Soap Production

Topic 16

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Problem

Vegetable and animal oils and fats are historically used to make soap. Investigate how the fatty acid composition of fats influences the properties of soap produced by saponification. What are the factors that affect the mass and pH of soap after maturity, as well as the lather produced in soft and hard water?

Saponification

Figure 1: Saponification is the alkaline hydrolysis of the ester group in a triglyceride to produce glycerol and three fatty acid salts.

Theoretical Background

How does soap work?

The hydrophilic end of the fatty acid anion forms hydrogen bonds with water. The hydrophobic fatty acid tails form London forces with hydrophobic impurities.

This results in the hydrophobic material being encased in a micelle, effectively dissolving the ‘dirt’ and resulting in a cleaning action.

Figure 2: Soap Forming Micelles

Theoretical Background

How does a soap bubble form?

A soap bubble is a film of water sandwiched between two layers of soap molecules.

The hydrophilic end of the fatty acid anion forms hydrogen bonds with water.

As a result the fatty acid hydrophobic tails are no longer in contact with water.

Figure 3: Soap Bubble Structure

Topics investigated:

Soap types:

- Type of fat/oil used
- Ratio of palm : sunflower oil to investigate the synergy of the oils.

Properties investigated:

- Mass of soap after maturity
- pH of the matured soap
- Lather produced in soft and hard water

Experiment 1
Soap Yield

Research Questions

How does the type of fatty acid found in the oil or fat used in saponification affect the yield of soap produced?

How does the palm / sunflower ratio used in saponification affect the yield of soap produced?

Variables:

Independent Variables

- Type of fat/oil used
- Ratio of palm : sunflower oil

Dependent Variable

- Yield of soap (g) after maturation.

Controlled Variables

- Cold Process: Water Bath at 50°C
- No lye discount: All the fat / oil should react during saponification.
- Mass of Fat: 100g

Materials: Soap Preparation

Materials

- Plant Fat
- Olive Oil
- Sunflower Oil
- Soya
- Coconut Butter
- Sesame oil
- NaOH
- Distilled water
- Muffin molds (6)

Figure 4 :Muffin Mold

Figure 6: Soya

Figure 7: Sunflower Oil

Figure 8:Olive Oil

Figure 9: Sesame Oil

Figure 5: Coconut Butter

Figure 11:Palm Oil

Figure 10 :NaOH

Measurements

Table 1: Amounts of water and NaOH for 100g of the different oil/fat

Fat (100g)	NaOH (g)	Water (g)	Total Mass (g)
Palm Oil	14.00	32.67	146.67
Olive Oil	13.53	31.57	145.1
Sunflower Oil	13.58	31.69	145.27
Soya Oil	13.50	31.50	145
Coconut Butter	18.30	42.70	161
Sesame Oil	13.70	31.97	145.67
Corn Oil	13.50	31.5	145

Measurements

Table 2: Different Amounts of Water and NaOH or 100g of the different palm / sunflower ratios.

Palm oil (g)	Sunflower Oil (g)	NaOH (g)	Water (g)	Total Mass (g)
10	90	12.24	31.85	144.09
30	70	9.52	32.08	141.6
50	50	6.8	32.32	139.12
70	30	4.08	32.55	136.63
90	10	1.36	32.78	134.14

Method : Soap Preparation

1. NaOH was weighed in a weighing boat
2. Distilled water was weighed in a 250 mL beaker
3. NaOH was slowly added to the distilled water and stirred
4. Oil/fat was weighed in a 350 mL beaker
5. The beakers with oil/fat was placed in a water bath at 50°C and left to melt
6. Water and NaOH solution was slowly added into the oil/fat while still stirring
7. The oil/fat and NaOH mixture was placed in the water bath at 50°C for 20 minutes
8. The oil/fat and NaOH mixture was placed in an ice bath
9. The solution was stirred until mixture had thickened
10. Using a spatula the soap mixture was removed from the beaker and placed into a muffin mold
11. The soaps were left to mature for 6 weeks
12. The procedure was conducted 2 times
13. A total of 28 soaps was produced

Quantitative Results Table 3: Mass of soap produced for different oils

Oil Name	Sunflower	Soya	Palm	Coconut	Sesame	Olive	Corn oil
Trial 1							
Mass of soap + mold (g)	135.43	134.99	144.55	153.01	138.48	136.99	133.42
Mass of Mold (g)	15.44	15.41	15.92	16.07	17.09	16.05	14.37
Mass of Soap (g)	119.99	119.58	128.63	136.94	121.39	120.94	118.96
Trial 2							
Mass of soap + mold (g)	92.17	92.75	94.71	102.21	91.68	87.26	96.06
Mass of Mold (g)	14.24	17.17	15.61	15.91	15.21	16.16	14.21
Mass of Soap (g)	77.93	75.58	79.1	86.3	76.47	71.1	81.85
Average Mass of Soaps (g)	98.6	97.58	103.87	111.62	98.93	96.02	100.4

Table 4: Average yield of soaps produced from pure oils.

