HL CHEMISRTY EXTENDED ESSAY

An investigation into synthesis of biodiesels and measurement of their properties, from organic waste samples chosen due to their popularities identified by poll.

How do biofuels made from domestic wastes [orange peels, banana peels, milk, eggs, avocado] differ from each other determined with enthalpy change of combustion [ΔH°c] and mass to mass biofuel efficiency in extend of their popularities identified by poll?

Word Count: 3980

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INTRODUCTION

Personal Engagement

We, in our daily lives, waste lots of organic content. Recycling organic content is not as much popular as recycling plastic but we can recycle our domestic wastes too. Fried and used oil is usually taken to synthesise biofuels such as biodiesel. There is oil abundant in our domestic wastes too. I thought we could recycle and have a better use of our domestic wastes if we can extract oil from our organic wastes. The oil which is going to be extracted from specific domestic waste can be used to synthesise biofuels as well. We can not synthesise biofuels from the mixture of all domestic waste oils, because the method for transesterification is specific to each type of oil and the molarity of meth oxide concentration added differs from oil to oil. As a result my Research question is formulated as:

"How do biofuels made from domestic wastes [orange peels, banana peels, milk, eggs, avocado] differ from each other determined with enthalpy change of combustion [ΔH°c] and mass to mass biofuel efficiency in extend of their popularities identified by poll?"

This experiment is mainly investigating which specific type of organic waste we should recycle in order to maximize the energy we get from combustion of biodiesel obtained from that organic waste.

BACKGROUND AND DESIGN

Background Information

Food wastes often contain lipid inside them. Amount of lipid content in different organic wastes can differ from each other. In order to synthesise biodiesel, lipid must be extracted from the sample. After the lipid extraction is completed, the sample can undergo the chemical process called 'Transesterification' to synthesise biodiesel from that sample.

In this investigation, lipid extraction is mainly done with the help of a specific organic solvent that only dissolves some particular lipid molecules. Methods used in this investigation are soxhlet extraction, bomb calorimeter, fractional distillation and solvent evaporation using water bath.

Soxhlet extractor was invented by Franz von Soxhlet in 1879 for the purpose of extracting lipid from a solid material. Thus respecting the purpose of method and apparatus, Solid organic waste samples such as orange peels and banana peels were lipid extracted with Soxhlet extraction.

Fractional distillation is the separation of a mixture into its component parts, or fractions. Chemical compounds are separated by heating them to a temperature at which one or more fractions of the mixture will vaporize. In this experiment this process is going to be used to fraction diethyl ether and lipid from the mixture in methodology A/ii.

Evaporation occurs in every temperature but solvent evaporation process is done by putting the mixture which consists of solvent and mixture into a hot water bath to increase the speed of evaporation. In order to prevent burning of a particular molecule which is going to be turned in as a biodiesel, a certain temperature is set while using water bath.

A bomb calorimeter is a device used to measure the heat of combustion of a substance. It consists of a small, sealed metal container, or bomb, in which a sample of the substance is burned completely in the presence of oxygen. The heat produced by the combustion reaction is transferred to the bomb, which is surrounded by water. The temperature rise of the water is then measured, and from this, the heat of combustion can be calculated.

Transesterification is a chemical process mainly used for conversion of triglycerides contained in oils into usable biodiesel. Biodiesel produced by the process of transesterification has a much lower viscosity, making it capable of replacing petroleum diesel in diesel engines.

Transesterification is an organic reaction in which the R group of an alcohol is exchanged with an R’ group of an ester. This is generally done via the introduction of an acid or base catalyst to the reaction mixture. In our investigation the catalyst NaOH is used in the process.

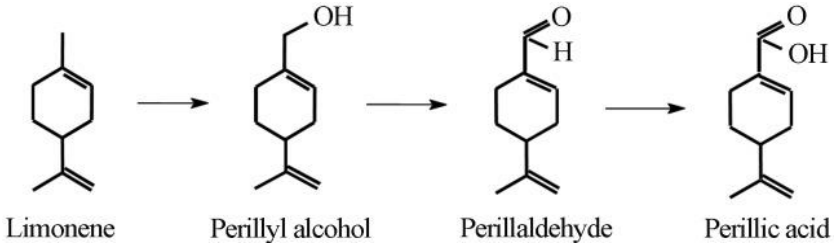
[Figure 1: Chemical process of transesterification]

This chemical process should be maintained between the temperatures 60.0 °C and 70.0 °C. If transesterification is made under the temperature of 60.0 °C, the process will take too long to occur. If it is made above the temperature of 70.0 °C, lipid molecules can undergo polymerization. Optimum temperature is 64.4 °C. Because boiling point of meth-oxide is just 64.4 °C So, the temperature should be held in the interval of 60.0 °C and 70.0 °C.

Meth-oxide is formed as acting catalyst and source for the transesterification to occur in most of the processes.

Hypothesis

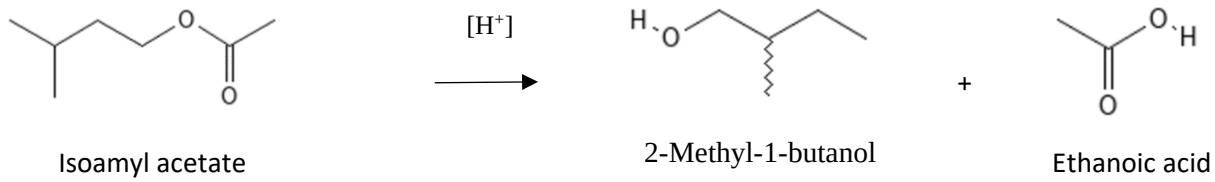
Oxidation occurs when lipids undergo transesterification. Centre of the molecule is going to be in the format (R'OCR'') but the radical groups will differ from each sample to each sample. Thus, combustion of these different transesterificated lipid samples are going to have different enthalpy changes.



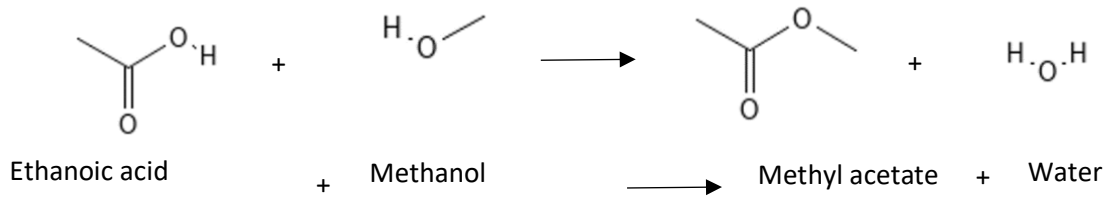
[**Figure 2:** oxidation of limonene]

Different radical groups' energy can be interpreted with using bond enthalpy.

