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Eco-friendly Detergent Powder from Waste Cooking Oil using Cold Process: Characterisation and Comparative Evaluation

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ABSTRACT

The appropriate disposal of waste cooking oil (WCO) is an urgent environmental concern due to its potential adverse impacts. This study introduces an eco-friendly approach to synthesise detergent powder from WCO using the cold process method. The WCO underwent comprehensive sand characterisation, including pH value, viscosity measurements, and colour observation, revealing properties comparable to new cooking oil (NCO). The detergent powder produced, DWCO (from WCO) and DNCO (from NCO), was compared to a commercial detergent powder (CDP) through a comprehensive evaluation. Fourier-Transform Infrared Spectroscopy (FTIR) analysis revealed characteristics of C−H bonding and O−H bonding in the samples. The detergent foam stability test indicated similar performance for DWCO and DNCO, with a volume loss of 54% and 35%, respectively, after 30 minutes. This study contributes to the sustainable management of WCO by transforming it into eco-friendly detergent powder with comparable performance to commercial alternatives. The utilisation of waste resources in detergent production offers a promising solution for responsible waste disposal and encourages the adoption of green practices in the detergent industry.

Keywords: *Waste Cooking Oil, Cold Process, Characterization, Foam Stability*

1. INTRODUCTION

The skin, the body's largest organ, serves as a physical barrier between the body and various contaminants in the environment. When soaps, shampoos, and cosmetics are applied to the skin, the components in them come into direct contact with the skin. Soap or detergent powder is a chemical compound that consists of Na+ or K+ ions and fatty acids [1]. Today, over a hundred fatty acids are known to exist.

Proper waste oil disposal is critical since waste cooking oil (WCO) has the potential to cause environmental and municipal problems. This study aim to synthesise detergent powder from waste cooking oil using the cold process method, to evaluate the physiochemistry of oil used in terms of the effect of oil pH value, oil physical observation and viscosity measurement and to investigate and compare the detergent powder produced and the commercial detergent powder in term of foam stability, FTIR and moisture content.

WCO used as a raw material in the fabrication and characterisation of the detergent powder significantly affecting the physiochemical properties of the detergent powder. The WCO is collected from several frying shops and sieved through a filter to remove any particulates, dirts or other suspended materials that might be present [2].

Sodium hydroxide (NaOH) is often used for the preparation of detergent powder that is frequently referred to as lye solution. When dissolved in the water or neutralised with acid, it emits significant quantities of heat, which may be enough to ignite flammable objects. Soap manufacture using the cold process method in this project study has been created by adding lye and water with oils and vigorously mixing them simultaneously.

In a process known as saponification, the lye combines chemically with the oil combination to form soap. The saponification process is completed once the soap has been allowed to cure for at least a month. Saponification occurs when triglycerides are mixed with a strong base to generate fatty acid metal salts. The hardness, aroma, cleansing, lather, and moisturising abilities of soaps are all determined by the distribution of unsaturated and saturated fatty acids [3]. Figure 1 shows the general saponification reaction [4]. Saponification is a chemical reaction in which sodium hydroxide (lye) breaks down a fat molecule into four smaller molecules, three of which are soap and one of which is glycerol. The advantage of cold-process handmade soap is that the soap contains no synthetic or harsh components. Any additive material, such as milk can be mixed with soap since the saponification process can be controlled [5].

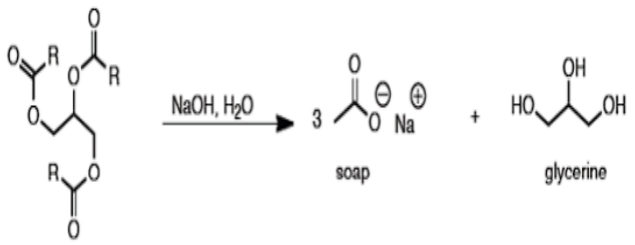

Figure 1. Distribution of unsaturated and saturated fatty acids [3].

