SYNTHESISING KOJIC PALMITATE NONIONIC SURFACTANTS AS AN ALTERNATIVE APPROACH TO REMOVE ENVIRONMENTALLY POLLUTING COOKING OIL

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Abstract: Non-ionic compared with charged surfactants have many advantages, such as hard water tolerant, and are therefore, widely used in many applications such as detergents. However, most synthetic non-ionic surfactants are non-biodegradable and harmful to aquatic organisms. Discarded cooking oil waste on the other hand, has contributed to environmental pollution and is also harmful to aquatic organisms due to the inability of oxygen to penetrate through the oil layer. In this study, biodegradable non-ionic surfactant was synthesised via esterification between palmitoyl chloride and kojic acid; the synthesis was later applied to remove cooking oil via cloud point extraction. The FTIR spectrum shows stretching bands, such as v(C=O) ester and v(C-O) ester at 1,697.77 cm^{-1} and 1,187.06 cm^{-1} respectively suggesting the successful formation of the compound and further confirmed with 13C NMR spectrum of the ester carbon (=C-O) signal observed at 168.59 ppm. The physicochemical properties of the synthesised surfactant showed typical critical micelle concentration (CMC) of 0.3% for non-ionic surfactants, emulsion stability (72.32%), and cloud point (60°C). The optimum removal of cooking oil (68.55%) was at surfactant concentration 0.4% (w/v) and mixing speed 2,500 rpm at 65°C. The findings of this study showed a promising environmentally friendly non-ionic surfactant which is a good alternative approach in eliminating waste cooking oil.

Keywords: Kojic acid, non-ionic surfactant, waste cooking oil, environmental pollution.

Introduction

Cooking oil wastes are daily domestic waste produced from culinary food with eatable vegetable oils and are recognised as harmful waste to the environment (Permadani *et al*., 2018; Mannu *et al*., 2020). During frying, cooking oils are contaminated by free fatty acids (FFA), heterocyclic compounds, Maillard reaction products (MRP), and metal traces, which are released from cooking pads and food (Mannu *et al*., 2020). Since oil has insoluble properties, the discharge of improperly treated cooking oil into the environment causes environmental pollution, namely soil and water. The water surfaces are covered by layers of oil. Oxygen cannot dissolve in water which leads to the reduction of dissolved oxygen in water, which is required by aquatic organisms to sustain their life. As marine life continuously dies, the risk of extinction of species increases (Hanish *et al*., 2013; Abd El-Gawad, 2014). Many studies have focused on the removal of oil contaminants using physical, chemical, and biological techniques. However, these conventional methods do not address environmental issues, instead they contribute to secondary pollution.

Recently, Cloud Point Extraction (CPE) has been reported as one of the most efficient and simplest extraction techniques where it uses green surfactant to extract organic and inorganic components from water. It is a cheap and eco-green method, which was first invented by Watanabe and Tanaka (Hussain & Keçili, 2020). Additionally, the use of non-ionic surfactants in CPE are considered eco-friendly and assist in removing cooking oil waste. According to Nurdin *et al*. (2016), the usage of

surfactants in cooking oil removal is attributed to their ability to modify the surface and interfacial properties of a liquid. Few organic compounds have been utilised as non-ionic surfactants, such as gallic acid, stearic acid, and palmitic acid. The usage of organic compounds, as non-ionic surfactants, is considered to be cheaper, mild, safe, effective, and has no impact on the environment (Piispanen, 2002; Kandeel, 2012).

Organic compounds such as kojic acid are produced by fungal fermentation, namely *Asperigillus* sp. and *Penicillium* sp. (El-Boulifi *et al.*, 2014). El-Boulifi *et al.* (2014) reported that kojic acid is water-soluble and unstable at high temperatures. In the presence of organic solvents, kojic acid undergoes an esterification reaction with fatty acids, such as stearic acid and palmitic acid to improve its stability, compatibility, and oil solubility (El-Boulifi *et al.*, 2014). Kojic acid and its derivatives have attracted attention, and intensive research has been conducted due to its important applications in many fields, such as agriculture, cosmetics, food, industry, medicine, and pharmacology (Aziz *et al.*, 2017; Lassfolk *et al.*, 2019). However, there are limited research available on the synthesis of kojic acid-based as non-ionic surfactants. In addition, other reported applications of non-ionic surfactants is for the removal of heavy metals, enhancing oil recovery, microbe removal and crude oil removal from soil (Urum *et al.*, 2004; Medrzycka *et al.*, 2009; Jensen *et al.*, 2017; Yin *et al.*, 2017).

In this study, kojic acid and palmitoyl chloride were used as biodegradable starting materials via esterification to produce non-ionic surfactant. The structure of synthesised kojic palmitate based non-ionic surfactant was determined by Fourier Transform Infrared Spectrometry (FTIR), proton nuclear magnetic resonance (^{1}H NMR), and Carbon-13 Nuclear Magnetic Resonance (^{13}C NMR). The synthesised kojic acid-based surfactant's properties, such as critical micelle concentration (CMC), cloud point, and emulsion stability were determined. The parameters used to investigate the effectiveness of kojic acid-based surfactant in waste cooking oil removal, are the concentration of non-ionic surfactants, temperature, and mixing speed.