Isoamyl acetate (iAAc) is found in the peels of banana and isoamyl acetate is one of the samples investigated in this experiment. Isoamyl acetate undergoes some chemical reactions to synthesize biodiesel.

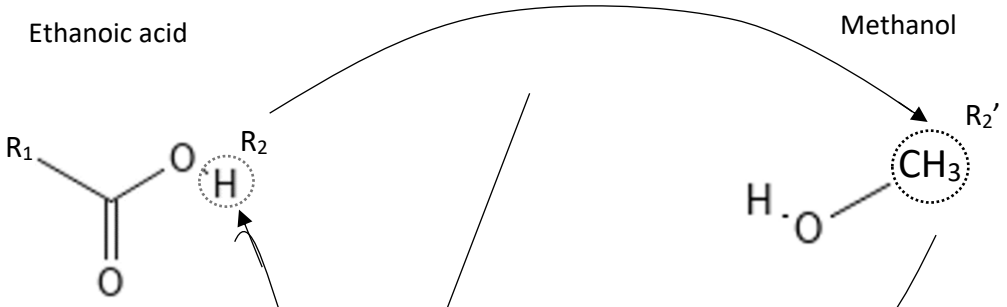


[**Figure 3:** Synthesis of ethanoic acid from iAAc & esterification of ethanoic acid]



[**Figure 4:** Esterification reaction

In first reaction hydrolysis occur to synthesize methyl but-1-ol (1°) and ethanoic acid from isoamyl acetate (iAAc). Ethanoic acid has ester bond, so methanol is used for transesterification of the molecule by replacing radical group from methanol.



[**Figure 5:** Radical replacement for ethanoic acid and methanol]

R_1: CH_3 R_2 radical group is replaced ~~with R_2' radical~~ group.

R_2: H Methyl acetate is formed. To figure out a theoretical value for combustion enthalpy for

R_2': CH_3 each sample, average bond enthalpies of all formed biodiesels are calculated.

Remaining [H^+] radical freed from ethanoic acid conjoins the [HO^-] part left from methanol to form water.

Single Bond Energies (kJ/mol of bonds)

	H	C	N	O	S	F	Cl	Br	I
H	436								
C	413	346							
N	391	305	163						
O	463	358	201	146					
S	347	272	—	—	226				
F	565	485	283	190	284	155			
Cl	432	339	192	218	255	253	242		
Br	366	285	—	201	217	249	216	193	
I	299	213	—	201	—	278	208	175	151

Multiple Bond Energies (kJ/mol of bonds)

C=C 602	C=N 615	C=O 799
C≡C 835	C≡N 887	C≡O 1072
N=N 418	N=O 607	
N≡N 945	O=O 498	

Bond enthalpy can be used to interpret the enthalpy of combustion for biodiesels we are going to obtain. Bond enthalpy or bond dissociation energy is energy needed to break the bond between two atoms. With the help of bond enthalpy, we can develop a theoretical value for combustion enthalpy of biodiesels obtained.

$$\Delta H = \sum \Delta H_{(bonds\ broken)} - \sum \Delta H_{(bonds\ formed)}$$

[**Figure 6:** Average bond enthalpy table]

Combustion ΔH°c for methyl acetate calculated with average bond enthalpy:

$$CH_3COOCH_3 + 7/2\ O_2 \longrightarrow 3CO_2 + 3H_2O$$

$$\Delta H°c = [\ (\ 6[C\text{-}H] + [C\text{-}C] + 2[C\text{-}O] + [C{=}O]\ ) + (7/2\ [O{=}O]\ )\ ]\ -\ [\ (\ 6[C{=}O]\ ) + (\ 6[O\text{-}H]\ )\ ]$$

$$\Delta H°c = (\ 6(413) + 348 + 2(358) + 799 + 7/2(425)) - (\ 6(799) + 6(463)\ )$$

$$\Delta H°c = 4681.5 - 7572$$

$$\Delta H°c = -2890.5\ Kj/mol$$

Biodiesel obtained from	ΔH°c
Orange peels	-5658.0 Kj/mol
Banana peels	-2890.5 Kj/mol
Milk	-3435.5 Kj/mol
Egg	----------
Avocado	-10605.0 Kj/mol

[**Data Table 1:** Table, consists of combustion enthalpy of each biodiesel obtained]

These values are calculated with average bond enthalpy given in the figure 2.4. Average bond enthalpy is not a very accurate way to measure enthalpy. This is due to the fact that they are average values and do not take into account situations in which the bond strength is different from the average.

However, interpreting from the table that sample x has the most combustion enthalpy. This means biodiesel obtained from avocado has a higher value as a biodiesel due to energy it gives. This value gives us the best biodiesel due to energy efficiency.

The amount of biodiesel obtained will differ in each sample. Because oil abundance in every sample is different. It will be reasonable to interpret that, substances that contains more oil will become biodiesel more efficiently.

Organic Content	**Oil Content**
Orange peels	0.5 g/kg.
Banana peels	0.2 g/kg
Milk	3.5 g/kg
Egg	29.0 g/kg
Avocado	85.0 g/kg

[Data Table 2: Table showing oil content for samples used in this investigation]

Interpreting from the table (Figure 2.2) avocado contains the most amount of fat. So, biodiesel obtained from banana peels will be the most efficient biodiesel in this sample space due to mass to mass efficiency.

Design-Methodology

Material List

200.0 ± 0.1 g of orange peel sample

200.0 ± 0.1 g of banana peel sample

1000.0 ± 0.5 ml of milk sample

200 .0± 0.1 g of egg sample

200.0 ± 0.1 g of Avacado sample

1000.0 ± 0.5 ml Ethanol

200.0 ± 0.5 ml Diethyl ether

1000.0 ± 0.5 ml Hexane-isoprophane

10.0 ± 0.1 g Catalyst lye ($NaOH_{(s)}$)

500.0 ± 0.5 ml Distilled water

Soxhlet extraction

- Condenser
- Extraction chamber
- 200.0 ± 0.5 ml Boiling flask
- Heating mantle

Fractional distillation

- 200.0 ± 0.5 ml Round bottom flask
- Fractioning column
- Condenser
- Beaker
- Bunsen burner
- Thermometer

Seperatory funnel

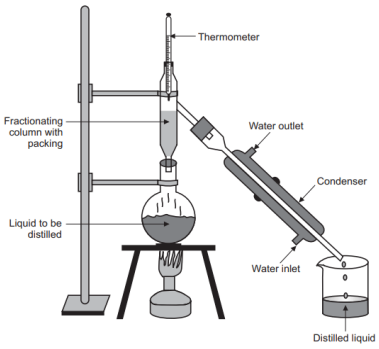
- Funnel
- Stand and clamp
- Separating funnel
- 1000.0 ± 0.5 ml Erlenmeyer flask