2. MATERIAL AND METHODS

The research utilised new cooking oil (NCO, Buruh), filtered waste cooking oil (WCO, Wajan Caterer Sdn Bhd), sodium hydroxide (NaOH, Merck), and distilled water as primary components for soap production. Borax ($Na_2[B_4O_5(OH)_4].8H_2O$), sodium bicarbonate ($NaHCO_3$), and soda carbonate (Na_2CO_3) from So Fast Empire (M) Sdn Bhd were utilised in the production of detergent powder.

2.1. Bar Soap Preparation

The experiment entails creating bar soap using the saponification method, employing a cold process with a sodium hydroxide (NaOH) solution, often known as lye solution [6]. To ensure safety, it was essential to wear long sleeves, nitrile gloves, and goggles when handling NaOH, as it was very reactive and corrosive, releasing fumes when in contact with water. The process commences by accurately measuring 500g of new cooking oil (NCO) and 74g of NaOH separately, while ensuring dry conditions were maintained. 148g of distilled water was used to dilute NaOH in a fume hood until it reaches a lower temperature. The diluted NaOH solution was added to the cooking oil and stirred with a hand blender until a thick mixture was formed. The mixture was put into the rectangular silicone soap mold and allowed to sit overnight. The bar soap was taken out of the mold and left at room temperature for 4 weeks to finalise the saponification process. The bar soap was gradually solidified as the saponification process takes place, eventually resulting in hardened soap bars. The procedure was replicated using waste cooking oil (WCO).

2.2. Detergent Powder Preparation

The prepared bar soap was fragmented into small pieces and cut into thin slices to facilitate the blending of soap, borax powder, sodium bicarbonate, and soda carbonate. 22 grams of each powder were mixed with 22 grams of sliced soap until the combination was homogeneous, requiring high-speed mixing to provide a smooth texture for the detergent powder. The detergent powder's texture is improved by placing the particles in a detergent container and combining them using a mixing machine. The detergent powder made from NCO was labelled as DNCO, and the one made from WCO was labelled as DWCO. Commercial detergent powder (CDP) was used for comparison.

2.3. Oil and Detergent Powder Characterisation

The rheological characteristics of the non-Newtonian materials were evaluated using the ASTM D2196 Standard test technique employing a rotating viscometer. Specifically, a viscometer equipped with an LV-2 (62) spindle operating at 100 RPM was utilised for viscosity measurement. A 1000 ml beaker was employed to contain 1000 ml of cooking oil, ensuring that the oil level reached at least half of the spindle height. Viscosity measurements were conducted at five-minute intervals for five measures to derive an average value for viscosity assessment.

The pH of detergent powder solution and oil was measured using Hanna Instruments edge pH digital sensors, calibrated for accuracy. Calibration buffers of pH 7.01 and pH 4.01 were used for acidic samples, while pH 7.01 and pH 10.01 were used for alkaline samples. The electrode was immersed in each solution, gently agitated until stable, and the pH was recorded.

2.4. FTIR

The ATR-FTIR analysis was conducted using a PerkinElmer 100 equipment in accordance with ASTM E168 and ASTM E1252 standards. The samples were placed in the sample cell, dried using nitrogen, and analysed using scanning parameters defining a wavenumber range of 4000-500 cm-1, a mirror velocity of 0.32 cm-1, and a spectral resolution of 4 cm-1. Pressure was used to compact the samples, improving the clarity and accuracy of the graph.

2.5. Foam Stability Measurement

10 grams of detergent were mixed with 200 mL of water to create a detergent powder solution in a beaker, generating foam. Subsequently, the solution was subjected to the OMNI macro-ES homogeniser, with the spindle immersed in the solution, operating at 19000 RPM for 1 minute to produce foam. Following this, the foam was left undisturbed for 10 minutes to ensure the stability of water and foam content. After a 30-minute interval, the foam volume was recorded to analyse changes in foam volume over time. Eq. 1 that was used to study the foaming stability is as follows.

$$FS\ (\%) = (V_f/V_i) \times 100\ \% \quad (1)$$

Where, FS = foam stability, V_f = value of foam after 30 minutes, V_i= initial value of foam.

