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Producing a Liquid Soap by Adding Lemon Extract from Used Cooking Oil for Multipurpose Cleaning Use

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Abstract

The production of liquid soap from used cooking oil represents an innovative approach to waste management and household cleaning, and this study examines the feasibility of using this common household waste as a raw material for liquid soap production to reduce environmental pollution. Additives such as natural and synthetic can be also added into soap composition and will identify how much of the amount will effect the soap's physicochemical properties. By incorporating natural additives like lemon extract, the liquid soap's performance will be tested. The production process involves several stages: saponification, additive incorporation, and subsequent testing for pH, density and stain removal effectiveness. Results indicate that the pH for used and new cooking oil is 6 and 5 respectively. The density difference for both oil are as much as 0.33% which UCO having 0.912 g/cm^3 and NCO is 0.909 g/cm^3. Stain removal for soap performance were tested and all of the samples composition showing similarity in result. This shows that adding lemon extraction and using used cooking oil is comparable to using new cooking oil. By that, the aimed to achieve environmental pollution can be reduce. Overall, this study highlights the potential of repurposing used cooking oil into a sustainable product, providing a practical solution for both waste management and household cleaning needs.

1. Introduction

Cooking oils are widely used as a primary material for deep-fried food in Malaysia. Palm-based cooking oil has been long promoted as a healthy and nutritious food commodity. Malaysia is the world's second-largest exporter of palm oil by volume, following Indonesia. In 2022, Malaysia exported approximately 15.35 million metric tons of palm oil, nearly five times its domestic consumption. From 2021 to 2022, domestic consumption of palm oil in Malaysia was around 3.3 million metric tons, constituting only a fraction of its total output, with the majority being exported [1]. However, the extensive use of cooking oil leads to disposal issues, with most household used cooking oil being improperly disposed of into drainage systems and soil, causing environmental harm [2]

Given the abundance of waste or used cooking oil, it can be repurposed into beneficial products [3]. Used cooking oil can be converted into biodiesel, soaps, lubricants, and paint removers. For instance, the community of Belo Horizonte, Brazil, has been transforming waste cooking oil into aromatic soap bars for washing and disinfecting since November 2020 [4]. Establishing a systematic and efficient recycling process for used cooking oil can mitigate environmental concerns while providing a sustainable and financially viable solution.

Soap was produced by using a combination of a few raw materials such as palm oil, alkali and distilled water through a process of saponification [5]. The alkali, fats or oils will react during saponification to produce soap molecules and glycerin. By reacting to the fatty acids generated from the breakdown of fats or oils with an alkali, soap is formed [6]. In this study, used cooking oil will be recycled into liquid soap (LS) using the hot process method. The cleaning power of soap from used cooking oil can be enhanced by adding natural or synthetic additives. Additives can significantly improve soap by providing various benefits, though they have some drawbacks. Synthetic additives, like essential oils such as lavender and tea tree, provide natural scents and therapeutic benefits, including calming effects and antibacterial properties. However, they can irritate sensitive skin, are expensive, and their fragrance may fade over time. Natural additives, like oatmeal and coffee grounds, help exfoliate by removing dead skin cells and smoothing the skin, improving its texture and appearance. Yet, they can be too harsh for sensitive skin and may cause irritation if used too often. Natural exfoliants are eco-friendly and sustainable, unlike synthetic, like plastic microbeads, can harm the environment. This study chosen the inclusion of lemon extract is expected to increase cleaning capabilities, as the citric acid in lemons helps break down stains and restore dull whites to brightness.

This study will focus on the soap production from used cooking oil by adding lemon extraction as natural additive. In this study, the oil will be used and new palm cooking oil. Physicochemical were investigated on how many amounts of lemon extraction will get affected on the properties. Soap performance will be tested on stain removal by using three types of stain which are chili sauce, soy sauce and lipstick on white cloth.