Quantitative Results Table 5: Mass of soap produced per palm / sunflower ratio

Fat masses (%) Sunflower oil x Palm Oil	10 x 90	30 x 70	50 x 50	70 x 30	90 x 90	100 sun	100 palm
Trial 1							
Mass of foil and soap (g)	130.45	130.90	133.45	132.83	141.85	135.43	144.55
Mass of foil (g)	15.28	16.91	16.11	11.00	14.59	14.44	15.95
Mass of soap (g)	114.17	113.99	117.34	121.83	127.26	128.63	128.63
Trial 2							
Mass of fold and soap (g)	131.73	131.83	122.55	126.22	130.78	92.17	94.71
Mass of mold (g)	17.09	15.75	16.8	18.44	15.44	14.28	15.61
Mass of soap (g)	114.64	116.08	105.75	107.78	115.34	77.93	79.1
Average mass of soap	114.4	114.03	111.55	114.8	121.3	102.97	103.87

Graph 1: Final average masses of the sunflower and palm oil mix

Figure 12:70 sun 30 palm

Figure 13: Coconut Butter Soap

Figure 14:Soya Oil Soap

Figure 16: Maturing Soaps

Figure 15:90 sun 10 palm

Conclusion

All of the soaps had lost masses. This has happened due to the evaporation of water over the times that the soaps were maturing. The soaps were not covered which allowed for a free flow of evaporating water to come out of the soaps. The **singular soaps had an average mass loss of 23.9 grams for the first trial** and **69.44 grams mass loss in the second trial**. The 45 gram difference may be explained by the time period over which the soaps were maturing. The first trial was measured after 3 weeks of maturing, whereas the second trial was measured after over 8 weeks of maturing (due to quarantine) therefore allowing for more time for the water to evaporate. **The mixture of Palm Oil and Sunflower Oil had been maturing for the same amount of time of about 3 weeks with average being 20.2 and 27.2 grams.**

Evaluation

-> The soaps lost mass due to the fact that they were not sealed thus, water could evaporate freely.

->Trial 1 had been measured 3 weeks into maturing, in contrast the second trial had been maturing for over 8 weeks (due to quarantine) which allowed more time for more water to evaporate.

-> some of the measurements were not precise to the gram.

-> when scooped out of the beakers into the molds, some mixture still remained on the walls of the beaker as well as on the spatula.

Experiment 2

Measuring Ph Level of the Soaps

Research Questions

How does the type of fatty acid found in the oil or fat used in saponification affect the pH of the soap produced?

How does the palm / sunflower ratio used in saponification affect the pH of the soap produced?

Variables:

Independent Variable

- Type of fat/oil used
- Ratio of palm : sunflower oil

Dependent Variable

- pH of the matured soap

Controlled Variable

- Concentration of soap solution (m/v)
- pH probe
- Temperature

Materials 2:

Materials

→ Soaps diluted in water
→ Distilled water
→ pH meter

pH Meter

Method 2: Measuring pH level of the soaps

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1. 2.5grams of soap were placed into a test tube
2. 50 mL of distilled water were added to a test tube
3. The soap was dissolved
4. The pH meter was calibrated
5. The pH meter was rinsed with distilled water
6. The pH meter was gently dipped into the dissolved soaps
7. The procedure was repeated 3 times