Materials and Methods

Chemicals and Reagents

Chemicals and reagents used in this study were used without any further purification while ethanol was distilled prior to usage. Kojic acid and palmitoyl chloride were used as starting materials to synthesise non-ionic surfactant. Distilled ethanol and potassium hydroxide (KOH) were used in the synthesis pathway, as solvent and catalyst respectively. Potassium bromide (KBr) powder was compressed into KBr discs and used for FTIR spectra of the synthesised compound. ^{1}H NMR and ^{13}C NMR spectra were recorded by using Deuterated dimethyl sulfoxide (DMSO-d$_6$) as a solvent in NMR spectroscopy. The elemental analysis of carbon hydrogen nitrogen sulphur (CHNS) was conducted using Thermo Scientific™ Flash 2000 CHNS/O Analyser. The water used in this study was double distilled and deionised. The vegetable cooking oil (Vesawit) was purchased from the local supermarket and used for Cloud Point Extraction (CPE) for the application of cooking oil removal.

Synthesis of Kojic Palmitate Non-ionic Surfactant

A ratio of 1:1 mol of kojic acid (1.4251 g) and palmitoyl chloride (2.7500 g) was weighed accurately and esterified in a reflux condenser with few drops of a base catalyst (10% KOH solution) and ethanol (20 mL) as solvent for not less than 24 hours. After esterification, the reaction mixture was allowed to cool at room temperature before being transferred into separatory funnel and left for at least 24 hours to form two immiscible layers of organic layer and the salt. In order to obtain the non-ionic surfactant, the organic layer was evaporated under reduced pressure and dried in the oven. The synthesised kojic palmitate was elucidated via FTIR, ^{1}H NMR and ^{13}C NMR.

Kojic palmate surfactant: 5-Hydroxy-4-oxo-4H-pyran-2-yl) methyl palmitate: Solid, white colour, mp = 76.2 ±1°C, yield = 2.55 g (67.28%), CHNS: (Found: C, 67.3%; H 8.91% $C_{22}H_{36}O_5$, Theoretical: C 69.44%; H 9.54%). IR (cm^{-1}): 3152.23 (v_{O-H}) 2914.45 - 2846.48 (v_{C-H} stretching of aliphatic fatty chain), 1697.77 ($v_{C=O}$ of ester), 1187.06 (v_{C-O}). (500 MHz, DMSO-d$_6$): 7.977 (s, 1H, alpha CH=CH), 6.292 (s, 1H, beta CH=CH), 4.244-4.243 (d, 2H, CH$_2$), 2.132- 2.129 (d, 2H, CH$_2$), 1.432-1.428 (d, 2H, CH$_2$), 1.190 (brs, 24H, (CH$_2$)$_{12}$), 0.807-0.800 (t,3H, CH$_3$); ^{13}C NMR (125 MHz, DMSO-d$_6$), δ (ppm): 14.456 (CH$_3$ alkyl chain), 22.625 (CH$_2$), 25.015 (CH$_2$), 29.574 (CH$_2$), 34.182 (CH$_2$), 40.488-39.653 (-CH$_2$- alkyl fatty chain), 59.973 (O-CH$_2$), 110.338 (C=C), 139.758 (C=C), 146.218 (C-OH), 168.592 (-CH$_2$-C=O), 171.14 (-CH$_2$-C-O), 175.014 (-CH-C=O).

Surface Tension of Synthesised Surfactant

The surface tension of non-ionic surfactant was measured using United Test TEN201 Tensiometer, based on the Du Nuoy platinum ring method. Initially, different concentration of surfactant solutions was placed into a clean Teflon cup with a diameter of 25 mm. The concentrations used were at 0.001% (w/v), 0.01% (w/v), 0.1% (w/v), 0.5% (w/v) and 1 % (w/v). The platinum plate was dipped into the surfactant solution to achieve an equilibrium. The force exerted on it due to its wetting was measured by a tensiometer.

The measurements were repeated three times to get a mean surface tension value (mN/m). Critical micellar concentration (CMC) was found by drawing a chart suitable for physical properties as a function of surfactant concentration. In this study, the graph was plotted between log (C) and surface tension in which CMC is the inflection of the curve.

Emulsion Stability of Synthesised Surfactant

About 15 mL of synthesised surfactant of different concentration (between 0.3% (w/v) and 1% (w/v)) with an equal volume of cooking oil were mixed into a graduated cylinder. The mixed solution was shaken for at least three minutes until two phase separation was obtained. The emulsion stability was expressed in percentage by the separation of oil and the synthesised surfactant (Ibrahim et al., 2015).

$$\text{Emulsion stability} = \frac{v_2 - v_1}{v_1} \quad (1)$$

where v_1 = Initial height of emulsion (before addition of oil), v_2 = Final height of emulsion (after addition of oil).

Cloud Point of Synthesised Surfactant

Synthesised kojic palmitate was dissolved in deionised water (0.03% w/v) in a boiling tube and immersed in a water bath. The temperature of the hot water bath was controlled in 0.2°C increments, reaching equilibrium every three to five minutes (Na et al., 1999). Once the surfactant solution becomes milky and cloudy, its temperature was recorded. This procedure was repeated three times to obtain an average cloud point.