2. Methodology

Used palm cooking oil was collected from household nearby Parit Haji Rais while Buruh cooking oil was chosen as new palm cooking oil and lemon bought from local store. Analytical research grade alkali: Potassium Hydroxide from QRëC used in this study. Physicochemical tests will be conducted on both used and new cooking oil and soap paste. Chili sauce from Puteri, soy sauce from Nur and lipstick from Treneda were locally bought in nearby store.

The physical tests that will be done are colour observation, density and viscosity test while chemical tests are pH value, Fourier Transform Infrared (FTIR), Free Fatty Acid (FFA) and saponification test. For soap performance analysis, the stain removal test will be done. The soap paste sample composition can be referred in Table 1.

Table 1 *Soap paste sample composition*

Sample	Type of Oil	Oil (g)	Lemon (g)	KOH (g)	Distilled Water (g)
UO1	Used	300	0	66	200
UO2	Used	300	50	66	150
UO3	Used	300	100	66	100
UO4	Used	300	150	66	50
NO1	New	300	0	66	200
NO2	New	300	50	66	150
NO3	New	300	100	66	100
NO4	New	300	150	66	50

2.1 Preparation of Liquid Soap

First and foremost, 300g of used cooking oil, 200g of distilled water, 66g of potassium hydroxide (KOH), and 100g of lemon extract were measured. The KOH then slowly added to the distilled water and stirred using the magnetic stirrer in the fume hood and was added to the solution and stirred again. Meanwhile, the oil was heated to 40℃, and the mixture poured into the oil. They were stirred together using a stick blender at a controlled temperature between 50 and 60 degrees Celsius. After that, the mixture was left to rest for about 15 minutes several times, with continued mixing until it reaches trace, where the mixture thickens and becomes a homogenous consistency. During the rest phase, the mixture was observed for oil or bubbles, indicating that it is not yet homogeneous. Once the desired texture is achieved, the mixture will be poured into a glass jar and allowed to cool, allowing the trace to thicken until it becomes soap paste. The process repeated with different amount of lemon extraction and new cooking oil.

2.2 Characterisation of Palm Oil

The oil will undergo a few analyses to determine the physicochemical properties such as colour observations, pH value, density test, viscosity test, FFA, FTIR and saponification test.

2.2.1 Density Test

First and foremost, prepare the balance for the density determination such as installing the support plate, bracket and pan. Place an empty high beaker on the pan and suspend the sinker from the bracket. Furthermore, ensure that the sinker does not touch the beaker and tare the balance. Add the sample whose density wish to determine to the beaker 1 centimeter above the suspension eye of the sinker. Ensure that no air bubbles adhere to the sinker or remove any air bubbles that occur with a fine brush. Afterwards, wait until the weight display of the balance is stable and note the displayed value of displaced liquid. Lastly, determine the density value of the liquid, using equation 1.

$$\rho = \alpha \frac{P}{V} + \rho_L \quad (1)$$

Where ρ is the density of liquid, A is the weight of sinker in air, B is weight of sinker in the liquid, V is volume of sinker, ρL is air density (0.0012 g/cm^3), α is the balance correction factor (0.99985), takes air buoyancy of the adjustment weight into account and P for weight of displaced liquid (P= A-B).

2.2.2 Free Fatty Acid

Begin by preparing a homogeneous sample 2g of oil to determine its free fatty acid content. Then the oil was poured into test tubes and mixed with 50mL of Isopropyl Alcohol, the mixture was already put in water bath and heated to approximately 50°C for homogenization. A 0.5mL drop of phenolphthalein is added to the homogenized mixture and stir for few seconds. The stirred sample was neutralized using 0.1 N of sodium hydroxide (NaOH) solution. Set up the titration apparatus with a burette, flask, and indicator after weighing the amount of the oil and dissolving it in Isopropyl Alcohol. Titrate the oil sample with a standardised base until a colour change indicates the endpoint. Titration volumes, titrant concentration, and molecular weight are used to calculate the free fatty acid content. If necessary, repeat the procedure for accuracy, and document all relevant details, such as the date, sample characteristics, and calculations. Interpret the results considering the oil's quality and suitability for different applications, considering industry standards for acceptable free fatty acid levels. The formula for calculating FFA value using equation 2.

$$\left(\%\text{FFA} = \frac{25.6 \times \text{N} \times \text{V}}{\text{w}}\right) \quad (2)$$

Where V is volume of NaOH, N = normality (concentration) of NaOH, w is weight of the oil used.