2.6. Moisture Content Measurement

The moisture content of all the detergent powder under consideration was assessed using a well-established relationship [1]. Each sample, weighing 125 grams, was spread evenly on a clean, dry laboratory plate and dried in an oven at 105°C for one hour. After cooling to room temperature, the samples were weighed, and the moisture content was calculated using Equation 2, where weight loss indicates moisture content.

$M_c(\%) = (w_d/w_w)\ X\ 100\%$ (2)

Where, M_C = Moisture content, w_d = dried weight, w_w= wet weight.

3. RESULTS AND DISCUSSION

A few tests and analysis were done on the DWCO, DNCO, and CDP samples. The oil characterisation test has been done before performing the analysis test, which is viscosity measurement test, oil colour observation and FTIR test. Detergent powder analysis test has conducted three tests, which are detergent FTIR analysis, foam stability analysis and moisture content analysis.

3.1. Oil Characterisation

Characterisation of the WCO and NCO in the creation of detergent powder has an impact on the detergent structure. When cooking oils are utilised in the frying process, they are subjected to extremely high temperatures in the presence of moisture and air. These circumstances cause complicated chemical processes that reduce the quality and nutritional content of the used cooking oil. The repetitive frying process then modifies fats through a variety of chemical events such as oxidation, hydrolysis, and polymerisation. Figure 2 shows the different colour of WCO and NCO samples. Through colour observation, it was determined that WCO had a darker hue than NCO. The increased quantities of free fatty acids and darker oil may be a result of the frying process, which includes substantial hydrolysis interactions between triglycerides and moisture content in meals (8-10).

Figure 2. The different colour of cooking oil. (a) WCO, (b) NCO.

Figure 3 shows both NCO and WCO did not have a significantly difference since the ingredients used in the manufacturing of oil are identical. The figure identified the first peak for NCO and WCO in the range of 2922 cm^{-1} was $C-H$ of bonding with the strong alkane of a functional group, which is the infrared spectrum of toluene. The second peak in the range of 1743 cm^{-1} was $C=O$ of bonding with strong anhydride of a functional group, which is the infrared spectrum of ethyl benzoate. The third peak in the range of 1160 cm^{-1} was $C-O$ of bonding with the strong ether of the functional group, which is the infrared spectrum of ethanol.

Table 1 shows the result of WCO and NCO viscosity measurement. The viscosity of WCO is significantly higher than the NCO, with the average value for WCO becoming 79.1 cP with 26.4% of torque and the average value for NCO 76.7 cP with 25.5% of torque. The probability that WCO has been used twice or more is considerable, causing an increased viscosity of the oil compared to new oil that has not yet been used.. Through colour observation, it was determined that WCO had a darker hue than NCO. The increased quantities of free fatty acids and darker oil may be a result of the frying process, which includes substantial hydrolysis interactions between triglycerides and moisture content in meals [8-10].

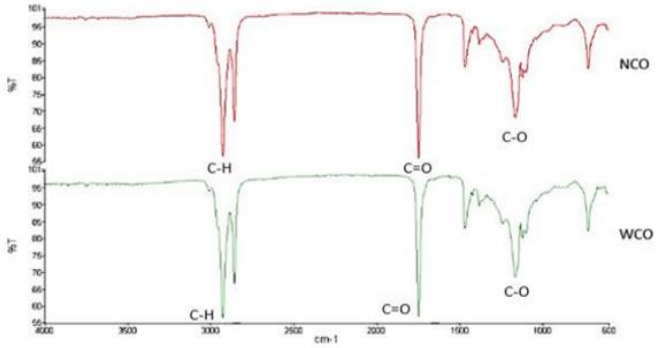

Figure 3. ATR-FTIR cooking oil.

