 0.020% g

$$A\% = \frac{(65.5 \pm 0.1 \times 0.0028 \times 100)}{5.109 \pm 0.020}$$

= 3.6% ± 0.1% ml/g oleic acid

Calculations for sample 2 (10 times frying):

Trial 1:

V = 61.0 ± 0.1 ml → Vε = 61.0 ± 0.2% ml

m = 5.150 ± 0.001 g →mε = 5.150 ± 0.019% g

$$A\% = \frac{(61.0 \pm 0.2\% \times 0.0028 \times 100)}{5.150 \pm 0.019\%}$$

= 3.3% ± 0.2% ml/g oleic acid

Trial 2:

V = 62.0 ± 0.1 ml → Vε= 62.0 ± 0.2% ml

m = 5.195 ± 0.001 g → mε = 5.195 ± 0.019% g

$$A\% = \frac{(62.0 \pm 0.2\% \times 0.0028 \times 100)}{5.195 \pm 0.019\%}$$

= 3.3% ± 0.2% ml/g oleic acid

Trial 3:

V = 65.5 ± 0.1 ml → Vε = 65.5 ± 0.1% ml

m = 5.665 ± 0.001 ml → mε = 5.665 ± 0.018% g

$$A\% = \frac{(65.5 \pm 0.1\% \times 0.0028 \times 100)}{5.665 \pm 0.018\%}$$

= 3.2% ± 0.1% ml/g oleic acid

Calculations for sample 3 (15 times frying):

Trial 1:

V = 54.5 ± 0.1 ml → Vε = 54.5 ± 0.2% ml

m = 5.253 ± 0.001 g → mε = 5.253 ± 0.019% g

$$A\% = \frac{(54.5 \pm 0.2\% \times 0.0028 \times 100)}{5.253 \pm 0.019\%}$$

= 2.9% ± 0.2% ml/g oleic acid

Trial 2:

V = 48.5 ± 0.1 ml → Vε = 48.5 ± 0.2% ml

m = 5.141 ± 0.001 g → mε = 5.141 ± 0.019% g

$$A\% = \frac{(48.5 \pm 0.2\% \times 0.0028 \times 100)}{5.141 \pm 0.019\%}$$

= 2.6% ± 0.2% ml/g oleic acid

Trial 3:

V = 53.0 ± 0.1 ml → Vε = 53.0 ± 0.2% ml

m = 5.479 ± 0.001 g → mε = 5.479 ± 0.018% g

$$A\% = \frac{(53.0 \pm 0.2\% \times 0.0028 \times 100)}{5.479 \pm 0.018\%}$$

= 2.7% ± 0.2% ml/g oleic acid

Calculations for sample 4 (20 times frying):

Trial 1:

V = 19.0 ± 0.1 ml → Vε = 19.0 ± 0.5% ml

m = 5.002 ± 0.001g → mε = 5.002 ± 0.020% g

$$A\% = \frac{(19.0 \pm 0.5\% \times 0.0028 \times 100)}{5.002 \pm 0.020\%}$$

= 1.1% ± 0.5% ml/g oleic acid

Trial 2:

V = 25.0 ± 0.1 ml → Vε = 25.0 ± 0.4% ml

m = 5.107 ± 0.001 g → mε = 5.107 ± 0.019% g

$$A\% = \frac{(25.0 \pm 0.4\% \times 0.0028 \times 100)}{5.107 \pm 0.019\%}$$

= 1.4% ± 0.4% ml/g oleic acid

Trial 3:

V = 27.5 ± 0.1 ml → Vε = 27.5 ± 0.4% ml

m = 5.238 ± 0.001 g → mε = 5.238 ± 0.019% g

$$A\% = \frac{(27.5 \pm 0.4\% \times 0.0028 \times 100)}{5.238 \pm 0.019\%}$$

= 1.5% ± 0.4% ml/g oleic acid

Calculations for sample 5 (25 times frying):

Trial 1:

V = 10.0 ± 0.1 ml V = 10.0 ± 1.0% ml

m = 5.005 ± 0.001 g m = 5.005 ± 0.020% g

$$A\% = \frac{(10.0 \pm 1.0\% \times 0.0028 \times 100)}{5.005 \pm 0.020\%}$$

= 0.6% ± 1.0% ml/g oleic acid

Trial 2:

V = 15.5 ± 0.1 ml → Vε = 15.5 ± 0.7% ml

m = 5.120 ± 0.001 g → mε = 5.120 ± 0.019% g

$$A\% = \frac{(15.5 \pm 0.7 \times 0.0028 \times 100)}{5.120 \pm 0.019\%}$$

= 0.9% ± 0.7% ml/g oleic acid

Trial 3:

V = 12.5 ± 0.1 ml → Vε = 12.5 ± 0.8% ml

m = 5.096 ± 0.001 g → mε = 5.096 ± 0.020% g

$$A\% = \frac{(12.5 \pm 0.8\% \times 0.0028 \times 100)}{5.096 \pm 0.020\%}$$

= 0.7% ± 0.8% ml/g oleic acid

Means of the trials of the samples:

Mean of sample 1 = $\frac{(3.6\% \pm 0.1 + 3.6\% \pm 0.1 + 3.7\% \pm 0.1)}{3}$

= 3.6% ± 0.3 ml/g oleic acid

Mean of sample 2 = $\frac{(3.3\% \pm 0.1 + 3.3\% \pm 0.1 + 3.2\% \pm 0.1)}{3}$

= 3.3% ± 0.3 ml/g oleic acid

Mean of sample 3 = $\frac{(2.9\% \pm 0.1 + 2.6\% \pm 0.1 + 2.7\% \pm 0.1)}{3}$

= 2.8% ± 0.3 ml/g oleic acid

Mean of sample 4 = $\frac{(1.1\% \pm 0.1 + 1.4\% \pm 0.1 + 1.5\% \pm 0.1)}{3}$

= 1.3% ± 0.3 ml/g oleic acid

Mean of sample 5 = $\frac{(0.6\% \pm 0.1 + 0.9\% \pm 0.1 + 0.7\% \pm 0.1)}{3}$

= 0.7% ± 0.3 ml/g oleic acid

Appendix 2: Error Propagation:

Random Error = $\frac{|\text{observed value} - \text{mean value}|}{\text{mean value}} \times 100$

Percentage Error For Sample 1:

Trial 1:

$\frac{|3.7 - 3.6|}{3.6} \times 100 \Rightarrow 2.8\%$

Trial 2:

$\frac{|3.6 - 3.6|}{3.6} \times 100 \Rightarrow 0\%$

Trial 3:

$\frac{|3.6 - 3.6|}{3.6} \times 100 \Rightarrow 0\%$

Percentage Error For Sample 2:

Trial 1:

$\frac{|3.3 - 3.3|}{3.3} \times 100 \Rightarrow 0\%$

Trial 2:

$\frac{|3.3 - 3.3|}{3.3} \times 100 \Rightarrow 0\%$

Trial 3:

$\frac{|3.2 - 3.3|}{3.3} \times 100 \Rightarrow 3.0\%$

Percentage Error For Sample 3:

Trial 1:

$\frac{|2.9 - 2.8|}{2.8} \times 100 \Rightarrow 3.6\%$

Trial 2:

$\frac{|2.6 - 2.8|}{2.8} \times 100 \Rightarrow 7.1\%$

Trial 3:

$\frac{|2.7 - 2.8|}{2.8} \times 100 \Rightarrow 3.6\%$

Percentage Error For Sample 4:

Trial 1:

$\frac{|1.1 - 1.3|}{1.3} \times 100 \Rightarrow 15.4\%$

Trial 2:

$\frac{|1.4 - 1.3|}{1.3} \times 100 \Rightarrow 7.7\%$

Trial 3:

$\frac{|1.5 - 1.3|}{1.3} \times 100 \Rightarrow 15.4\%$

Percentage Error For Sample 5:

Trial 1:

$$\frac{|0.6 - 0.7|}{0.7} \times 100 \Rightarrow 14.3\%$$

Trial 2:

$$\frac{|0.9 - 0.7|}{0.7} \times 100 \Rightarrow 28.6\%$$

Trial 3:

$$\frac{|0.7 - 0.7|}{0.7} \times 100 \Rightarrow 0\%$$

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