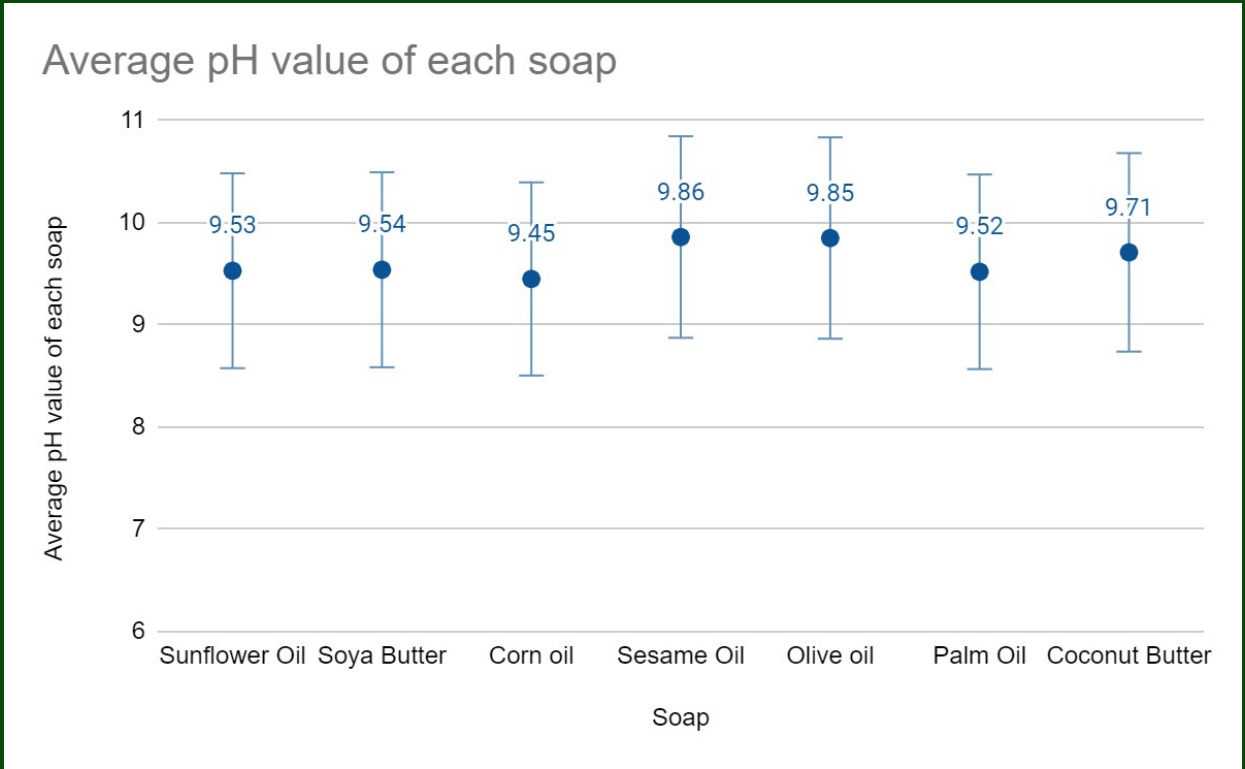
pH meter submerged in diluted soap

Results

Table 6: pH of soaps from different oils

Soap	Sunflower Oil	Soya Butter	Corn oil	Sesame Oil	Olive oil	Palm Oil	Coconut Butter
Trial 1							
Ph Level	9.51	9.55	9.41	9.81	9.6	9.21	9.44
Trial 2							
Ph Level	9.54	9.53	9.54	9.91	10.09	9.82	9.98
Average ph level	9.53	9.54	9.45	9.86	9.85	9.52	9.71