Table 1 The result of WCO and NCO viscosity measurement

Sample	Speed (RPM)	Viscosity (cP)	pH Value
WCO	100	79.1	6.51
NCO	100	76.7	6.35

3.2. Detergent Powder Characterisation

Table 2 summarises the detergent powder's properties, which shows that the pH is in the 9-10 range. The pH values of the DWCO and DNCO samples are like those of commercial detergents, which typically range between 8 and 10. A pH exceeding 11 can be harsh on the skin, causing irritation. Still, a pH below 8 is not suited for handcrafted soap since it lacks cleansing power and is also not beneficial for the skin, potentially causing discomfort [11]. High pH levels, in combination with the presence of linear alkyl benzene sulfonate, might weaken skin's protective barrier, increase permeability, and possibly result in conditions such as hand eczema, causing significant discomfort and impairment.

Colour observation and moisture of content of the detergent powder solution is also shown in Table 2. Commercial detergent powder (CDP) became pink colour after mixed with water because the detergent powder was contained colouring chemicals rather than DWCO and DNCO, which synthesised using essential detergent

powder raw material without a mixture of additives such as colourant and fragrances. Meanwhile, both samples (DWCO and DNCO) have a similar moisture content, measuring 1.38% and 1.39%, respectively, showing a slight difference. The results may not be directly applicable to CDP due to potential differences in moisture content resulting from variances in production procedures.

Table 2 The pH value and powder observation

Sample	pH value	Moisture content (%)	Colour of soluble detergent in water
DWCO	9.76	1.38	white
DNCO	9.66	1.39	white
CDP	9.00	0.20	pink

Figure 4 shows the FTIR analysis using the ATR method. It was found that the first peak for each sample in the range of 2924.55 cm^{-1} to 2919.10 cm^{-1} was C–H bonding with a strong alkane of a functional group, which is the infrared spectrum of toluene. It was identified as sodium carbonate salt because free alkali in soaps usually consist of hydroxide and carbonate of sodium. The free caustic alkali is the hydroxide and is usually expressed as Na_2O. The second peak for DNCO and DWCO samples in the range of 1558.63 cm^{-1} was N–O bonding with a strong nitro compound of the functional group, which is the infrared spectrum of nitromethane. The second peak for CDP and the third peak of DNCO and DWCO sample in the range of 1425 cm^{-1} to 1397 cm^{-1} was $O–H$ of bonding with a medium carboxylic acid of the functional group which is an infrared spectrum of hexanoic acid.

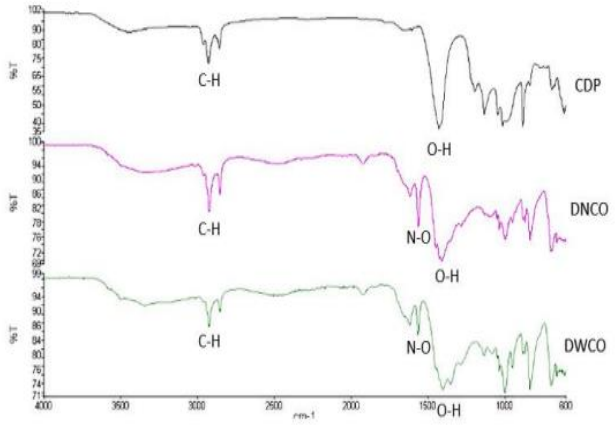

Figure 4: ATR-FTIR detergent powder.

3.3. Foam Stability Analysis

Foam stability occurs in three temporal levels for DWCO and two phases for detergent powder of DNCO and CDP, as depicted in Figure 5. When foam is produced using a homogeniser machine, the initial step is known as foaming, and all samples create foam with varying levels of foam stability. In the first level, the measurement of foam stability based on the height of the foam is taken on a pad every 30 minutes when the foam starts to collapse while drainage is still taking place. Total height continues to decrease with time. The time corresponding to the end of drainage is referred to as the transition time, indicates the formation of a stable amount of foam. The second level is known as drainage, and it happens when liquid runs out of the foam column without damaging it. The total height remains unchanged currently. This is since the drop in foam column height is perfectly matched by the increase in liquid column height. The third level, foam is unaffected by destructive processes such as gravity drainage and coalescence, which is the process by which sol particles dissolve and redeposit themselves on the surfaces of larger sol particles.