2.2.3 Fourier Transform Infrared (FTIR)

FTIR spectroscopy showing the details on the functional groups and chemical bonds that are present in the material by analysing the infrared radiation absorption. For oil sample analysis, 2-3 drops were placed on the FTIR sample compartment. The machine scans the sample and then displays a graph of wavenumber versus transmittance. For the soap samples, soap paste were placed in the sample compartment and pressed using the auto sampler presser before scanning. After a few minutes, the machine generates the wavenumber to transmittance graph, covering a range from 600 to 4000 cm^{-1}. The FTIR model used for this analysis was the PerkinElmer Spectrum 100.

2.2.4 Saponification Test

The procedure starts by accurately weighing 2-5 grams of oil. Then, a standardized alcoholic solution of potassium hydroxide (KOH) is prepared, with its concentration being crucial for accurate results. The oil is dissolved in a mixture of ethanol and water to ensure complete solubility. A few drops of phenolphthalein indicator are added, and any color change from colorless to pink is observed as the pH shifts from acidic to slightly basic. The solution is then titrated with the standardized KOH solution. The fatty acids in the oil react with the potassium hydroxide, forming soap and glycerol. The titration endpoint is reached when the pink color of the phenolphthalein persists for at least 30 seconds, indicating all the free fatty acids have reacted with the alkali. The volume and concentration of the KOH solution used in the titration are then used to calculate the amount of alkali that reacted with the oil sample. The saponification value is expressed in milligrams of potassium hydroxide needed to saponify one gram of fat or oil. The formula for calculating the saponification value is then determined using equation 3.

$$\left(\mathrm{SV} = \frac{28.05 \times (A - B) \times F}{S}\right) \tag{3}$$

Where SV is the saponification value, S is the sample weight, A is the titration value of blank (ml), B is the titration value of sample (ml) and F is the factor of 0.5N HCI standard solution.

2.3 Characterization of Soap Paste.

For the soap paste analysis, the physicochemical test involves colour and appearance observation, pH value, FTIR, moisture content test and performance test such as stain removal test.

2.3.1 pH value Test

The soap pastes were put on the agar plate and dipped the pH strip into the samples, completely submerging it for a few seconds. The colours on the pH strip are then compared based on the given colour chart. All samples pH value are 10 and fall in available liquid soap range which is 8 to 11 according to Indonesian National Standard (SNI 3532-2016).

2.3.2 Moisture Content

The drying oven method was used to determine the soap paste moisture content. We can find the moisture content of soap paste by drying it in an oven and measuring the weight loss. A sample of soap paste is weighed, heated at 100°C for two hours, and then weighed again to get its final weight. The moisture content is calculated using equation 4.

$$\text{Moisture content (\%)} = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight} \times 100 \tag{4}$$

2.4 Stain Removal

To get the liquid soap, soap paste must be diluted with a ratio of 4:1 which consists of 10 g of soap paste and 40 g of distilled water. The size of 2X2 cm of white cloth was used with three different types of stain such as chili sauce, soy sauce and lipstick. The clothes were then soaked in liquid soap for 6 hours and will be taken out every one hour for observation.

3. Results and Discussion

3.1 Physicochemical Characteristics of The Oils

The colour observations for both used and new cooking oil have been done and captured to see the difference. The used cooking oil colour is darker and more brownish compared to the new cooking oil which is lighter and yellowish.

New cooking oil has a slightly lower density than used cooking oil. NCO recorded a density of 0.909 g/cm^3 while UCO recorded a density of 0.912 g/cm^3. The difference for both oils is as much as 0.33%. The values were calculated using equation 1.