Table 7: Average pH levels of each individual soap

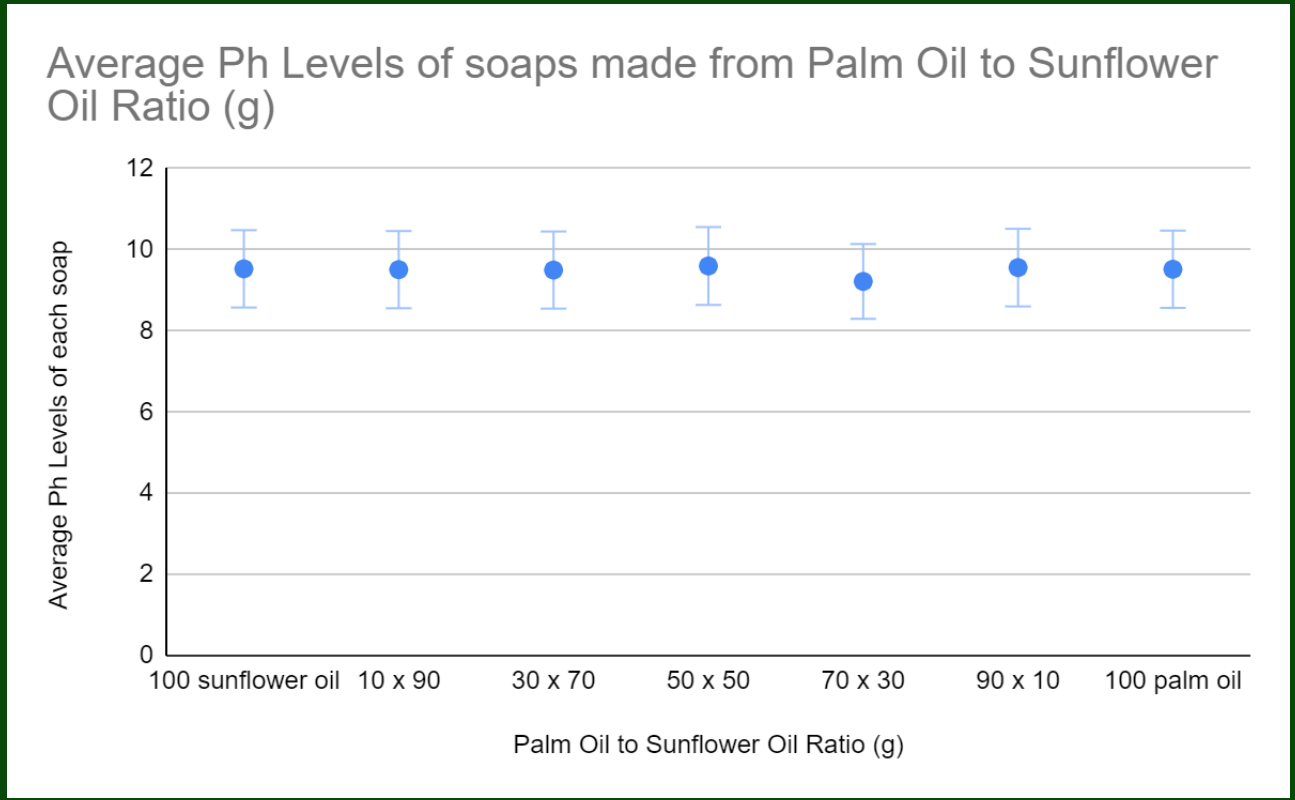


Results

Table 8:Ph Levels of Palm Oil and Sunflower Oil Mixture

Palm Oil to Sunflower Oil Ratio (g)	100 sunflower oil	10 x 90	30 x 70	50 x 50	70 x 30	90 x 10	100 palm oil
Trial 1							
pH Level	9.51	9.48	9.33	9.69	9.11	9.5	9.21
Trial 2							
pH Level	9.54	9.54	9.66	9.46	9.33	9.62	9.82
Average Ph Levels of each soap	9.53	9.51	9.5	9.6	9.22	9.56	9.52

Graph 5: Average pH level of each soap vs the percentage of Palm oil



Experiment 3
Measuring the effect of soap type on the

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Soaps

Research Questions and Hypotheses on soap lathering

Research question: How does the type of fatty acid found in the oil or fat used in saponification affect the pH of the soap produced?

Hypothesis: Soaps produced from oil containing more short-chain fatty acids will produce the most lather due to their higher solubility in water.

Research question: How does the palm / sunflower ratio used in saponification affect the pH of the soap produced?

Hypothesis: Soaps produced from oil containing a higher ratio of palm:sunflower oil will produce more lather due to palm oil containing more short chain fatty acids that have a higher solubility in water.

Variables:

Independent Variable

- Type of fat/oil used
- Ratio of palm : sunflower oil

Dependent Variable

- Lather produced

Controlled Variable

- Concentration of soap solution (m/v)
- Temperature
- Number of times the mixture is shaken