Water Bath

- Stand and clamp
- Erlenmeyer flask,

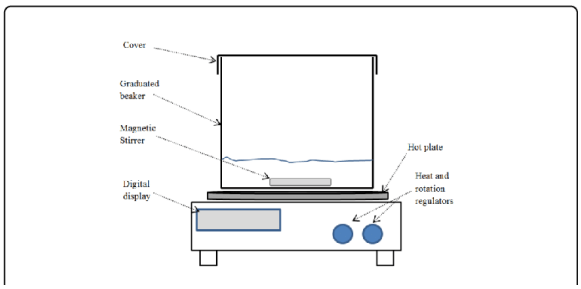
Transesterification

- 250.0 ± 0.5 ml Erlenmeyer flask
- Heating mantle
- Temperature probe
- Fish

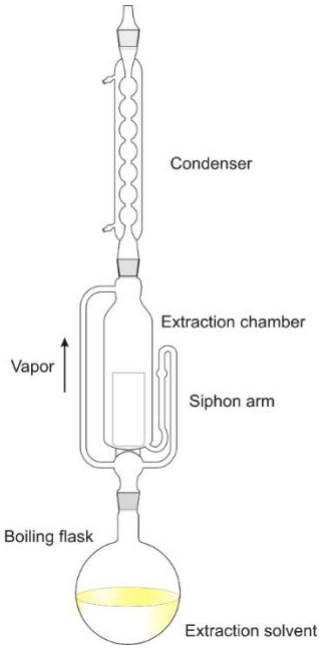


[Figure 7: Fractional Distillation]

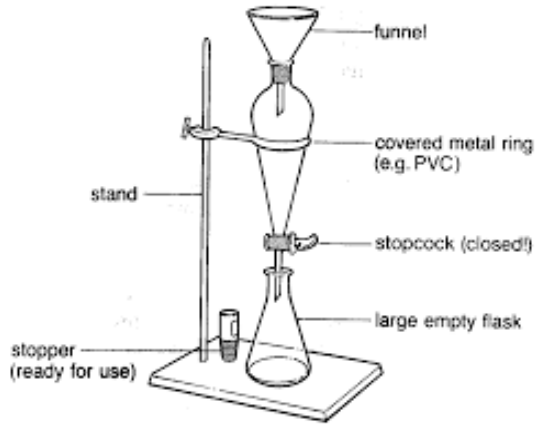
[Figure 6: Fractional distillation setup]



[Figure 8: Hot plate and Magnetic stirrer diagram]

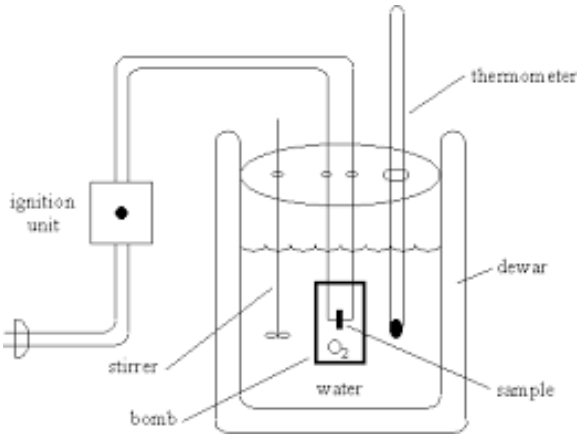


[Figure 9: Soxhlet extractor diagram]



[Figure 10 Seperatory funnel]

[Figure 11: water bath diagram]



[Figure 12: bomb calorimeter diagram]

Variables

Independent Variable: Organic waste samples

Dependent Variable: Combustion enthalpy ($\Delta H°_c$) of obtained biodiesel & Amount of biodiesel obtained

Controlled Variables: Temperature, amount of organic waste by mass

PROCEDURE AND SAFETY

Methodology

A) Lipid Extraction

i) Lipid extraction from Orange peels

1. Orange peels are put in rondo and chopped until pieces of orange peels become very small that can not be chopped more.
2. 50.0 g of orange peels are put in filter paper and then put in soxhlet extractor.
3. Distillation flask is filled to its half with Ethanol.
4. Soxhlet extraction acted for 2 cycles for each 50 grams of orange peel sample.
5. After 2 cycles of soxhlet extraction is finished, ethanol is evaporated from the distillation flask using water bath at 65.0 °C heat.

ii) Lipid extraction from Banana peels

1. Banana peels are put in rondo and chopped until, pieces of banana peels become very small that can not be chopped more.
2. 50 g of banana peels are put in filter paper and than put in soxhlet extractor.
3. Distillation flask is filled to its half with Ethanol.
4. Soxhlet extraction acted for 2 cycles for each 50 grams of banana peel sample.
5. After 2 cycles of soxhlet extraction is finished, ethanol is evaporated from the distillation flask using water bath at 65 °C heat.
6. Organic solvent 200 ml of diethyl ether is added to sample.
7. Solution is fractioned by using fractional distillation. While using fractional distillation thermometer is put in the distillation flask in from perforated stopper. This process is maintained under the temperature 142 °C to prevent isoamyl acetate (banana peel fat) from burning.

8. After there is nearly 150 ml of diethyl ether is condensed into the beaker, sample in distillation flask is taken to an Erlenmeyer flask.

iii) Lipid extraction from Milk

1. 1000 ml of (3:2) hexane-isopropane solution is formed.
2. 200 ml of hexane-isopropane is added on 200 ml of milk in a separatory funnel.
3. Separatory funnel is shaken vigorously until the sample is observed to be white.
4. Concentration formed is settled for 5 minutes.
5. When phase difference is observed, the upper phase is separated and taken to an Erlenmeyer flask.
6. Solvent in Erlenmeyer flask is evaporated with using water bath which is set to be 65.0 °C.

iv) Lipid extraction from Egg

1. 200.0 ml of ethanol/chloroform solution with the ratio of 6/4 (v/v) is formed.
2. Yolk of the egg is separated from the rest of the egg.
3. Yolk of the egg is mixed with the help of a glass rod to obtain a homogeneous looking mixture.
4. (4:6) ethanol-chloroform solution is mixed with the egg yolk in an Erlenmeyer flask.
5. Solution is swirled for 30 seconds.
6. Mixture is put in a separatory funnel. Stopper of the separatory funnel is put on top in order to stop chloroform from evaporating.
7. Solution is held in rest for about 30.0 minutes.
8. After the phase difference is observed, Organic top layer is separated from the mixture.
9. Than, solution is put in a hot water bath which is running at 60.0 °C.
10. Solution is rested in the water bath until most of the organic solvent is evaporated.

v) Lipid extraction from Avocado

1. Avocado is split in two using a sharp knife. Than, seed of avocado is taken out.

2. Remaining avocado sample is put in rondo and chopped until, pieces of avocado become very small that can not be chopped more.
3. 50.0 g of avocado sample is put in filter paper and then put in soxhlet extractor.
4. Distillation flask is filled to its half with Ethanol.
5. Soxhlet extraction acted for 2 cycles for each 50.0 grams of avocado sample. After 2 cycles of soxhlet extraction is finished, ethanol is evaporated from the distillation flask using water bath at 65.0 °C heat.