Cloud Point Extraction (CPE)

About 8 mL of sample containing cooking oil (at phase concentration 25%) were transferred to a 14 mL centrifuge tube. It was followed by adding 0.5 mL of 0.3% (w/v) kojic palmitate solution and a 2.5 mL of sodium acetate or acetic acid buffer solution at pH 8 into the centrifuge tube containing sample solution (Jamali et al., 2013). The mixture was shaken for a few seconds and placed in water bath at 60°C for 10 minutes (Jamali et al., 2013; Karadaş, 2017). Centrifugation of mixture solution at 2,500 rpm for eight minutes accelerated the separation of phases. It was cooled down in an ice bath for 10 minutes to increase the viscosity of surfactant-rich phase. The aqueous phase was removed by inverting the centrifuge tubes (Jamali et al., 2013). The viscosity of surfactant-rich phase was introduced to FTIR and compared with pure kojic palmitate surfactant to investigate the interaction between surfactant and cooking oil. The percentage of cooking oil removal (%) was calculated based on the formulae:

$$\% \ Removal = \frac{\text{initial weight of oil (g) – initial weight of oil (g)}}{\text{initial weight of oil}} \ x \ 100 \qquad (2)$$

A few key parameters, such as surfactant concentration, temperature and mixing speed conditions, were carefully examined and optimised in order to achieve higher sensitivity, selectivity, and precision for removal of oil waste using the CPE method (Jamali *et al*., 2013).

Effect of Surfactant Concentration on CPE

The procedure of CPE was conducted by using different concentration of surfactant at constant mixing speed (2500 rpm) and temperature (60°C). The surfactants solutions were prepared in various concentration, 0.01% (w/v), 0.1% (w/v), 0.2% (w/v), 0.3% (w/v), 0.4% (w/v), 0.5% (w/v) and 1.0% (w/v).

Effect of Temperature on CPE

The procedure of CPE was performed at constant mixing speed (2,500 rpm) and concentration of non-ionic surfactant at 0.5% (w/v). The mixture of cooking oil and surfactants were placed in thermostatic water bath at different temperature, in the range of 60°C to 90°C for exact 10 minutes.

Effect of Mixing Speed on CPE

The cooking oil and surfactants were mixed at different speeds, in the range of 500 rpm to 3,500 rpm. The procedure of CPE was repeated by using constant temperature (60°C), volume and concentration of non-ionic surfactant at 1.0 mL and 0.5% (w/v).

### **Results and Discussion**

Kojic palmitate was prepared via esterification between palmitoyl chloride and kojic acid in the presence of potassium hydroxide (KOH) as catalyst. Synthesised kojic palmitate was recrystallised by heating, cooling, and washing to obtain pure kojic palmitate. (Figures 1 to 3). The ^{1}H NMR ascribed the existence of kojic acid moieties, two olefinic protons which were found at peak δ 7.97 ppm and δ 6.29 ppm as singlet (Sie *et al.*, 2018). A signal was also found at peak δ 4.24 ppm which indicated the presence of oxymethyl proton for kojic acid (Kaatz *et al.*, 1999). The interaction of kojic acid and palmitoyl chloride via esterification can be signified by the presence of OCH$_2$ at δ 2.13 ppm as a singlet indicating kojic acid substituent with palmitoyl chloride (Borah *et al.*, 2014).

The FTIR spectrum of the surfactant derived from kojic acid shows a carbonyl ester stretch at 1,697 cm^{-1} indicating reaction of Kojic acid with palmitoyl chloride. The presence of long alkyl fatty acid chains (-CH$_2$ and -CH$_3$ stretching bands) gives significant intensity at 2,914 cm^{-1} and 2,846 cm^{-1} respectively. High stretching pattern at 1,072 cm^{-1} was attributed to the presence of CO of esters. The broad for O-H stretching band in kojic acid was found to be at 3,152 cm^{-1} (Khamaruddin *et al.*, 2008) (Figure 3).

Surface Activity

Surface activity can be evaluated by determining the surface tension of the kojic palmitate solution at different concentrations (Esteves *et al*., 2016). Figure 4 shows the relationship between the surface tension and Log (C). It can be deduced that the surface tension moderately decreases, from 62.57 to 37.5 mN/m, as the surfactant concentration increases from Log (C) = -5 to Log (C) = -2.5 (Region I). A downtrend of surface tension may be attributed to two reasons. First, the long alkyl chain on the produced kojic palmitate displays strong hydrophobicity of the compound, allowing the surfactant's molecules to be densely packed at the solution's interface, thus lowering the surface tension (Mędrzycka *et al*., 2009; Sayed *et al*., 2012). Second, the presence of an acyl chain in the synthesised surfactant also decreases the solubility of the solution, thus pumping the surfactant molecules at the interface of the solution (Sayed *et al*., 2012; Esteves *et al*., 2016). Nevertheless, surface tension plateaued as it reached concentrations above Log (C) = -2.5 (Region II).