Materials: Latherability

Materials

- Diluted Soaps
- Beaker
- Measuring cylinder
- Boiling tube with stopper

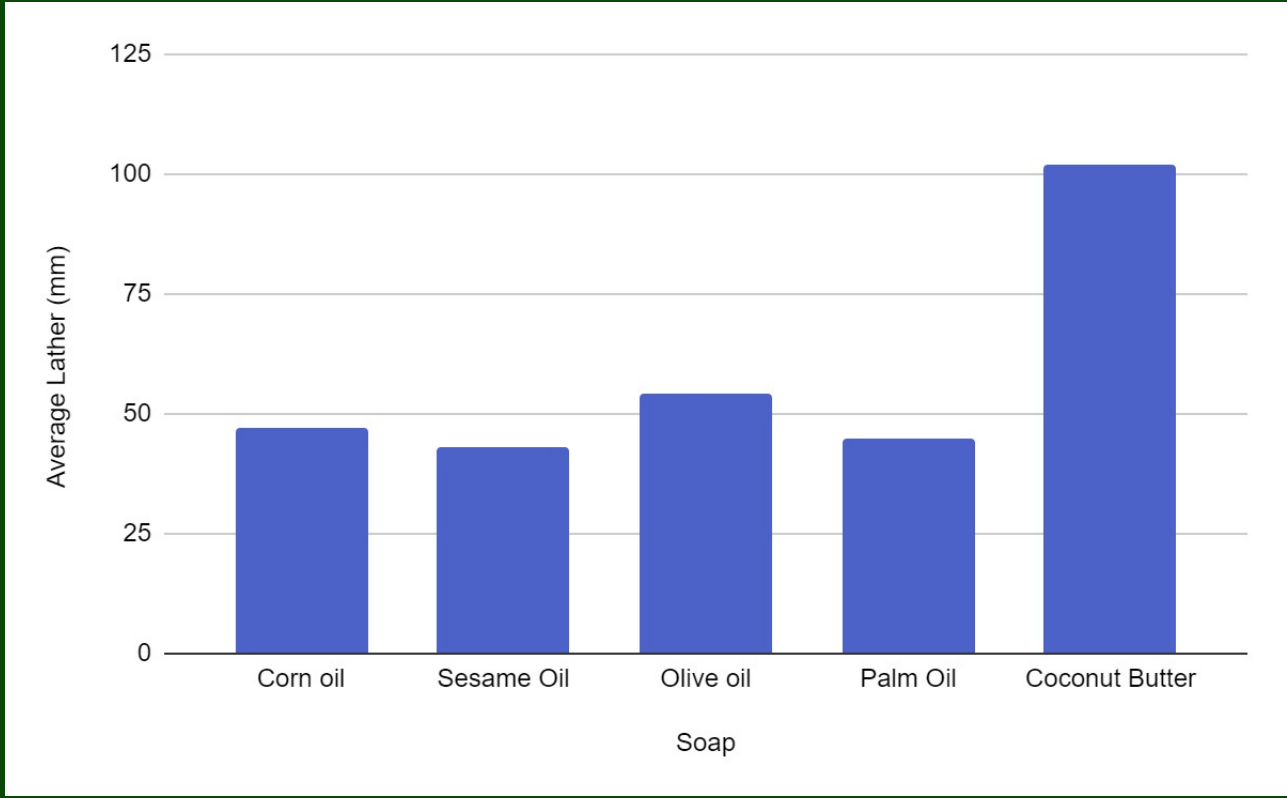
Method 3: Measuring lather of the soaps

1. 2.5grams of soap were placed into a test tube
2. 10 mL of distilled water were added to a test tube
3. The test tube was shaken well 10 times
4. The amount of bubbles formed was measured in mm from the top of the liquid until the end of the tallest bubble
5. The procedure was conducted 3 times

Quantitative Results: Table 9: Lather formed from soaps produced from different oils

Soap	Sunflower Oil	Soya Butter	Coconut Butter	Sesame Oil	Olive oil	Palm Oil	Corn oil
Trial 1							
Lather (mm)	30	33	121	40	59	57	15
Trial 2							
Lather (mm)	36	57	100	47	61	35	20
Trial 3							
Lather (mm)	38	40	85	42	43	43	12
Avg. (mm)	34.7	43.3	102	43	54.4	45	47

Table 10: Average Lather produced per pure oil



Quantitative Results: Table 11: Lather formed from soaps produced from different palm: sunflower oil ratios.

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Palm Oil to Sunflower Oil Ratio (%)	0	10	30	50	70	90	100
Trial 1							
Lather (mm)	30	28	4	22	3	2	57
Trial 2							
Lather (mm)	36	19	5	11	2	5	35
Trial 3							
Lather (mm)	38	29	3	13	5	3	43
Avg	34.7	25.3	4	15.3	3.3	3.3	45