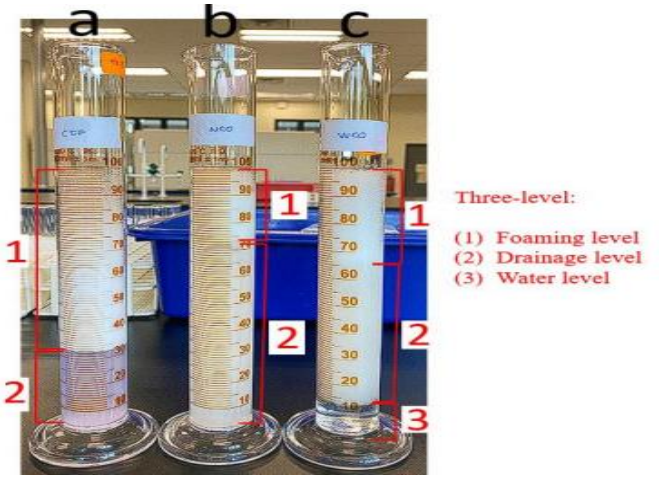

Figure 5. Level of foam of (a) CDP, (b) DNCO and (c) DWCO.

Figure 6 shows the foam stability performance for all samples. During the initial foaming stages, stable static foam is formed. but after 30 minutes, DWCO experiences a 54% decline, and DNCO sees a 35% drop in foam volume. Meanwhile, CDP maintains a stable 92% foam over 60 minutes. This could be attributed to the inclusion of other surfactants and stabilisers in the production of commercial detergent to uphold its lathering properties. Fameau and Fujii suggested that the stability of a foam can be altered by a stimulus that modifies solution conditions (pH, temperature, and ionic strength) or by applying an external field (light and magnetic) [12].

While DWCO exhibits the lowest foaming capacity, it is essential to note that the quality of soap foam is not the primary consideration here. The height and stability of foam are more related to consumer perception and aesthetic preferences rather than the cleaning efficacy of the soap. The foaming ability of soap products can be influenced by factors like unsaturated chemicals, oil combinations, and the type of water used [13]. For instance, soap derived from palm oil can generate abundant foam in water with high salt or alkali content. Lauric acid and myristic acid contribute to soft foam, while palmitic and stearic acids play a role in foam stabilisation. Oleic acid and linoleic acid, on the other hand, contribute to both the stability and softness of foam [14].

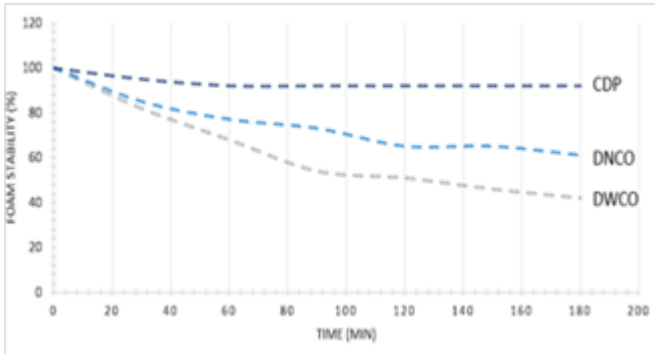

Figure 6. Percentage of foam stability of detergent powder for DWCO, DNCO and CDP.

4. CONCLUSION

The eco-friendly detergent powder from waste cooking oil, utilising a cold process technique was successfully synthesised. This method demonstrates promise as an environmentally sustainable solution and economic potential. A comparative study of the characteristics and foam performance of waste cooking oil and new cooking oil revealed minimal differences. DWCO exhibited characteristics including a pH range of 9-10, a white colour, and a foam height of 35 cm. Future research endeavours can explore opportunities for refinement by investigating a diverse range of builders, encompassing inorganic, organic, and polymer-based additives, as well as the integration of enzymes and other innovative components. These efforts aim to optimise WCO production and its environmental sustainability, contributing to a greener and more economically viable future for the detergent manufacturing industry.

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