B) Transesterification

i) Transesterification of orange peels, banana peels, milk and avocado

1. 2.0 g of lye (solid NaOH) is dissolved in 50.0 ml of distilled water.
2. Solution is swirled until observing that all lye is dissolved completely and looked homogeneous.
3. NaOH solution is added on lipid sample extracted from organic wastes, in an Erlenmeyer flask.
4. Erlenmeyer flask is put on magnetic stirrer hot plate and heated for 30.0 minutes straight at exactly 64.4 °C.
5. In heating process, magnetic stirrer stirs the concentration vigorously.
6. After 30.0 minutes is passed sample is taken to another glassware and let it rest for 24 hours straight for phases of glycerol and biodiesel to separate.
7. After 24 hours, If the sample is observed to be in 2 definite phases, phase 1 which is the upper phase in sample is taken out with the help of pipette.
8. Sample taken is put in test tube and marked.

ii) Transesterification of egg yolk

1. 2.0 g of lye (solid NaOH) is dissolved in 50.0 ml of distilled water.
2. Solution is swirled until observing that lye is completely dissolved.

3. 2 grams of calcium metal is mixed with the meth oxide solution.

4. Hot plate is set at 65.0 °C and a fish is used while PC (Phosphatidylcholine) is going under transesterification process. (Swirling is held at medium) This process should last for 30.0 minutes.

5. After 30 minutes, sample is put inside a separatory funnel and rested for 24 hours straight.

6. After 24 hours, a phase difference should be observed. Bottom layer is glycerol and upper layer is FAME (fatty acid methyl esters) which is the biodiesel we are trying to obtain.

7. Bottom layer is removed with the help of separatory funnel. Remaining biodiesel is taken into a test tube. Stopper is added to test tube to prevent further contamination.

Energy of combustion for biodiesels using bomb calorimeter procedure

1. Biodiesel samples are weighted to be 1 gram with the help of electronic scale and pastor pipette
2. 1.0 gram biodiesel is put inside the crucible. Then, crucible is placed inside the steel bomb.
3. Steel bomb is covered with a lid; which two platinum electrodes are attached. Fuse wire is attached across platinum electrodes.
4. Bomb is filled with oxygen tank to 25 atmospheric pressure.
5. Bomb is placed inside the calorimeter.
6. 200.0 ml distilled water is measured with graduated cylinder then, 200.0 ml of distilled water is poured inside the calorimeter.
7. Electric stirrer is attached. After a through stirring temperature of water is noted (t_1)
8. Battery wires are attached to the electrodes, with 6-volt battery power, fuel is burnt.
9. Rise in Backmann's thermometer is noted.
10. Following calculations are made to determine the calorific value of fuel.

$$q = -C\Delta T$$

where ‘q’ is heat released in joules, ‘C’ is the heat capacity of the calorimeter and ‘ΔT’ is the temperature change calculated via $t_2 - t_1$.

Risk Assessment

Safety precautions

This experiment requires interaction with hazardous chemicals. Inhalation of some of these organic solvents used in this process can be detrimental to lungs and central nervous system. In order to prevent those risks most of the process is continued to progress in a fume hood.

Diethyl ether ($(C_2H_5)_2O$) is a hazardous organic solvent. Breathing Diethyl Ether can cause drowsiness, excitement, dizziness, vomiting, irregular breathing, and increased saliva (x). In procedure, A/ii lipid extraction from banana peels occur. Diethyl ether is used in the process, so this part should be progressed under the fume hood.

Hexane (C_6H_{14}) is used for extracting edible oils from seeds and vegetables. Inhaling n-hexane can irritate the nose, throat and lungs. Higher levels of exposure can lead to serious lung defects. In part A/iii hexane is used in the process. Part A/iii must be done in the fume hood.

Transesterification of banana peel lipids (iAAc) and milk fat should be done under the fume hood. Because of the risk that organic solvents used in lipid extraction may not be fully evaporated.

Strong base, sodium hydroxide (NaOH) is used in the process of transesterification. Sodium hydroxide is a strong base, so contact with skin should be prevented. Gloves and lab coat is used in the process.

Ethical and Environmental

This project involves the use of waste materials, such as orange peels, banana peels, milk, eggs, and avocado, for lipid extraction and transesterification to produce biodiesel. There are no direct ethical concerns related to the use of waste materials for this purpose, as they are not intended for human consumption and would otherwise be discarded as waste. But synthesis of biodiesel is costly and most of the time it uses more

energy than it provides. Storage of organic waste material often lead to molding of that sample. This also leads to bad odor and hygiene due to bacterial growth.

RESULT ANALYSIS

Raw Data

Biodiesels obtained

Samples	Biodiesel Obtained
Orange peels (200.0 g ± 0.1 g)	3.0 ± 0.5 ml
Banana peels (200.0 g ± 0.1 g)	20.0 ± 0.5 ml
Milk (1000.0 ± 0.5 ml)	8.0± 0.5 ml
Egg (50.0 g ± 0.1 g)	5.0 ± 0.5 ml
Avocado (210.0 g ± 0.1 g)	33.0 ± 0.5 ml

[Data table 3: Table including biodiesel obtained]

As stated in hypothesis part, avocado was the sample which was estimated to be highest proficiency organic waste due to mass to mass efficiency. Avocado has highest fatty acid concentration between other organic waste samples.

Processed Data

Biodiesel obtained for 1 gram of organic waste sample

Samples	Biodiesel Obtained
Orange peels (1.0 g)	$1.50 \times 10^{-2} \pm 0.05$ ml
Banana peels (1.0 g)	$1.03 \times 10^{-2} \pm 0.05$ ml
Milk (1.0 g)	$0.8 \times 10^{-2} \pm 0.5$ ml
Egg (1.0 g)	$10.3 \times 10^{-2} \pm 0.5$ ml
Avocado (1.0 g)	$15.7 \times 10^{-2} \pm 0.5$ ml

[Data table 4: calculated amount of biodiesel for 1 gram of organic waste sample]

This conversion of table is made to understand and compare mass to mass efficiency in a greater scale. As seen from the table orange peel and milk samples were not the most ideal option to make biodiesel from. They have low concertation of fatty acids. Because conversion of orange peels to biodiesel is harder, takes greater time and costly due to milk, it is stated that orange peels are the worst organic waste material to make biodiesel from this investigation's sample space.