Table 11: Average Lather Formed for palm-sunflower ratio

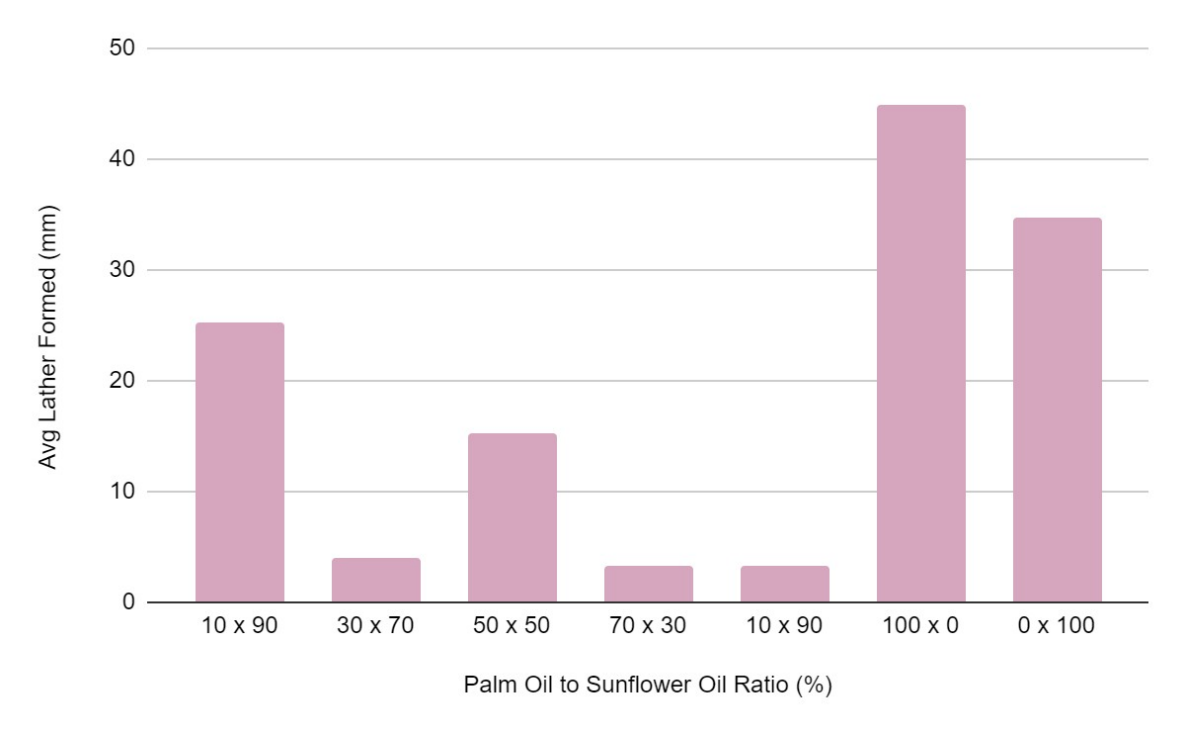
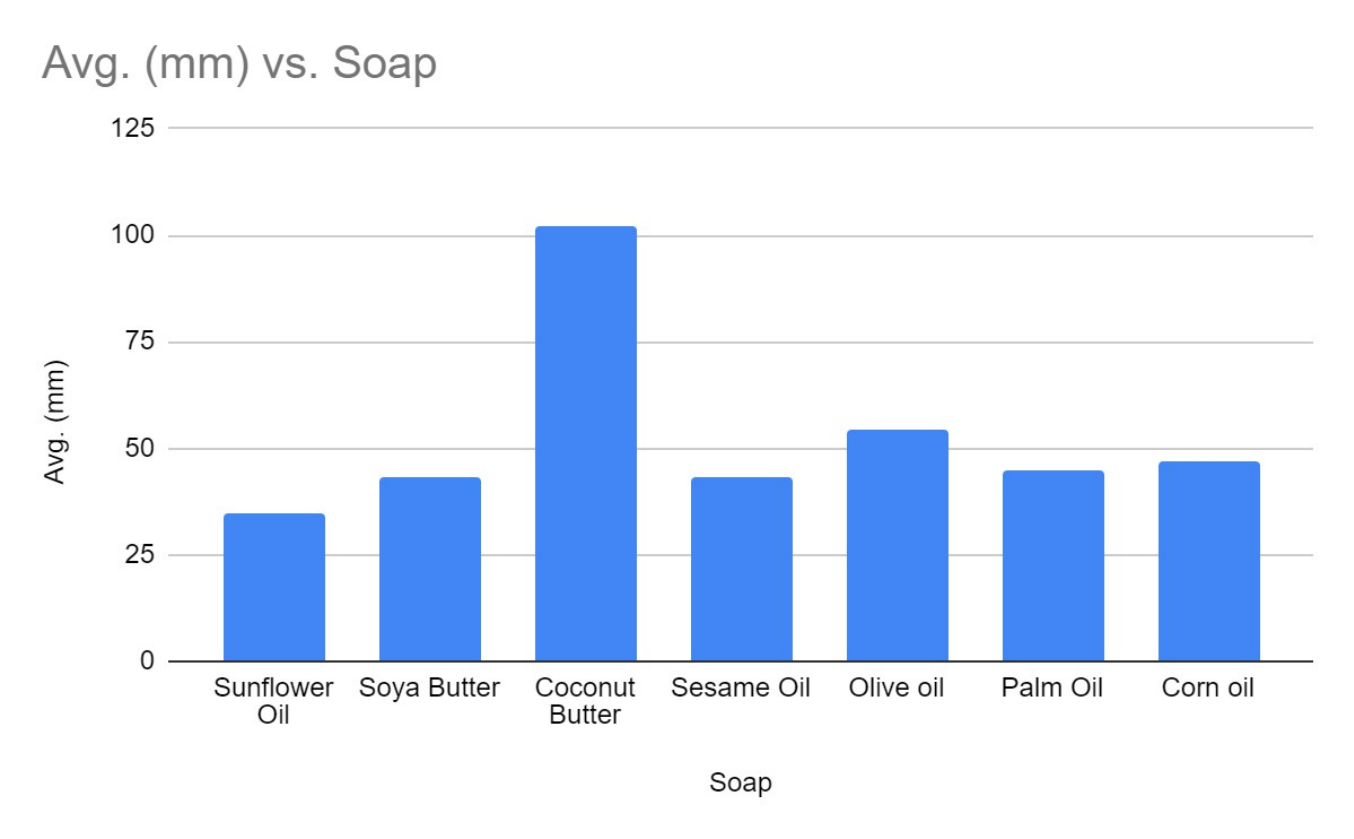