Figure 1: ¹H NMR of kojic palmitate
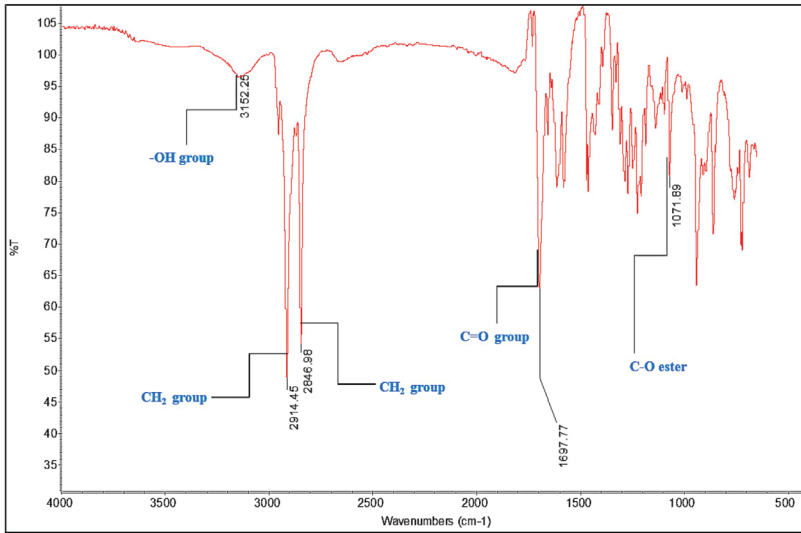

Figure 2: ¹³C NMR of kojic palmitate
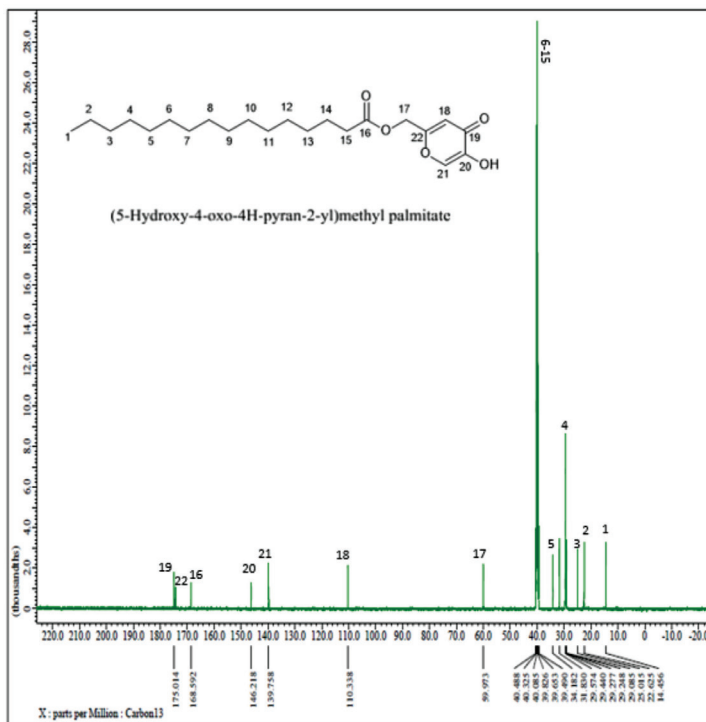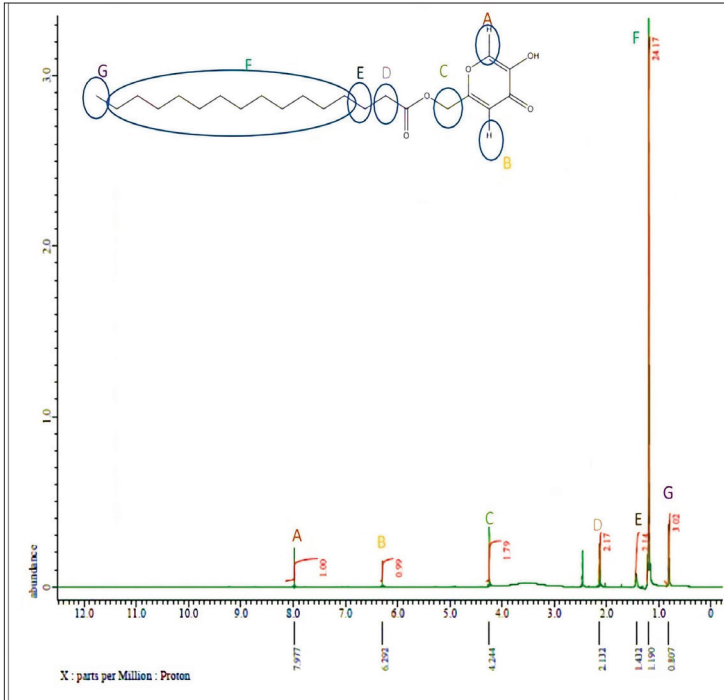
Figure 3: IR spectrum of kojic palmitate