UCO and NCO have pH values of 6 and 5 respectively. NCO is slightly acidic due to the presence of free fatty acid and other minor acidic components.

Viscosity value for UCO is 120.0 mPa.s while for NCO is 80.0 mPa.s. The results show that viscosity of UCO is thicker compared to NCO. This happened because the viscosity of the frying medium during repeated frying can be expected to affect buoyant bubble removal from the food surface and, consequently, the convective heat transfer from the oil to the food that undergoes frying [7].

Both new and used cooking oil were tested for free fatty acid (FFA) content and calculated using equation 2, which measures the amount of free fatty acids present in the oil. The FFA test showed that new cooking oil has an FFA value of 2.56%, while used cooking oil has a higher FFA value of 5.12%. This increase in FFA content in used oil is due to the breakdown of triglycerides during cooking. When heated, triglycerides break down into glycerol and free fatty acids, and oxidative degradation also produces free fatty acid [8].

The saponification test measures the saponification value (SV), which indicates the amount of alkali needed to saponify a given quantity of fat or oil. The test results showed that the saponification value for new oil is 84.0 mg/g, while for used oil it is 56.0 mg/g. Both values were calculated using equation 3. Table 2 shows the physicochemical properties of both UCO and NCO.

Table 2 *Physicochemical properties of UCO and NCO*

Type of Oil	Colour	Density value (g/cm^3)	pH value	Viscosity value (mPa.s)	FFA value (%)	Saponification value (mg/g)
Used	Darker and brownish	0.912	6	120.0	5.12	56.0
New	Lighter and yellowish	0.909	5	80.0	2.56	84.0

Fourier transform infrared was used to identify the chemical properties and chemical bond in the oil. Notably, a strong peak is identified at approximately 2922 cm^{-1}, which assigned to (C-H) symmetrical and asymmetrical stretching of the saturated carbon-carbon bond [9]. Another prominent peak at around 1743 cm^{-1} corresponds to the C=O stretching vibration, further confirming the presence of the alcohol group in the molecule. In the fingerprint region below 1500 cm^{-1}, there are broad absorptions that reveal more about the overall molecular structure of the oil. According to Paulina et al [10], the band near 723 cm^{-1} is due to the overlapping of the $(CH_2)n$ rocking vibration and the out-of-plane vibration (CH wag) of cis-di-substituted olefins. The flat and consistent baseline of the spectrum indicates that the data is reliable, and the lack of significant shifts in peaks confirms the accuracy of the FTIR results. This thorough analysis of the FTIR spectrum for oil provides detailed information about its chemical composition and the functional groups present in the sample. Figure 1 displays the FTIR results for both UCO and NCO.

