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The Effect of Water Ratio Variation in Soap from Cooking Oil

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Abstract

The rate at which various waste products, such as used cooking oil (UCO), are produced is rising in line with the global population growth. The process of making soap helps spread awareness to people about the dangers of disposing of used cooking oil in rivers or drainage systems. The study focused on production on soap from cooking oil using cold method process. The ratio of oil to water to alkali was changed to make six different kinds of soap which were (20:4:3, 20:6:3, 20:8:3) for both new and used cooking oil. The research on physicochemical properties of cooking oil have been found using four different types of tests: the pH value, the moisture content test, the density test, and the Fourier transform infrared (FT-IR). There are also three types of tests have been be used to determine the physicochemical properties of the soap that has been produced: the pH value, the measurement of the foam level and stability, and the Fourier transform infrared (FT-IR). The study analyses U4 (20:4:3) soap had the best foam stability and lowest foam losses, with 98.26% and 1.74% respectively. The pH test indicated that the soap produced was alkaline with the pH of 10. The strong present of C-CH3 and CH2 group also appeared during FT-IR analysis. Sample N6 with the ratio of (20:6:3) achieved the most effective cleaning power based on the result of a study on the performance of soap made from new and used cooking oil.

1. Introduction

Cooking oil is a common component of daily meal preparation. However, the production of large amounts of used cooking oil (UCO)is an unavoidable result of its widespread use. This phenomenon is found worldwide, with UCO generation taking place in almost every part of globe. Despite going attempts to decrease cooking oil use, a significant amount of UCO still requires appropriate management and disposal [1].

Instead of disposing of UCO as waste, there is an increasing interest in investigating its potential for valorisation (2,3). One of promising method for converting UCO is through soap production. Soap is chemically synthesised by combining fatty acids, obtained from fats or oils like UCO, with an alkali such as sodium hydroxide or potassium hydroxide. The process called saponification, produces soap molecules and glycerol as byproduct. [4].

This research work investigates the production of soap using the cold process method, comparing the use of both new and used cooking oil across various formations with different ratios of oil, water and alkali. The physicochemical properties of both cooking oil and the resulting soap were analysed using series of tests, including pH, moisture content, foam stability and FTIR spectroscopy. The optimal formulation for soap production are identified and assess its quality and cleaning effectiveness.

2. Materials and methods

The materials used in this research were new cooking oil (NCO) and used cooking oil (UCO), sodium hydroxide (NaOH) and distilled water as main materials in soap making process. The NCO was purchased at supermarket while the UCO was collected from house, and nearby restaurant in Parit Raja. The distilled water was gathered from Nanostructure and Surface Modification (Nanosurf) UTHM and the NaOH was obtained from Lab Biodiesel, UTHM. The sample of cooking oil and soap produced both underwent several investigations, which are FT-IR and pH tests. For oil determination, both new and used cooking oil were gone under moisture content and density determination while the soap produced were test on its foam level and stability and the cleaning power.

2.1 Soap preparation

The soap was made using cold process method. Since no outside heat was utilised to make the soap, it is known as the "cold process" [3]. The preparation process involves weighing 200g of cooking oil into a beaker. Next, adding 3g of NaOH to dissolved in distilled water. The mixture was stirred until homogeneous, as the NaOH mixes with the water, the temperature of the solution will rise in which then it was let cool to a lukewarm temperature before added to the oil mixture. The mixture was then placed into moulds, dried for 48 hours, and then collected for further analysis. The soap was then placed in moulds and analysed after three to four weeks. The processes were repeated with different water ratio to oil and NaOH and both new and used cooking oil. This process is called cold process method because there was no external heat were used during the soap production. The soap sample, made with varying water ratios, was analysed in an experiment, with 3 soaps made using NCO and 3 using UCO, and their respective codes listed as Table 1.