The plateau can be explained as the surfactant starting to aggregate and form packed micelle at its maximum value. The close-packing hydrophilic group and the formation of intra- hydrogen bonds between the neighbouring molecules also may cause plate behaviour after the maximum (Sayed *et al*., 2012). CMC of kojic palmitate was obtained by the interception between region I (premicellar) and region II (post micellar). Based on the interception, the CMC value obtained for kojic palmitate surfactant is 0.3% (w/v). Since micelle is formed above CMC value, thus kojic palmitate at above CMC 0.3% (w/v) was interpreted for the potential of the surfactant in removing cooking oil.
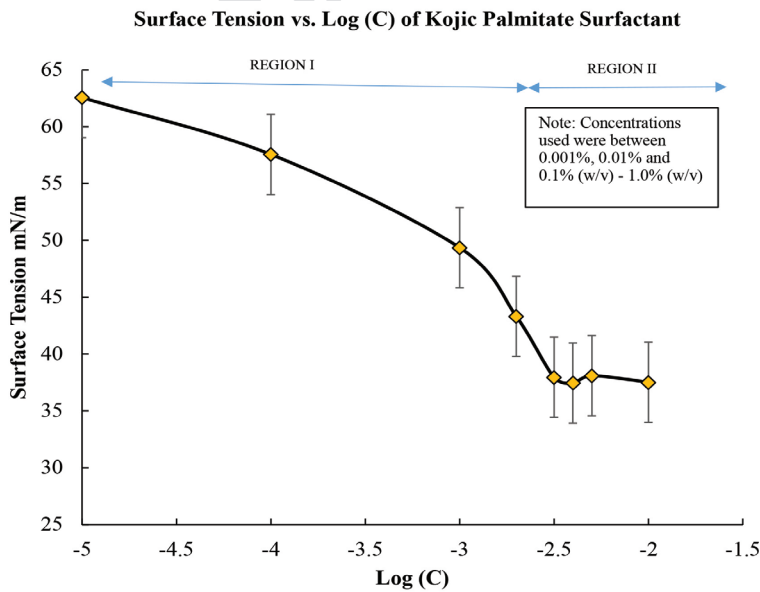

Figure 4: Surface Tension vs. Log (C) of kojic palmitate

Stabilisation of Emulsion using Kojic Palmitate Surfactant

Emulsion stability is defined as the duration for the two immiscible liquids to return to their natural state when mixed (Green & Rousseau, 2018). In this method, the separation of oil and water was measured at constant time taken which is 30 minutes. The variation of surfactant concentration has been conducted to determine its maximum emulsion stability until it reaches its optimum concentration (Figure 5). The concentration used was from 0.1% (w/v) to 1.0% (w/v).

Prior to the CMC value, the stability increases significantly as the surfactant concentration increases. Kojic palmitate-based surfactant has shown a high percentage of emulsion stability at 72%, at a CMC concentration value of 0.3% (w/v). The kojic palmitate structure is responsible for excellent emulsion stability where a high number of alkyl chains at the hydrophilic tail improves the surfactant dispersion in the oil and water emulsion (McClements & Jafari, 2018). Furthermore, surfactants that have higher emulsion stability have the potential to be advantageous because they can act as additives to improve the extraction yield of oil as well as heavy metals by increasing the mass transfer and contact area between the phases. Nevertheless, surfactant needs to be optimised at different parameters (such as concentration and temperature) to ensure that they are easy to break and split after the extraction process. The elevation in stability shows the presence of an emulsifier dispersed between two immiscible mixtures, oil, and water. Consequently, it was noted that the emulsion stability is constant. Higher concentration surfactant favours in forming micelle (Fan *et al.*, 2009). Micelle forms a hydrophobic and hydrophilic chain that performs as an additive to remove oil. The presence of emulsifiers can also be traced by comparing the interfacial tension of cooking oil before and after adding the surfactant solution. Figure 6 shows the synergism effect formed between the surfactant solution and the cooking oil, where the interfacial tension had been reduced, indicating the interaction between both components.
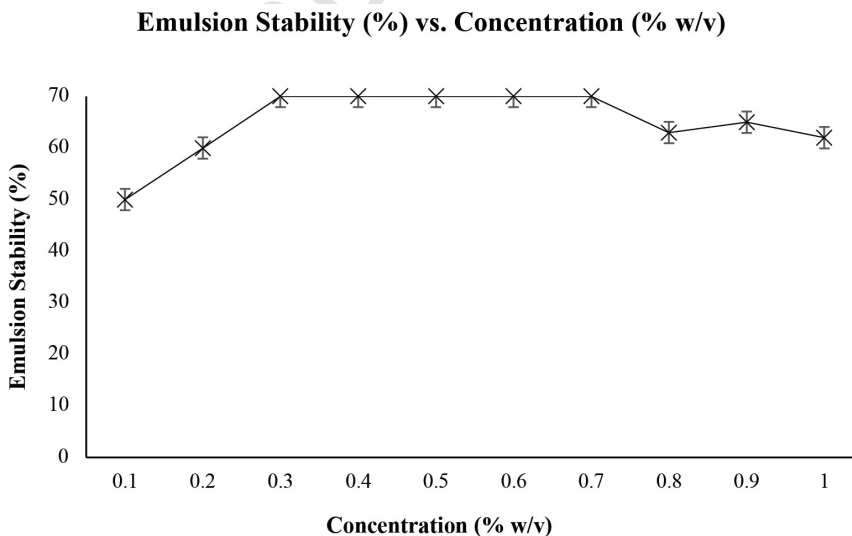
Emulsion Stability (%) vs. Concentration (% w/v)