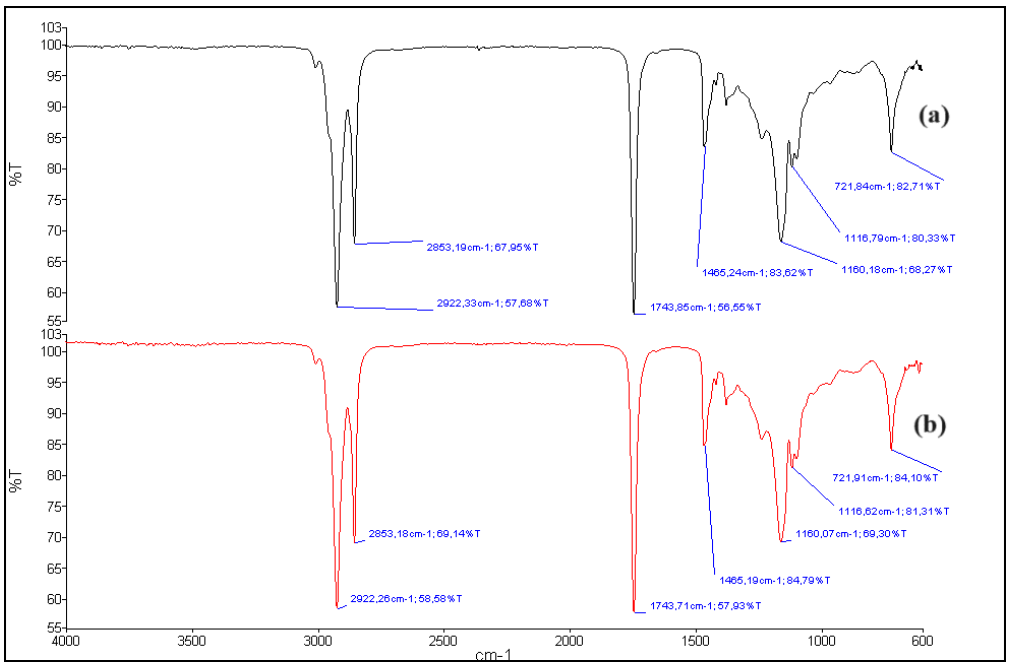


Fig. 1 *FTIR result for (a) new cooking oil (b) used cooking oil*

3.2 Characterization of Soap

For the soap analysis, different samples of soap are analyzed for its physicochemical properties in terms of color and appearance, pH value, FTIR and moisture content. The results were compiled and shown in Table 3.

Table 3 *Physicochemical properties of soap paste sample*

Sample	Color	pH value	Moisture content value (%)
UO1	Brown	10	39
UO2	Brown	10	19
UO3	Brown	10	26
UO4	Brown	10	26
NO1	Yellow	10	26
NO2	Yellow	10	30
NO3	Yellow	10	29
NO4	Yellow	10	15

FTIR was run again to identify the properties of the different samples of soap paste. All samples using UCO and NCO came with five peaks but for every peak, the range between all the samples is similar. The first peak shows a range of 3337 to 3379 cm^{-1} showing a broad of O-H stretching due to moisture or residual water in the soap paste. With the addition of lemon extract, the intensity of the O-H stretching peak increases due to the citric acid and other hydroxyl-containing compounds. The carbonyl region will also show increased absorption, reflecting the presence of citric acid and other carbonyl-containing components from lemon extract. The second and third peak, which fall in range 2800 to 3000 cm^{-1} displays typical C-H stretching absorptions from the fatty acids and oils in the soap paste. The C-H stretching peaks may become more pronounced or exhibit slight shifts with the increasing amount of lemon extract, indicating interaction between the soap base and lemon components. In the fingerprint region below 1500 cm^{-1}, there are presences of CH2 and CH3 bending vibrations at peak 1394 to 1405 cm^{-1}. Figures 2 and 3 show the FTIR result for all soap paste samples analysis.