In order to reach the energy of biodiesel when it is combusted, some calculations are done. Temperature rise in the bomb calorimeter does not directly provides us energy released by biodiesel. Energy taken by calorimeter is energy released by combustion of biodiesel.

For example, to calculate the combustion energy of biodiesel obtained from milk, Rise in the Beckmann's thermometer in bomb calorimeter is noted. Change in temperature is multiplied with heat capacity of bomb calorimeter.

Temperature changed in the combustion of biodiesel obtained from milk is 22.7.

$$q = -C\Delta T$$

$$q = -2.3 \times (22.7 \pm 4.4\%)$$

$$q = -52.2 \pm 4.4\% \; Kj$$

Energy of combustion for Biodiesels Samples

BIOFUEL SAMPLE	**energy of combustion trial #1**	**energy of combustion trial #1**	**energy of combustion trial #1**	**energy of combustion trial #1**	**energy of combustion trial #1**
Orange peels (200.0 g ± 0.1 g) 1,2-dihydroxy-1-methyl-4-isopropyl hexane	48.53 ± 2.37% Kj	44.89 ± 2.56% Kj	49.89 ± 2.31% Kj	48.90 ± 2.35% Kj	40.31 ± 2.85% Kj
Banana peels (200.0 g ± 0.1 g) Methyl ethanoate	55.89 ± 2.06% Kj	56.90 ± 2.02% Kj	56.41 ± 2.04% Kj	50.23 ± 2.29% Kj	49. 45 ± 2.33% Kj
Milk (1000 ± 0.5 ml) 2-(acetyloxy)-1-[(acetyloxy)methyl]ethyl acetate	52.21 ± 2.20% Kj	53.88 ± 2.13% Kj	50.72 ± 2.27% Kj	50.87 ± 2.26% Kj	34.56 ± 3.33% Kj
Egg (50 g ± 0.1 g) -	58.42 ± 1.97% Kj	58.76 ± 1.96% Kj	61.98 ± 1.86% Kj	57.45 ± 2.00% Kj	53.09 ± 2.17% Kj
Avocado (210 g ± 0.1 g) octadec-9-enoate	67.62 ± 1.70% Kj	69.03 ± 2.56% Kj	66.67 ± 1.67% Kj	66.97 ± 1.72% Kj	65.81 ± 1.75% Kj

[Data table 5: Energy of combustion for biodiesel samples]

Example calculation for biodiesel obtained from orange peels average energy of combustion with uncertainties:

$$\frac{(48.53 \pm 1.15) + (44.89 \pm 1.15) + (49.89 \pm 1.15) + (48.90 \pm 1.15) + (40.31 \pm 1.15)}{5}$$

$\frac{233\pm3}{5}$ = $46.6 \pm (\max - \min)/2\sqrt{5}\ Kj$

BIOFUEL SAMPLE	average energy of combustion
Orange peels (200 g ± 0.1 g) **1,2-dihydroxy-1-methyl-4-isopropyl hexane**	-46.6 ± 1.83 Kj
Banana peels (200 g ± 0.1 g) **Methyl ethanoate**	-53.8 ± 1.49 Kj
Milk (1000 ± 0.5 ml) **2-(acetyloxy)-1-[(acetyloxy)methyl]ethyl acetate**	-48.4 ± 4.32 Kj
Egg (50 g ± 0.1 g) **-**	-58.0 ± 1.99 Kj
Avocado (210 g ± 0.1 g) **octadec-9-enoate**	-67.2 ± 0.72 Kj

[Data table 6: Arithmetic mean of the energy released by specific biodiesel type

To obtain molar combustion energy, these combustion energy values are divided to their mole numbers calculated with: $n = \frac{m}{ma}$. Where n is number of moles, m is mass of the sample and ma is the molar mass of the sample.

An example calculation is given below:

$n = \frac{m}{ma}$

$n = \frac{1.0g}{218.20\ g}$ = $0.0045\ mol$

Average energy of combustion per mole is,

$\frac{48.4 \pm 8.92\%\text{Kj}}{0.0045\ mol \pm 10\%}$ = -10800 $\pm$ $18.9\%Kj/mol$

BIOFUEL SAMPLE	Average energy of combustion per mole
Orange peels (200 g ± 0.1 g) **1,2-dihydroxy-1-methyl-4-isopropyl hexane**	-6380 ± 13.9% Kj/mol
Banana peels (200 g ± 0.1 g) **Methyl ethanoate**	-3990 ± 12.8% Kj/mol
Milk (1000 ± 0.5 ml) **2-(acetyloxy)-1-[(acetyloxy)methyl]ethyl acetate**	-10800 ± 18.9% Kj/mol
Egg (50 g ± 0.1 g) **-**	-17500 ± 13.4% Kj/mol
Avocado (210 g ± 0.1 g) **octadec-9-enoate**	-19200 ± 11.1 Kj/mol

[Data table 7: Average energy of combustion per mole]

BIOFUEL SAMPLE	**Experimental values for average energy of combustion per mole**	**Theoretical values for average energy of combustion per mole**	**% Error compared by the theoretical values given in appendix**
Orange peels (200 g ± 0.1 g) **1,2-dihydroxy-1-methyl-4-isopropyl hexane**	-6380 ± 13.9% Kj/mol	-5658 Kj/mol	12.8%
Banana peels (200 g ± 0.1 g) **Methyl ethanoate**	-3990 ± 12.8% Kj/mol	-2890 Kj/mol	38.1%
Milk (1000 ± 0.5 ml) **2-(acetyloxy)-1-[(acetyloxy)methyl]ethyl acetate**	-10800 ± 18.9% Kj/mol	-3435.5 Kj/mol	200%
Egg (50 g ± 0.1 g) **-**	-17500 ± 13.4% Kj/mol	-	-
Avocado (210 g ± 0.1 g) **octadec-9-enoate**	-19200 ± 11.1 Kj/mol	-10605 Kj/mol	81%

[Data table 8: %error calculated from theoretical Average energy of combustion per mole with the experimental values measured by bomb calorimeter]

CONCLUSION

As indicated on my research question; *"How do biofuels made from domestic wastes [orange peels, banana peels, milk, eggs, avocado] differ from each other determined with enthalpy change of combustion [ΔH°c] and mass to mass biofuel efficiency in extend of their popularities identified by poll?", for five different oil source biofuels are obtained by certain chemical processes and energy values per mole calculated.*

In conclusion, the investigation aimed to determine the most suitable organic waste to recycle in order to maximize the energy obtained from the combustion of biodiesel synthesized from that waste. The experiment used various methods including Soxhlet extraction, fractional distillation, bomb calorimeter, and transesterification. The transesterification process was carried out using NaOH as the catalyst, and it was estimated that the optimum temperature for this reaction is 64.4°C. This is because above 70.0 °C lipids undergo polymerization and under 60.0 °C reaction is taking place is a much slower pace. The hypothesis that different transesterificated lipid samples will have different enthalpy changes upon combustion was also tested.