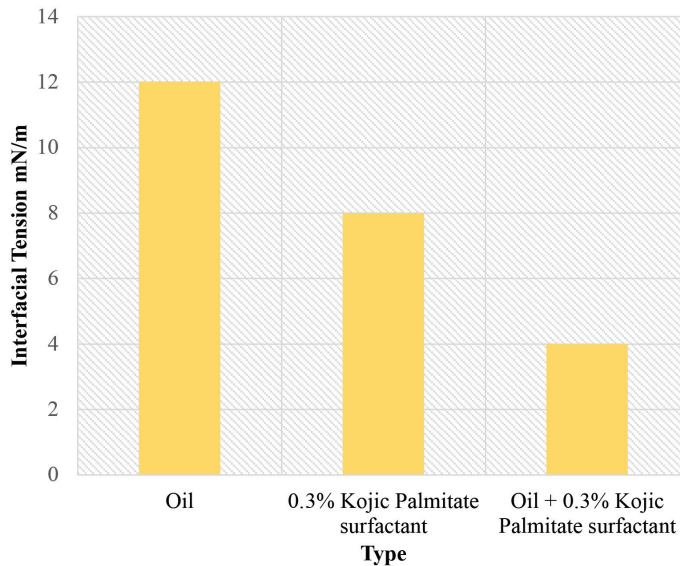Figure 5: Emulsion Stability (%) vs. Concentration % (w/v)

Figure 6: Interfacial tension of cooking oil and kojic palmitate surfactant

Cloud Point

Cloud point plays an important role in determining the properties of surfactants for the importance of storage stability. After three readings were recorded, the average reading for the surfactant solution to reach its cloud point at CMC was 60°C. The kojic palmitate surfactant becomes clearly turbid at CMC and above as it reaches its cloud point temperature (CPT). The turbid solution can be explained by the formation of micelles aggregates and grow more prominent as concentration increases due to an increase in micelles formation. High alkyl chain length also proves that the synthesised surfactant exhibits moderate cloud point property. A non-ionic surfactant with a long alkyl chain has a higher cloud point, showing greater capacity to hydrate at high temperatures (Na *et al.*, 1999). This is because the presence of a long alkyl chain causes high distortion motion of the molecules in a water solvent. Thus, it enables the ethylene oxide chain to de-coil at its energy breakdown and is solubilised by more water molecules to produce more hydrogen bonds.

Cooking Oil Removal via CPE

In this study, kojic palmitate was mixed with cooking oil, thus forming a homogenous and isotropic solution by dispersion. Dispersion of surfactant molecules in cooking oil solution causes the mixture to become turbid, reducing the solubility of surfactant in water and later, leads to phase separation between the aqueous bulk solution (water) and surfactant-oil-rich phase. The IR spectrum of cooking oil, kojic palmitate surfactant and surfactant-oil-rich phase are compared in Figure 7 to investigate the behaviour of the surfactant in forming micelle. The cooking oil characterisation by IR spectroscopy is shown in Figure 7. Several peaks were observed in cooking oil molecules. At about 2,920 cm^{-1} and 2,852 cm^{-1} it indicates the presence of asymmetric and symmetric C-H stretch bands. The intense stretch was observed at around 1,742 cm^{-1} proving the presence of C=O stretching of the carboxyl group in the molecules.

All the bands' absorption is proven to be similar to bands of cooking oil reported by

Goh *et al.* (2021). Compared to kojic palmitate surfactant, a broad band at 3,152 cm^{-1} signifies the presence of OH stretch while absorption bands at 2,914 cm^{-1} and 2,846 cm^{-1} are attributed to the formation of CH$_2$ symmetric and CH$_2$ asymmetric stretch. The signal then shifted to a lower frequency for kojic palmitate at 1,698 cm^{-1} corresponding with formation of the ester group.

Furthermore, based on cloud point extraction of oil by surfactant (surfactant-oil phase), the CH2 asymmetric and CH2 symmetric stretch in the cooking oil molecule shifted respectively at around 2,915 cm^{-1} and 2,947 cm^{-1}. From spectrum (c), it can be inferred that the alkyl chain of the surfactant is successfully linked with cooking oil molecules via intermolecular hydrogen bonds. In the three IR spectrum, the peaks of the surfactant oil-rich phase is narrower compared with the peaks of kojic palmitate and cooking oil. This phenomenon indicates that the surfactant forms micelles by the interaction of the hydrophobic group with cooking oil molecules, forming a more ordered structure.