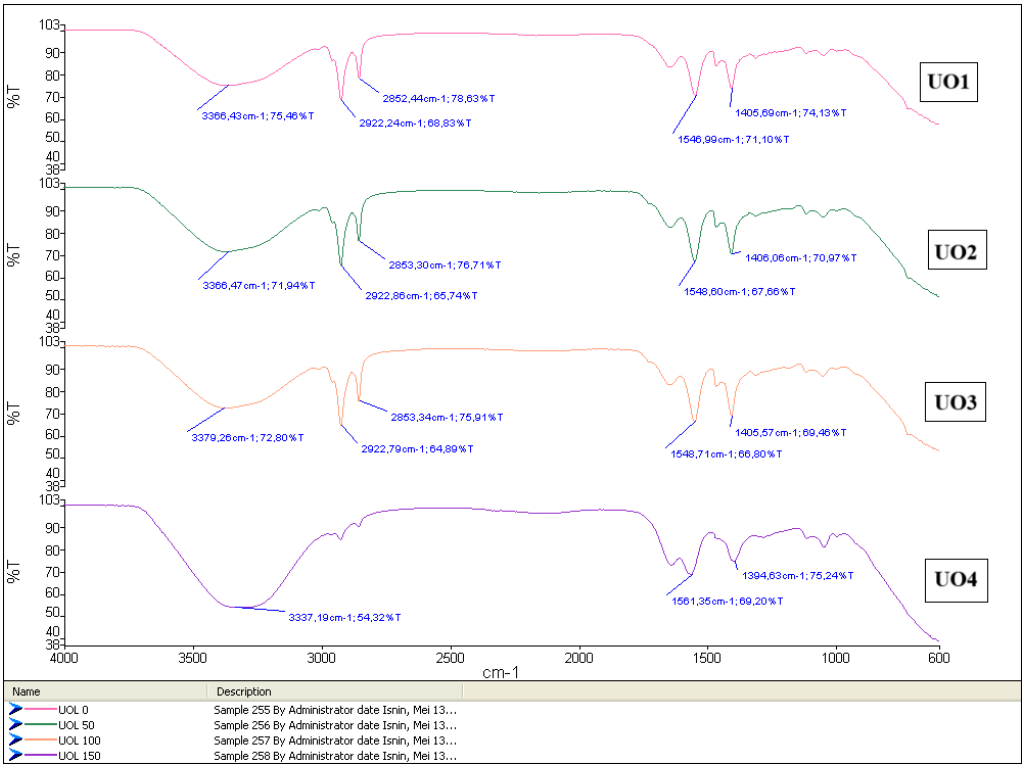


Fig. 2 *FTIR result for (UO1) used cooking oil with 0g lemon (UO2) used cooking oil with 50g lemon (UO3) used cooking oil with 100g lemon (UO4) used cooking oil with 150g lemon*

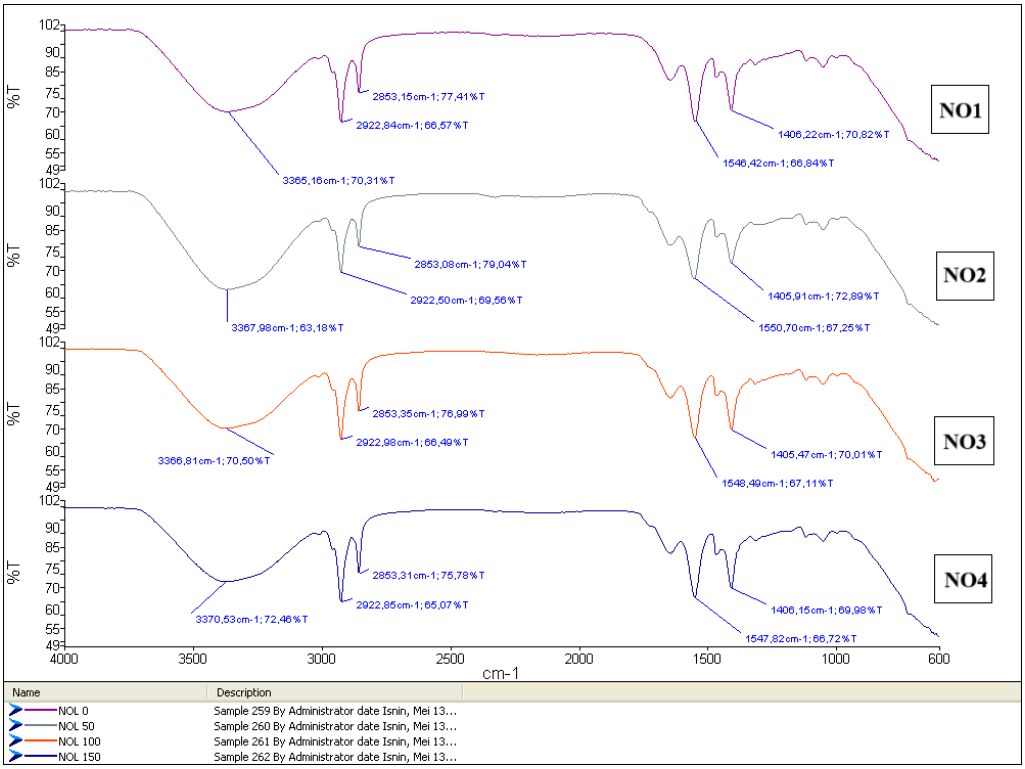


Fig. 3 *FTIR result for (NO1) new cooking oil with 0g lemon (NO2) new cooking oil with 50g lemon (NO3) new cooking oil with 100g lemon (NO4) new cooking oil with 150g lemon*