The results obtained from the experiment revealed that the energy content of biodiesel obtained from egg and avocado were the highest, with an calorific value for combustion per mole of 17500 Kj/mol and 19200 Kj/mol. This suggests that eggs and avocados are the most suitable organic wastes to recycle for the synthesis of biodiesel. The findings of this investigation have significant implications for promoting the use of organic waste as a sustainable source of energy. By reducing the amount of waste in landfills and maximizing the energy obtained from organic waste, we can contribute to a cleaner and more sustainable environment. Overall, this investigation provided valuable insights to use organic waste as a renewable source of energy, this investigation also carried out which organic wastes should be used in order to maximize mass to mass and calorific efficiency.

EVALUATION

The experiment has a number of strengths. To start with, it provides valuable insights into the potential for extracting oil from various food waste and synthesizing biodiesel from different oils. This is a valuable area of research, as recycling organic waste and using it to produce biofuels has the potential to reduce our reliance on fossil fuels, making environment more sustainable.

The experiment demonstrates the importance of careful temperature control during the transesterification process. This is a critical step in the production of biodiesel, and the experiment provides a clear example of how variations in temperature can impact the quality and energy content of the final product.

Despite these strengths, there are also few weaknesses that should be discussed. Firstly, the experiment only examines a limited range of food waste samples, including orange peels, banana peels, milk, egg, and avocado. While these samples were chosen for specific reasons (such as their known lipid content), it would be valuable to expand the range of samples in future research.

In addition theoretical and experimental values are too much different from each other where %error calculated as 200%. In this way we should do more trials, or it is concluded that amount of transesterification was not done efficiently where extraction should be repeated.

Secondly, although the experiment uses various techniques for lipid extraction and transesterification, it does not take into account peripheral factors that could affect the efficiency of the process. For instance, the experiment does not investigate the effect of varying reaction times, molar ratios of alcohol to oil, or catalyst loading on the yield and quality of biodiesel. These factors are known to impact the efficiency of the transesterification process.

Lastly, the experiment does not consider the economic feasibility of the process. While it is interesting to investigate the potential energy content of biodiesel produced from food waste, it is also important to consider whether it is economically viable to extract oil from this source.

Suggestions for Improvement:

To improve the experiment in future research, it would be valuable to expand the range of food waste samples investigated, as well as to consider alternative methods of lipid extraction and transesterification. Additionally, it would be useful to investigate the economic feasibility of the process, to determine whether it is a viable method for producing biodiesel on a larger scale.

Finally, it would be valuable to investigate the potential environmental impacts of using food waste to produce biodiesel, including the potential impact on soil quality and the overall sustainability of the process. This would provide a more comprehensive understanding of the potential benefits and drawbacks of this approach, and could help to guide future research in this area.

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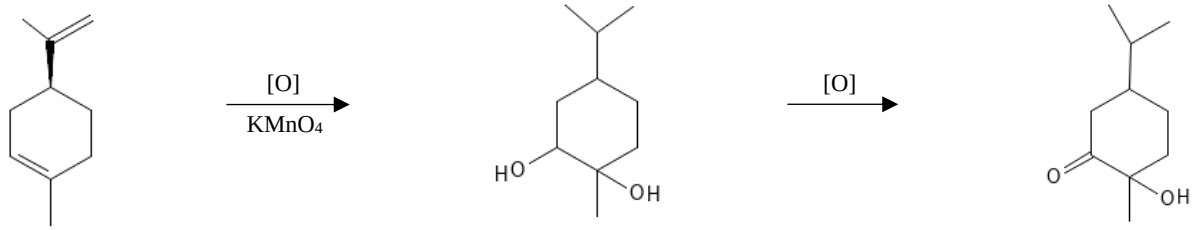
APPENDIX- THEORETICAL VALUES OF ΔH°c

Orange Peels

Oxidation and transesterification of lipid extracted from some of organic wastes are included in the background information, where hypothesis in this investigation is trying to be constructed. In the appendix, it is tried to have an organised and full understanding of further reactions, bond enthalpy calculations and percentage error calculations.

Oxidation of limonene:



Enthalpy change of combustion for oxidised limonene using bond enthalpy:

$C_{10}H_{16}O_{2\,(l)} + 13\ O_{2\,(g)} \longrightarrow 10\ CO_{2\,(g)} + 8\ H_2O_{(l)}$

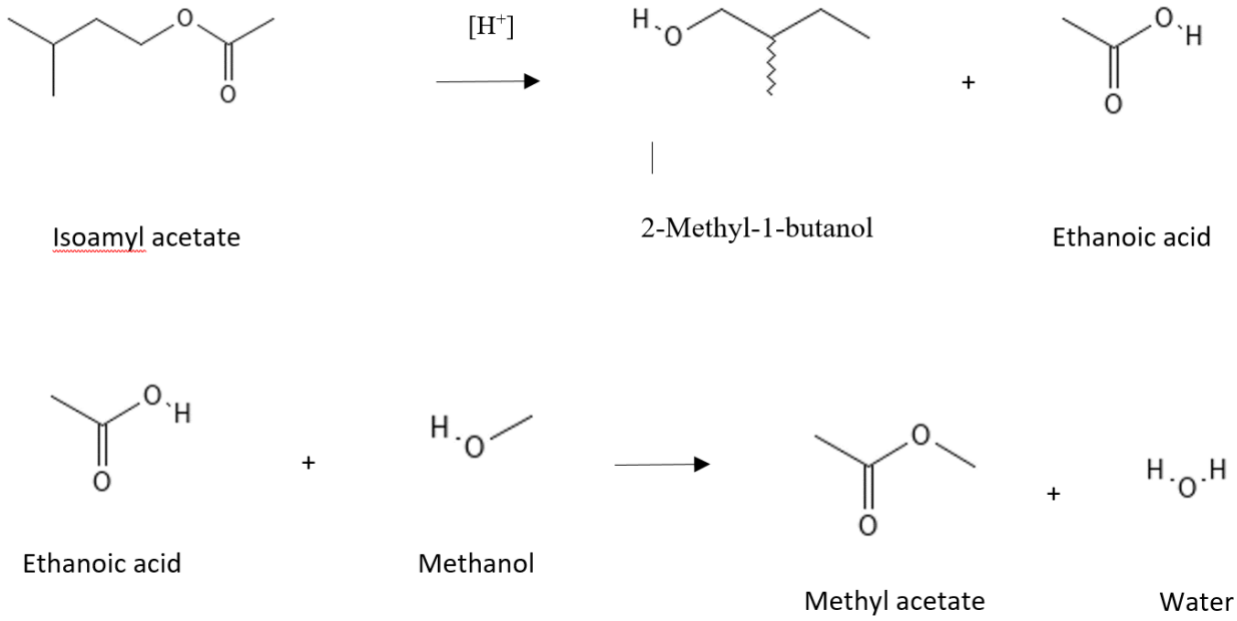
ΔH°c = [15 (C – H) + 10 (C – C) + (C = O) + (C – O) + (O – H)] - [20 (C = O) + 16 (H – O)]