Table 1 Soap sample's code and its ratio

Code	Type of cooking oil	Ratio	Oil (g)	Water (g)	NaOH (g)
N4	New	N20:4:3	20	4	3
N6	New	N20:6:3	20	6	3
N8	New	N20:8:3	20	8	3
U4	Used	U20:4:3	20	4	3
U6	Used	U20:6:3	20	6	3
U8	Used	U20:8:3	20	8	3

2.2 Determination of cooking oil properties

The properties of cooking oil can be determined through various methods such as pH value, moisture content test, density test, and Fourier transform infrared (FT-IR).

2.2.1 Moisture content

A dry beaker containing 10 g of used cooking oil was filled, heated in an electric drying oven at 103±2°C for 1 hour, moved to the dryer, and then was allowed to cool at room temperature before getting weighted (precise to 0.001 g). At 30 minutes intervals, the stages of heating, cooling, and weighing were repeated. It was repeated until the difference between two consecutive weights was no greater than 4 mg. The samples' moisture contents were determined, and the average of three separate experiments was determined.

$$x = \frac{m_1 - m_2}{m_1 - m_0} \quad [1]$$

where m_0 is the mass of the empty beaker, g; m_1 is the total mass of the beaker and sample before heating; and m_2 is the total mass of the beaker and sample after heating; x is the moisture content, %.

2.2.2 Density determination

Using a micropipette, 1 mL of the oil sample was taken, placed in a dry conical flask, and weighed on an analytical balance.

$$\rho = \frac{m - m_0}{V} \qquad [2]$$

where ρ is the oil sample's density in g/mL, m is the oil sample's mass in g, m_0 is the conical flask's mass in g, and V is the oil sample's volume in ml.

2.3 Determination of soap properties

The soap properties were assessed through various experiments, including pH value, foam level and stability, and Fourier transform infrared (FT-IR), with each details provided.

2.3.1 pH value

The surface of the soap sample was wet with water, then swab the wet portion of the soap with the pH paper. After around 3 seconds, wait and check the colour produced on the pH paper and compare it with the indicator pads. The figure 3.2 indicates the colour indicator and its pH value.

2.3.2 Foam level and stability

1 g of soap sample was dissolved in distilled water and diluted in a 10 ml test tube which was shaken for a minute and the foam volume was measured after. The height of foam formed was measured using a ruler (initial foam height). The height of the foam was measured again after a few minutes (high foam end).

Foam Stability = 100% - % Foam Loss (3)

% Foam Loss = (High initial foam – High final foam) / (High initial foam) x 100% (4)

2.3.3 Fourier Transform Infrared (FT-IR)

The FT-IR spectrum of a sample soap was analysed to identify functional groups and chemical makeup. The sample was placed on the sample holder, and the baseline was adjusted to account for background movement or instrument response differences. The spectrum was analysed to identify distinctive patterns and peaks, which are then compared to databases or reference spectra to understand the molecular structure of the material. The findings are then analysed in accordance with the sample's chemical makeup and data requirements.

3. Results and Discussion

In the context of soap making, results and data analysis refer to the observations and measurements made during the soap making process and the process of examining the physicochemical of the cooking oil and soap produced.

3.1 Oil Determination

The pH level of a substance is crucial for its safety, chemical reactivity, and environmental impact. Based on Table 2, the new cooking oil tested had a slightly acidic pH of around 6, while the used oil had a pH around 5. The moisture content of the new oil was 0.077%, lower than the used oil's 0.107%. This is due to the higher steam produced during cooking, which increases the moisture content. The density of both oils was higher in the used cooking oil compared to the new oil. This is due to the thermolytic process that converts saturated fatty acid into unsaturated fatty acid, increasing the density in UCO and NCO as the frequency of frying increased. The rising density may be due to the moisture content from the steam and heterogeneous contaminants created during the cooking process. Overall, the moisture content and density of the oils are essential factors in determining their quality and safety.