Table 12 :Average Lather Formed per soap



Experiment 4: Measuring the effect of water type on the soaps

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Research Question

How does the water type affect the lather formed by soaps produced from different oils?

Variables:

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Independent Variable

- Amount of $CaCl_2$ added to the soap solution.

  (Soft water: 0g, hard water: 0.33g)

Dependent Variable

- Lather produced (mm)

Controlled Variable

- Concentration of soap solution (m/v)
- Temperature
- Number of times the mixture is shaken.

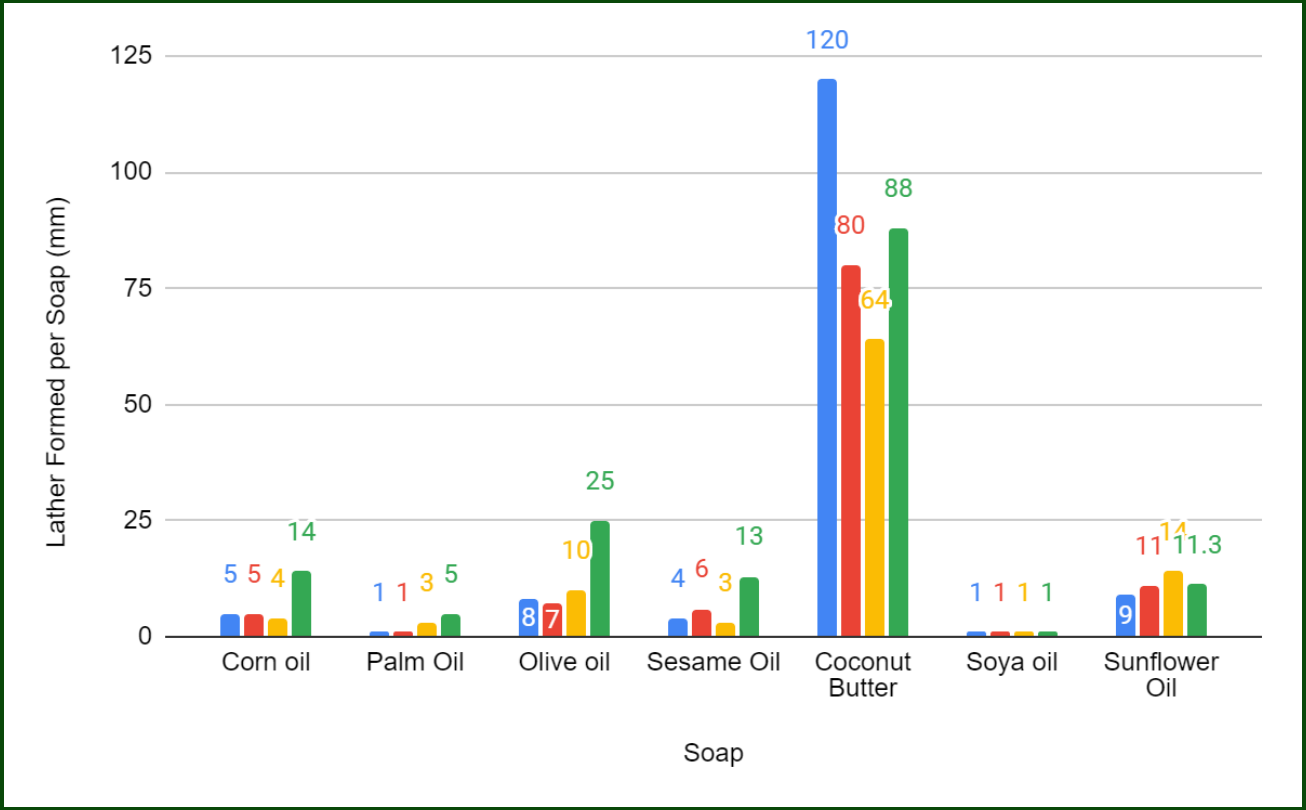
Method 3: Measuring lather of the soaps when 0.33 g of CaCl2 was added.