Effect of Surfactant Concentration on CPE

The effects of surfactant concentration on the removal of cooking oil were determined using different concentrations of kojic palmitate surfactant. The concentrations used ranged between 0.1% to 1.0% (w/v). Figure 8 reveals that the mean percentage for oil removal increased from 65.75% to 68.56% when the concentration of surfactant at a range of 0.1% (w/v) to 0.7% (w/v) and plateaued at 0.3% (w/v) until 0.7% (w/v). The increasing concentration of the surfactant improves the extraction of cooking oil, however above 0.7% (w/v), the percentage for cooking oil removal decreased from 68.56% to 67.66%. This may be due to the micelle formation; more micelles form in the solution with increasing concentration of the surfactant and more oil molecules transfer into the micelle phase (Kojro & Wroczyński, 2020; Ji *et al.*, 2021). When the micelles (surfactant-rich phase) are separated from the aqueous solution, the targeted oil molecules are isolated and enriched via phase separation. Although the highest removal (68.79%) of cooking oil
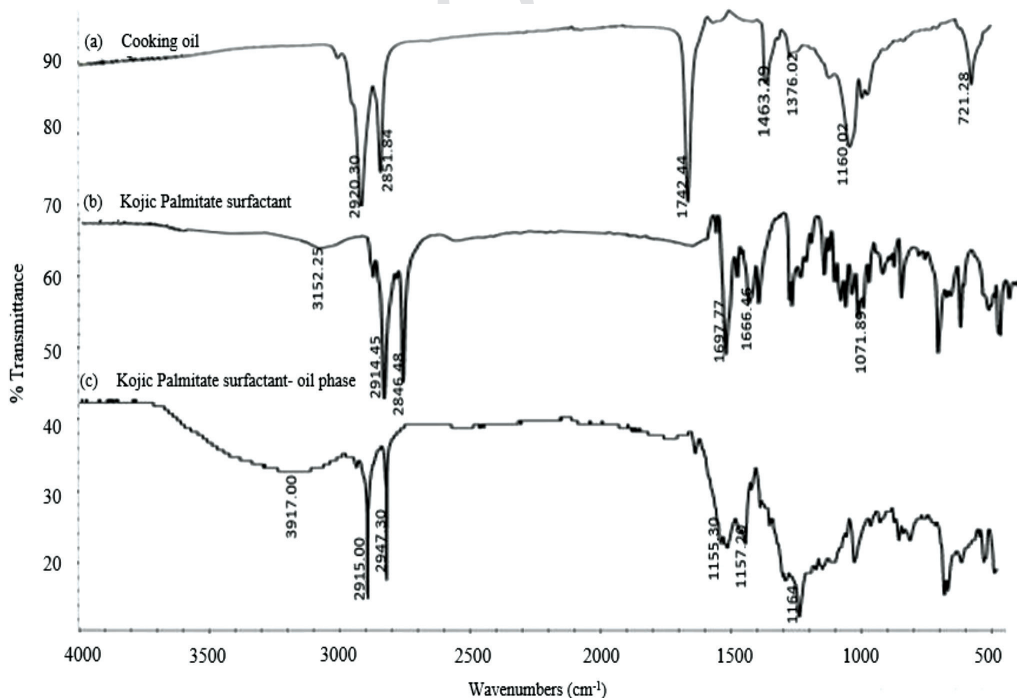

Figure 7: The IR spectrum of (a) Cooking oil, (b) kojic palmitate surfactant, and (c) surfactant-oil rich phase

was at surfactant concentration of 0.5% (w/v), it is not significant with removal using 0.4% (w/v) surfactant with removal of 68.78%. Hence 0.4% (w/v) concentration was determined as the combined optimum conditions.

Effect of Temperature on CPE

Cloud Point Extraction (CPE) was performed at a fixed concentration (0.4% w/v), fixed mixing speed (2,500 rpm), and different temperature ranged from 60°C to 90°C, as shown in Figure 9. The temperature was initially set to 60°C because the kojic palmitate has shown cloud point temperature (CPT) at above 60°C. The mixtures of cooking oil and surfactant were heated above the CPT causing the micellar solution to separate oils from the bulk solution and form clouds.

As shown in Figure 9, as the temperature increased from 60°C to 75°C, the extraction yield for cooking oil removal increased from 70.22% to 68.48%. A high percentage of cooking oil removal may be attributed to the hydrophobicity of the kojic palmitate surfactant. As the temperature increases, kojic palmitate surfactant becomes more hydrophobic and dehydrated thus, more micelle aggregates and causing repulsion between oil molecules

in the mixture (Purkait *et al.*, 2004; Kojro & Wroczyński, 2020; Ji *et al.*, 2021).

In addition, increasing temperature also indicates more oil molecules were retained at the surfactant-rich phase, easier for subsequent oil extraction. Nevertheless, at above 75°C, the growth trend activity of cooking oil removal started to decline from 68.48% to 53.23% as the temperature reaches 80°C. High temperature (> 75°C) could greatly impact the thermal instability of the surfactant to aggregates and forming micelles. In addition, elevated temperature above the maximum point could also degrade the nature of the surfactants (Purkait *et al.*, 2004). Thus, considering the extraction efficiency and the convenience of experimental operation, 65°C was chosen as the optimum temperature for the solubilisation capacity of kojic palmitate to form micelles and accelerating the cooking oil extraction.

Effect of Mixing Speed on CPE

Mixing speed was also studied to determine the efficiency of surfactant in removing cooking oil. The influence of mixing speed on the removal of cooking oil was determined by applying different mixing speed. The mixing speed was adjusted at 500 rpm to 3,500 rpm. From the data obtained