Table 2 The Oil Determination

Sample	New cooking oil	Used cooking oil
pH	6	5
Moisture Content (%)	0.077	0.107
Density (kg/L)	0.8848	0.89680

Based on Figure 1 and Table 3, it shows the FTIR spectrum of the NCO and UCO, where there is 4 peak that were analysed. There are also group $C-CH_3$ detected in the range of 2652-2972 cm^{-1} and 2843-2863 cm^{-1}. Then, the group of CH_2 were also found in between 2843-2863 cm^{-1}. The other two group were conjugated at peak between 1590-1750 cm^{-1} and the nonconjugated at 1700-1900 cm^{-1}.

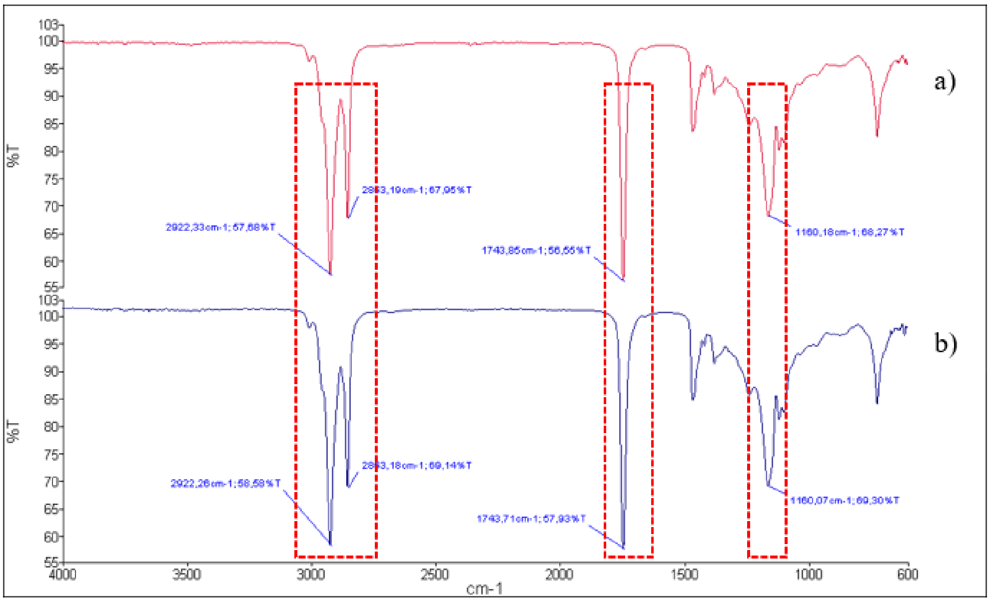


Fig. 1 IR spectra of the a) New cooking oil b) Used cooking oil

Table 3 The FT-IR spectra over the range 600-4000 $cm^{-1}$for (a) new and (b) used cooking oil

Frequency Range (cm^{-1})	Group
2652-2972	$C-CH_3$
2843-2863	$C-CH_3$ & CH_2
1590-1750	Conjugated
1700-1900	Nonconjugated

3.2 Soap Determination

Based on Table 4, the colour of cooking oil soap samples varies depending on the amount of FFA present. New cooking oil produces a pale or white soap, while used oil has a slightly orange colour. The colour darkens as cooking time increases due to the combination of brown pigment from food and oxidation and polymerization of unsaturated fatty acids in the frying medium. Longer frying frequency leads to a higher percentage of FFA content, resulting in a deeper oil colour [5]. The soap samples for N20:4:3, U20:4:3, and U20:6:3 is hard, while N20:6:3, and U20:8:3 is firm. All samples have a lye pocket present.