1. 2.5 g of soap and 0.33 g of $CaCl_2$ were added to 50 mL of water. This simulated the calcium ions that are present in hard water.
2. 10 mL of this soap solution was placed into a test tube
3. The test tube was shaken well 10 times
4. The amount of bubbles formed was measured in mm from the top of the liquid until the end of the tallest bubble

Quantitative Results: Table 13:Lather formed from soaps produced from different oils when $CaCl_2$ was added

Soap	Sunflower Oil	Soya oil	Coconut Butter	Sesame Oil	Olive oil	Palm Oil	Corn oil
Trial 1							
Lather (mm)	9	1	120	4	8	1	5
Trial 2							
Lather (mm)	11	1	80	6	7	1	5
Trial 3							
Lather (mm)	14	1	64	3	10	3	4
Avg.	11.3	1	88	13	25	5	14

Table 14:Lather formed from soaps produced from different oils when $CaCl_2$ was added in mm



Quantitative Results: Table 15:Percent decrease in lather formed from soaps produced from different oils when $CaCl_2$ was added

$CaCl_2$ added (g)	Average Lather produced						
	Sunflower	Soya	Coconut	Sesame	Olive	Palm	Corn
	34.7	43.3	102	43	54.4	45	47
0							
	11.3	1	88	13	25	5	14
0.33							
% decrease	67	98	14	70	54	89	70

Conclusion

- All of the soaps had a **pH level around 9 and 10** which makes them unsafe as the pH of human skin is usually between pH 4-6. This suggests the saponification reaction was not complete resulting in unreacted NaOH being present.
- Yields of soaps were similar for each batch. **This suggests that oil type does not affect the yield of the saponification reaction.**
- A slight positive correlation is observed between shorter fatty acid content and lather produced. **The hypothesis is supported**.
- **No trend was observed in the palm / sunflower soaps and lather production. The hypothesis is not supported.**
- Hard water containing **Calcium ions significantly decreases lather produced in most soaps**, particularly palm and soya. **Only coconut soap was not significantly affected.**

Evaluation

Errors:

Some water could have gotten into the solution while it was being made.

Mass measurement could be affected as some soap could have been lost during the transfer from the beaker to the mold.

Soap solutions were not tested for lather immediately and became very thick indicating that not all the soap was dissolved in the water.

Improvements:

More tests on soap's effectiveness eg. how well they clean a surface.

More trials to improve accuracy.

Thank You

Bibliography:

- https://labmuffin.com/is-sodium-hydroxide-safe-in-beauty-products/
- https://science.jrank.org/pages/6214/Soap.html
- https://www.google.com/search?q=soap+micelle&tbm=isch&ved=2ahUKEwjvieHyrfnpAhXHi6QKHY7SCncQ2-cCegQIABAA&oq=soap+mic&gs_lcp=CgNpbWcQARgAMgQIABATMgQIABAT
- https://byjus.com/chemistry/saponification/
- https://www.medicaljournals.se/acta/content_files/files/pdf/93/3/3854.pdf