ΔH°c = + 17730 Kj – 23388 Kj

ΔH°c = -5658 Kj/mol

Banana Peels

Isomayl acetate is the lipid molecule extracted from orange peels.



Isoamyl acetate is firstly reduced to obtain 2-methyl-1-butanol and ethanoic acid. Than ethanoic acid is reacted with methanol with the help of strong base catalyst at 64.4 C. Catalyst used in this process is meth-oxide.

Enthalpy change of combustion for methyl acetate using bond enthalpy is given below:

$CH_3COOCH_3 + 7/2\ O_2 \longrightarrow 3CO_2 + 3H_2O$

$\Delta H°c = [\ (\ 6[C\text{-}H] + [C\text{-}C] + 2[C\text{-}O] + [C{=}O]\ ) + (7/2\ [O{=}O]\ )\ ]\ -\ [\ (\ 6[C{=}O]\ ) + (\ 6[O\text{-}H]\ )\ ]$

$\Delta H°c = (\ 6(413) + 348 + 2(358) + 799 + 7/2(425)) - (\ 6(799) + 6(463)\ )$

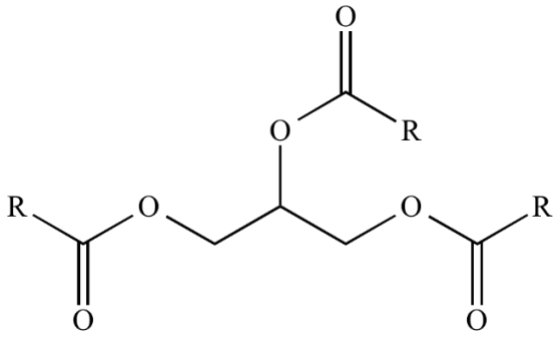
$\Delta H°c = 4681.5 - 7572$

$\Delta H°c = -2890.5$ Kj/mol

Milk

After the lipid extraction is completed for milk sample, transesterification is processed with the help of methanol.

$C_6H_8O_{6\,(l)} + CH_3OH_{\,(aq)} \longrightarrow C_9H_{14}O_{6\,(aq)}$



This is a triglyceride. In the reaction above, Radical groups which are hydrogens are changed with methyl groups to obtain FAME (fatty acid methyl esters). This process increases combustion enthalpy of the following molecule.

Enthalpy change of combustion for FAME (fatty acid methyl esters) obtained from milk waste is calculated with the help of bond enthalpy.

$C_9H_{14}O_{6\,(aq)} + 25/2\ O_{2\,(g)} \longrightarrow 9\ CO_{2\,(g)} + 7\ H_2O_{\,(l)}$

Calculations are given below:

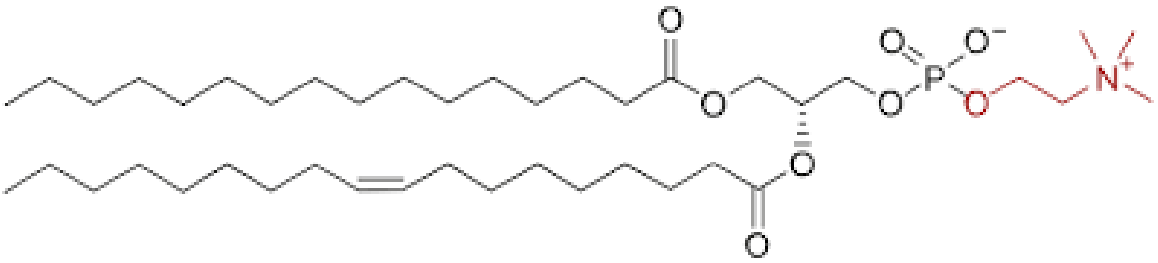
$\Delta H°c = [\ 12\ (C – H) + 5\ (C – C) + 3\ (C = O) + 6\ (C – O) + 25/2\ (O = O)\ ] - [\ 18\ (C = O) + 14\ (H – O)\ ]$

$\Delta H°c = (4956 + 2397 + 2148 + 1740 + 6187.5) – (12382 + 6482)$

$\Delta H°c = -3435.5$ Kj/mol

Egg Lecithin

Phosphatidylcholines (PC) are a class of phospholipids that incorporate choline as a head group. They are a major component of biological membranes and can be easily obtained from a variety of readily available sources, such as egg yolk or soybeans, from which they are mechanically or chemically extracted using organic solvent.

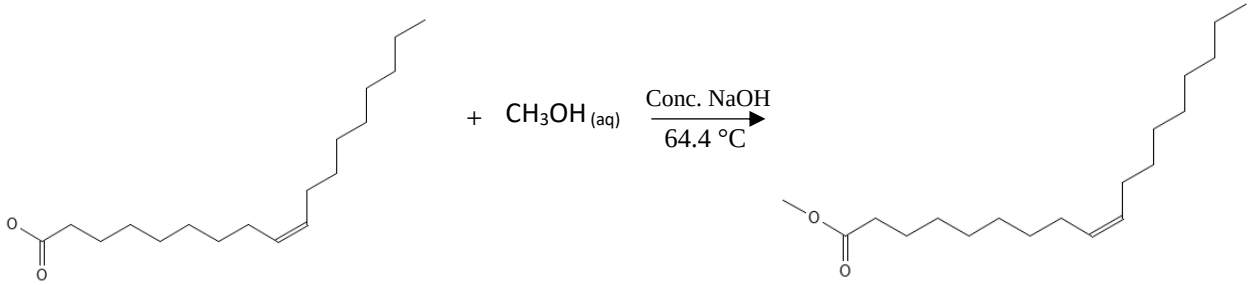


Avocado

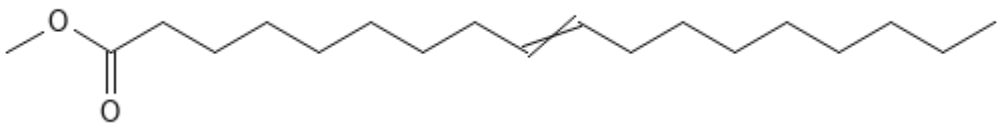
Avocado (*Persea americana Mill.*) is a fruit native to Central America, grown in warm temperate and subtropical climates throughout the world. The pulp of this fruit contains about 60% oil, 7% skin, and approximately 2% seed. (Flores et al., *Avocado oil: Characteristics, properties, and applications* 2019) Indication of quality and quantity of oil extracted from avocado depends on maturity of the fruit and technique of extraction method.