Table 4 The soap determination

Sample	N20:4:3	N20:6:3	N20:8:3	U20:4:3	U20:6:3	U20:8:3
Appearance						
Colour	White	White	White	Slightly orange	Slightly orange	Slightly orange
Texture	Hard	Firm	Soft	Hard	Hard	Firm
Lye pocket	Present	Present	Present	Present	Present	Present

The results from Figure 2 and Figure 3 show the foam loss and stability testing revealed that sample N4 had the highest foam loss of 2.78%, while sample U4 had the highest stability of 97.22%. The foam level and stability of the samples were compared, with U4 containing 40g of water showing the best stability.

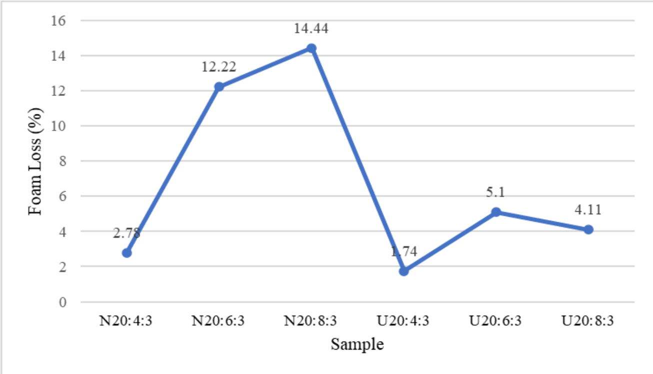


Fig. 2 The graph of Foam Loss

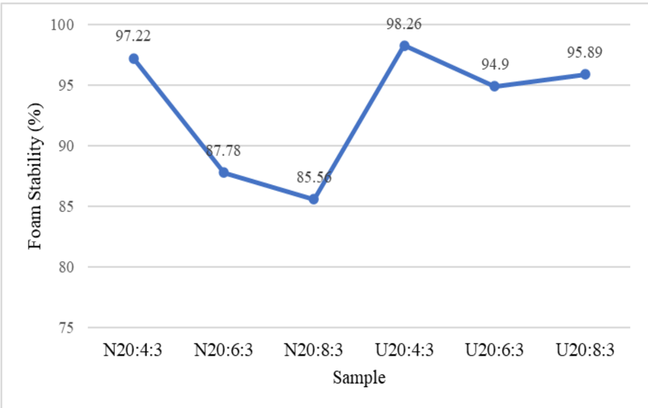


Fig. 3 The graph of Foam Stability

The pH test was conducted to determine the value of the handmade soap produced from the 1st week to the 5th week. Based on Table 5, during the second week, only samples N4 and N6 maintained a pH of around 11, while the other sample decreased to 10. This decrease can be attributed to the breakdown of triglycerides and increased free fatty acids.

Table 5 Soap's pH weekly result

Sample	W1	W2	W3	W4	W5
N20:4:3	11	11	10	10	10
N20:6:3	11	11	10	10	10
N20:8:3	11	10	10	10	10
U20:4:3	11	10	10	10	10
U20:6:3	11	10	10	10	10
U20:8:3	11	10	10	10	10

Based on Figure 4 and Table 6, the soaps produced have identical peaks with a slightly vary values. The soap is mainly contained group of alkenes CH_2 where they are found in all other three peaks which are between 2916-2936 cm^{-1}, 2843-2863 cm^{-1} and 1405-1465 cm^{-1}. Other functional group peaks in soaps, such as stretching vibration $C-CH_3$ were also detected in the range of 2652-2972 cm^{-1}.