3.3 Soap Performance

To evaluate the soap's performance, an experiment focusing on cleaning power was conducted. Clothes were stained with chili sauce, soy sauce, and lipstick, and then left to dry. The stained clothes were soaked in containers filled with liquid soap from different samples and left to clean. After 6 hours, the clothes were removed, dried, and compared to the initially stained clothes. For chili sauce and soy sauce, the stains for all samples were fully removed as they come in natural ingredient making it easier to remove. For lipstick stain, it was not fully removed. According to Azme et al [5], lipstick stains were the hardest stain to clean with soap because they contained synthetic ingredients such as wax and oil combination that gave them smooth quality and it said that lipstick contain two main components which are oily and waxy substance and a colored dye making it harder to remove, especially from white clothing [11]. To remove the lipstick stain, it needs to be rubbed a few times. All the stains show similarity in result causing the presence of lemon extraction does not give any effect on stain removal efficiency thus can conclude that the amount of lemon extraction has no effect on the cleaning power of the soap. Table 4,5 and 6 shows the soap performance analysis for all the soap samples.

Table 4 *Liquid soap performance result for soy sauce*

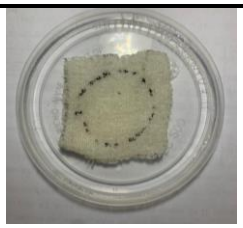
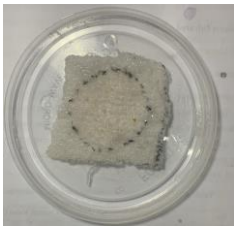
Sample	Before	After	Description
UCO			Stain was 100% removed
NCO			Stain was 100% removed

Table 5 *Liquid soap performance result for chili sauce*

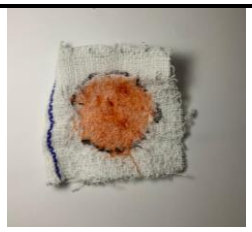
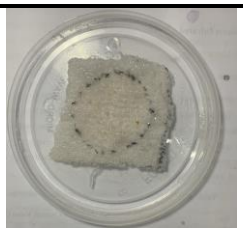
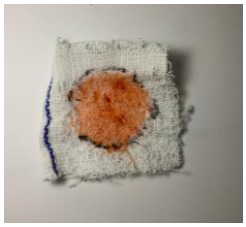
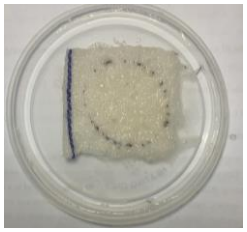
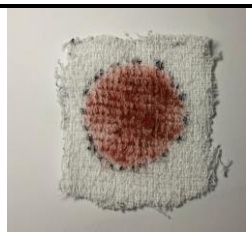
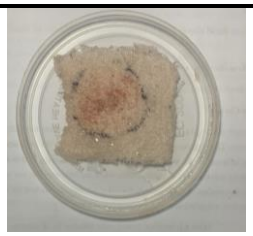
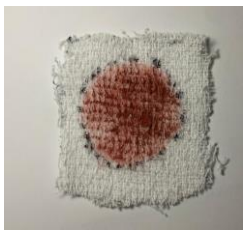
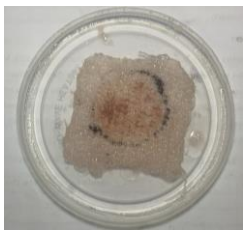
Sample	Before	After	Description
UCO			Stain was 100% removed
NCO			Stain was 100% removed