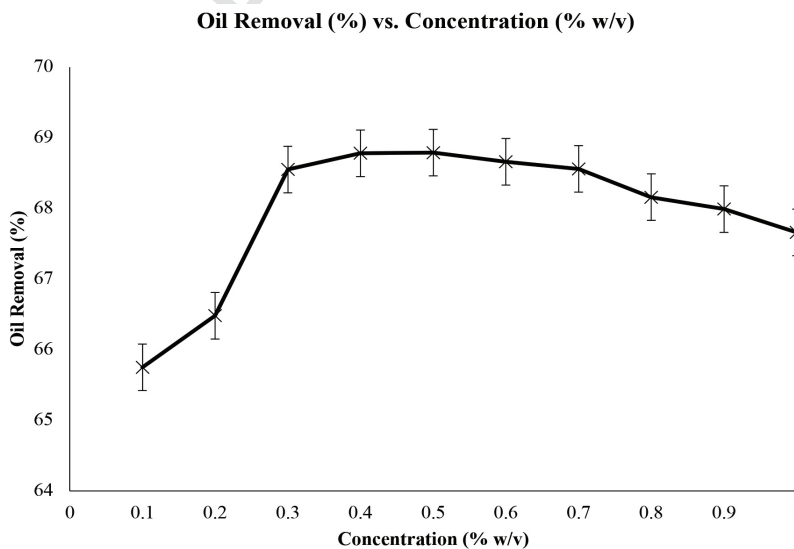**Oil Removal (%) vs. Concentration (% w/v)**

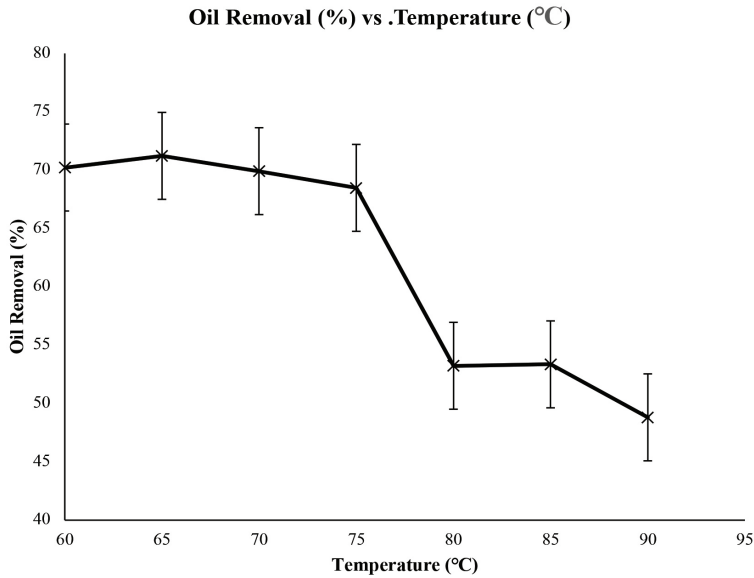Figure 8: Effect of surfactant concentration on cooking oil removal

Figure 9: Effect of temperature on cooking oil removal

in Figure 10, the efficiency for cooking oil waste removal increases from 53.21% to 68.55% at mixing speed from 500 rpm to 2,500 rpm. Cooking oil removal was enhanced at high mixing speed because the resistance of the surface film was reduced and accelerated the oil molecules to react with the surface of kojic palmitate particles. In addition, increasing the mixing speed also caused a decrease in the size of oil droplets and raised the stability and viscosity of the emulsion (Peralta-Martínez *et al.*, 2004). At mixing speeds above 2,500 rpm, the percentage of cooking oil removal decreased abruptly. Mixing speed greater than 2,500 rpm reduced oil extraction efficiency because the oil droplets can no longer attach to the surfactant at a very high speed. In addition, loose clumps of mass particles was found at the bottom of the centrifuge tube where it reduced the turbidity value of the surfactant system (Yang, 2007).
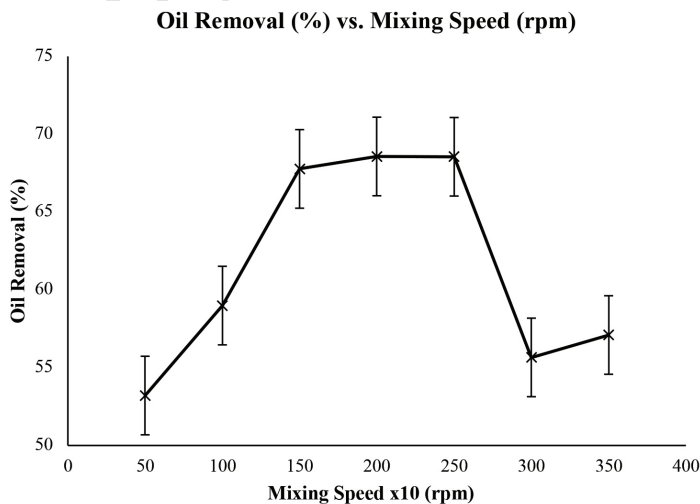

Figure 10: Effect of mixing speed on cooking oil removal

Conclusion

In conclusion, kojic palmitate was successfully synthesised and employed as a good non-ionic surfactant in cloud point extraction (CPE) for the removal of cooking oil. Oil removal was also supported based on the interaction of kojic palmitate surfactant and cooking oil, which was confirmed and compared using FTIR. In addition, parameters such as concentration, mixing speed and temperature of kojic palmitate, were measured to find the optimum conditions in removing cooking oil. The study found best optimisation for oil removal (68.55%) was at surfactant concentration of 0.4% w/v, mixing speed 2,500 rpm and temperature of 65°C. Therefore, this study has shown an efficient environmentally sustainable approach that shows potential in reducing pollution caused by waste cooking oil.

Acknowledgements

Conflicts of Interest Statement

The authors declare that they have no conflict of interest.

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