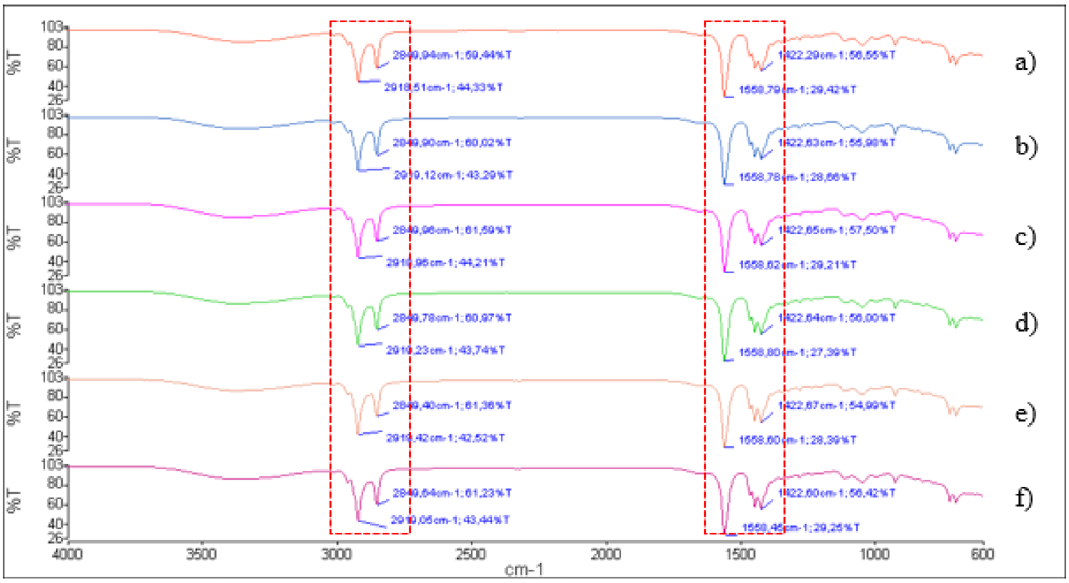


Fig. 4 IR spectra of the a) N4 b) N6 c) N8 d) U4 e) U6 f) U8

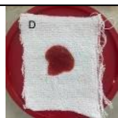
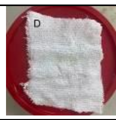
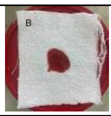
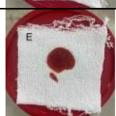
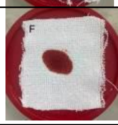
Table 6 The FT-IR spectra over the range 600-4000 cm^{-1} for all soap produced

Frequency Range (cm^{-1})	**Group**
2652-2972	$C-CH_3$
2916-2936	CH_2
2843-2863	CH_2
1405-1465	CH_2

3.3 Soap Performance

The soap performance of stained cloths was observed after they were soaked in soapy water made with homemade soap. Based on Table 7, the cloths were ranked from best to least clean performance, with the best cleaning performance observed at a water ratio of 20:6:3 for both new and used cooking oil. The hydrophobic end of soap molecules plays a crucial role in stain removal. It dissolves in water, attracts water, and repels water. The hydrophilic head of the soap molecule points towards water, while the hydrophobic tail attaches to stains, forming micelles that effectively remove stains in water [7].

Table 7 Results of before and after soap performance

Sample (Code)	Before	After	Description	Percentage of stain removed (%)	Sample (Code)	Before	After	Description	Percentage of stain removed (%)
N20:4:3 (N4)			Few stains left	95	U20:4:3 (U4)			Few stains left	88
N20:6:3 (N6)			No stain residue	98	U20:6:3 (U6)			Few stains left	90
N20:8:3 (N8)			Few stains left	97	U20:8:3 (U8)			Few stains left	85

4. Conclusion

The study successfully produced soap from used cooking oil using a cold process method. Tests were conducted to determine the effect of water ratio variation on soap properties, including pH, foam level, stability, and Fourier transform infrared (FT-IR). The pH test indicated that the soap was basic, with a pH level 10. The foam stability test showed that U4 had the best foam stability and lowest foam losses. The FT-IR test revealed that N6 had the best cleaning power, with no residue left and 98% of stains removed. The study concluded that used cooking oil with different water ratios can be used as soap but cannot surpass the soap produced by new cooking oil, which has better appearance, colour, texture, and cleaning power. This suggests that soap production with different water ratios could be used in the absence of commercial soap.

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