Table 6 *Liquid soap performance result for lipstick*

Sample	Before	After	Description
UCO			Stain was 80% removed
NCO			Stain was 80% removed

4. Conclusion

The environmental friendly soap from used cooking oil has been successfully produced. It was found that the presence of lemon extraction in the soap does not give any effect on the physicochemical properties and soap performance as all the samples show similarity in result. It is recommended that this study can purse higher by testing it antibacterial properties because lemon extraction contains acid citric and recognized as its good disinfecting properties. This demonstrates that adding lemon extract and using used cooking oil is just as effective as using new cooking oil. As a result, the goal of reducing environmental pollution can be achieved.

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References

[1] Statista Research Department (2024, February 27). Malaysia: Palm Oil Consumption 2023. Statista. https://www.statista.com/statistics/489441/palm-oil-consumption-malaysia/

[2] Foo, W. H., Chia, W. Y., Tang, D. Y. Y., Koay, S. S. N., Lim, S. S., & Chew, K. W. (2021). The conundrum of waste cooking oil: Transforming hazard into energy. Journal of Hazardous Materials, 417. https://doi.org/10.1016/j.jhazmat.2021.126129

[3] Foo, W. H., Koay, S. S. N., Chia, S. R., Chia, W. Y., Tang, D. Y. Y., Nomanbhay, S., & Chew, K. W. (2022). Recent advances in the conversion of waste cooking oil into value-added products: A review. *Fuel*, *324*. https://doi.org/10.1016/j.fuel.2022.124539

[4] Noronha, P. M. (2022, February 27). Transforming waste into soap. *Nature*. https://www.nature.com/articles/d41586-022-01817-6

[5] Azme, S. N. K., Yusoff, N. S. I. M., Chin, L. Y., Mohd, Y., Hamid, R. D., Jalil, M. N., Zaki, H. M., Saleh, S. H., Ahmat, N., Manan, M. A. F. A., Yury, N., Hum, N. N. F., Latif, F. A., & Zain, Z. M. (2023). Recycling waste cooking oil into soap: Knowledge transfer through community service learning. *Cleaner Waste Systems*, *4*. https://doi.org/10.1016/j.clwas.2023.100084

[6] Carrere, H., Antonopoulou, G., Affes, R., Passos, F., Battimelli, A., Lyberatos, G., & Ferrer, I. (2016). Review of feedstock pretreatment strategies for improved anaerobic digestion: From lab-scale research to full-scale application. In Bioresource Technology (Vol. 199, pp. 386–397). Elsevier Ltd. https://doi.org/10.1016/j.biortech.2015.09.007

[7] Kalogianni E.P, Karapantsios T.D, Miller R., Effect of repeated frying on the viscosity, density and dynamic interfacial tension of palm and olive oil, Journal of Food Engineering,Volume 105, Issue 1, 2011, Pages 169-179, ISSN 0260-8774, https://doi.org/10.1016/j.jfoodeng.2011.02.021.

[8] Goswami, G., Bora, R., & Singh Rathore, M. (2015). Oxidation of Cooking Oils due to Repeated Frying and Human Health. https://www.researchgate.net/publication/282701462

[9] Ullah, Z., Bustam, M. A., & Man, Z. (2014). Characterization of Waste Palm Cooking Oil for Biodiesel Production. *International Journal of Chemical Engineering and Applications*, *5*(2), 134–137. https://doi.org/10.7763/ijcea.2014.v5.366

[10] Mata P., Vidal A.D., Sendra J.M.B., Medina A.R., and Rodríguez L.C., "Olive oil assessment in edible oil blends by means of ATR-FTIR and chemometrics," Food Control, vol. 23, pp. 449-455, February 2012.

[11] Leverette, M. M. (2024, April 29). How to remove lipstick stains from clothing. The Spruce. https://www.thespruce.com/remove-lipstick-stains-from-clothes-and-upholstery-2147105#:~:text=Colored%20lipstick%20stains%20usually%20contain,since%20they%20have%20fewer%20dyes.