There are various ways to extract oil from avocado such as: cold press method, ultrasound-assisted aqueous extraction method (UAAE), supercritical CO_2 method, CO_2 subcritical method and solvent extraction. Method chosen for extraction oil from avocado is solvent extraction. Compared to other four extraction methods to obtain avocado oil, the traditional solvent extraction method yileds the most reproducible results, which fatty acid content obtained yields 69.94%. (Flores et al., 2019) Thus, without too much expense solvent extraction method is applied. Soxhlet extractor is used in this process.

After the extraction is completed, oleic acid is obtained. Oleic acid reacted with methanol to form ester.



Obtained molecule is methyl octadec-9-enoate. This molecule is too flexible, so it's structure is showed as:



Enthalpy change of combustion for methyl octadec-9-enoate is calculated with the help of bond enthalpy.

Calculations are given below:

$$C_{19}H_{36}O_{2\,(l)} + 28\ O_{2\,(g)} \longrightarrow 19\ CO_{2\,(g)} + 18\ H_2O_{\,(l)}$$

$\Delta H°c$ = [36 (C – H) + 16 (C – C) + (C = O) + 2 (C – O) + (C = C) + 28 (O = O)]

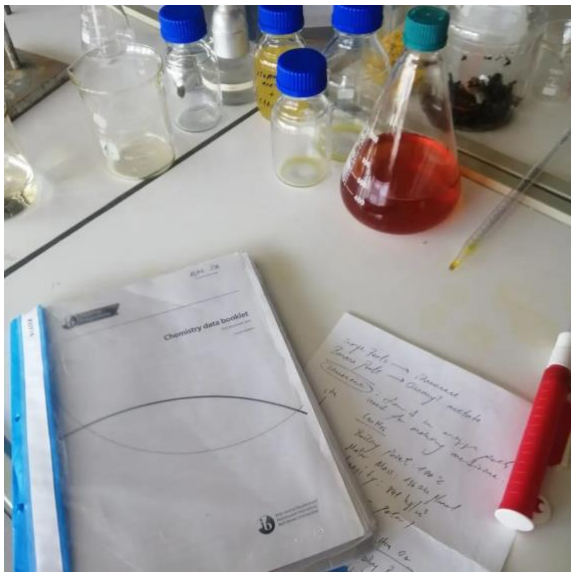
- [38 (C = O) + 36 (H – O)]

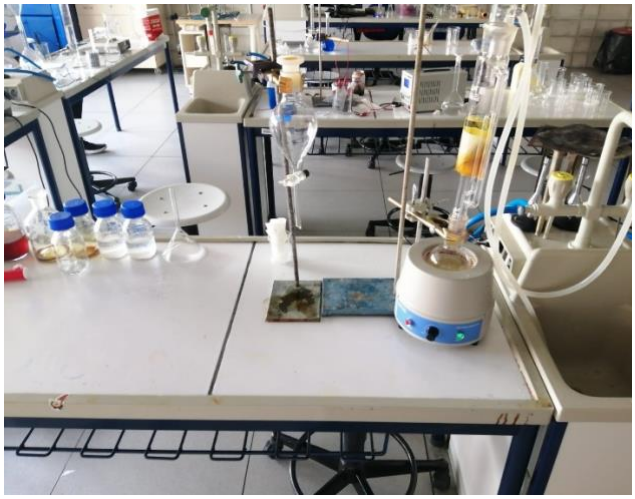
$\Delta H°c$ = [36(413) + 2(358) + (799) + 16(348) + (614) + 28(495)] – [38(799) + 36(463)]

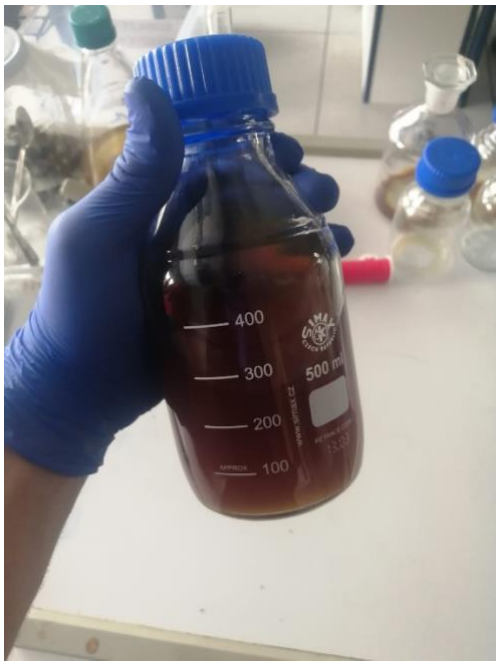
$\Delta H°c$ = (22565 + 13860) – (30362 + 16668)

$\Delta H°c$ = -10605 Kj/mol

PHOTOS OF EXPERIMENTATION



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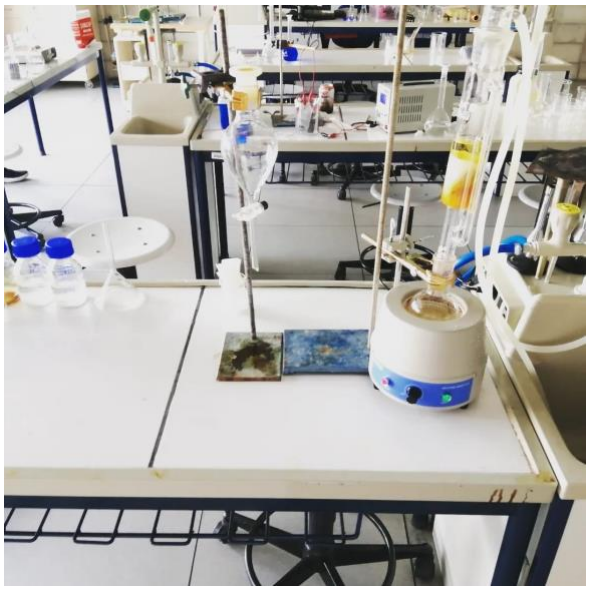


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