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# The effect of Used Cooking Oil (UCO) pre-treatment using bagasse on Free Fatty Acid (FFA) content

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**Abstract**

Used Cooking Oil (UCO) refers to cooking oil that has been previously used. UCO can be reused through impurity removal and reduction of the FFA high content. The reduction of FFA content in UCO can be achieved using the adsorption method, employing adsorbents derived from various materials such as agricultural waste and zeolite. Examples of agricultural waste suitable for this purpose include rice husks, straw, and bagasse, the latter of which can serve as a natural adsorbent. This study aimed to investigate the impact of UCO pre-treatment on FFA content. The research comprised three stages: preparation, adsorption, and analysis. Initially, the FFA content in UCO was 5.50 %. The pre-treatment of UCO involved using bagasse with varying stirring speeds (0, 150, 200 rpm) and adsorption temperatures (70, 85, 100 $^{o}$C). Optimal pre-treatment conditions were identified, with the most significant reduction in FFA to 1.49 % observed at 200 rpm and 100 $^{o}$C. The utilization of bagasse as a natural adsorbent effectively reduces the high FFA content in UCO as part of its pre-treatment process.

**Keywords:** adsorption, bagasse, FFA, pre-treatment, UCO

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## 1. INTRODUCTION

Used Cooking Oil (UCO) or waste cooking oil is one of the vegetable oils that can be used as raw material for methyl ester production. UCO is vegetable cooking oil that has been used in the frying process. Cooking oil used continuously at temperatures above 100 °C for a long time will undergo degradation processes, leading to the formation of various other chemical compounds in the oil. Degraded oil will experience increased levels of Free Fatty Acids (FFA) and viscosity. This is due to the formation of dimer and polymer acids and glycerol in the oil as a result of heating processes (Mahreni, 2010). Processing of used cooking oil (UCO) can be carried out through recycling via several processes.

UCO can be recycled and converted into methyl esters. Methyl esters are fatty acid esters obtained from the esterification or transesterification process of fatty acids with alcohol, commonly methanol. Methyl esters can be used as raw material for biodiesel production through further processing. UCO intended for conversion into methyl esters still contains impurities and a relatively high Free Fatty Acid (FFA)

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content. The high FFA content can be reduced through various processes, such as neutralization using bases catalysts or esterification with acid catalysts (Irawan et al., 2013). Both methods require complex processes and are relatively expensive, making them less efficient. An alternative method to reduce FFA content in oil is through pre-treatment through adsorption processes (Clowutimon et al., 2011).

Adsorption requires an adsorbent in its process applications. Various types of adsorbents can be used, including rocks and organic waste. Reduction of FFA using zeolite, the rock type adsorbent, categorized as chemical adsorption due to the chemical bonds formed with the adsorbent surface (Usman, 2020). Meanwhile, organic waste adsorbents are typically obtained from agricultural waste such as rice husks, straw, corn cobs, coconut husks, bagasse, and others (Hananto dan Rosdiana, 2023). Organic waste processed into adsorbents can either be used directly or undergo carbonization processes to become activated carbon.

Previous studies, such as those conducted by Wannahari et al. (2012), have shown that the use of adsorbents derived from activated carbon of bagasse can reduce free fatty acid (FFA) levels by up to 82.14 %. Similarly, research by Wijayanti (2009), demonstrated that activated carbon adsorbents from bagasse can absorb over 80 % of FFAs. Furthermore, a study by (Rahayu et al., 2014), concluded that activated carbon from bagasse is the most effective adsorbent for adsorbing FFAs compared to pineapple waste and coconut fiber.

Research on reducing FFA levels was also conducted by Pakpahan et al. (2013) using coconut fiber and straw, with the most effective reduction observed during adsorption processes obtained on adsorption with the straw size of 100-mesh. Removing impurities from UCO can be achieved through processes such as filtration, heating, or sedimentation. Filtration of UCO involves using a thin cloth after heating the UCO to make it easier to filter (Ratno et al., 2013). Therefore, UCO requires pre-treatment. Pre-treatment can be carried out in various ways, one of which is using bagasse to adsorb impurities or unwanted compounds.

Bagasse is an organic waste consists of cellulose from the sugarcane. Bagasse has many potential uses, such as in making brake linings, furfural, glucose syrup, ethanol, carboxymethyl cellulose (CMC), and as an adsorbent (Herawaty dan Chaterina, 2018). Besides fibers, bagasse also contains various chemical compounds useful as adsorbent or catalyst. According to research by the Affiliation Team and Industrial Consultancy at ITS Surabaya, bagasse consists primarily of silica chemical compounds, with a relatively high percentage of 70.79 %. Other chemical compound components in bagasse include $Al_2O_3$ (0.33 %), $Fe_2O_3$ (0.36 %), $K_2O$ (4.82 %), $Na_2O$ (0.43 %), MgO (0.82 %), and $C_5H_{10}O_5$ (22.27 %).

Research on purifying UCO using bagasse as an adsorbent has been previously conducted by (Ramdja et al., 2010). The duration of immersion affects the expected purification results of UCO. Smaller particle diameter of the bagasse as adsorbent leads to the optimal adsorption of impurities. Another study related to UCO purification using bagasse as an adsorbent was also conducted by (Sulung et al., 2019). UCO subjected to three treatments using bagasse showed significant quality changes, including reductions in FFA, peroxide value, and water content. Research on oil pre-treatment using bagasse has also been conducted previously by Ferdian et al. (2022). In this study, oil purification was performed using bagasse as an adsorbent with the variations of stirring speed (50, 100, and 150 rpm) and heating temperature (50, 60, and 70 °C). Samples with stirring speed at 150 rpm and heating temperature at 70 °C showed the best result, indicated by the lowest FFA content among the samples.

The purification of UCO through adsorption has gained significant attention due to its potential to recycling UCO efficiently. Previous studies have primarily focused on common adsorbents such as activated carbon and zeolites. However, there remains some research gap concerning the systematic comparison of different adsorbents in terms of their effectiveness in reducing FFA on UCO and adsorbent manufacturing process. While previous studies applied adsorption using bagasse as an adsorbent processed into activated carbon, this research focuses on exploring adsorption using bagasse directly as an adsorbent without prior conversion into activated carbon. This research experiment focuses on processing UCO with a pre-treatment stage using bagasse to reduce FFA levels. The aim is to determine the extent of the effect of adding bagasse during the UCO pre-treatment stage on FFA levels.

As mentioned earlier, the previous research about oil pre-treatment using bagasse by Ferdian et al. (2022) indicated that the optimal adsorption conditions obtained on stirring speed at 150 rpm and heating temperature at 70 °C. However, there remains potential to achieve higher reduction of FFA under more elevated reaction conditions. This research experiment focuses on varying the adsorption temperature and stirring speed conditions that are different from previous studies to investigate the possibility of better FFA reduction. Therefore, the results of this study can provide information on the reuse of UCO, both for personal use in households and on a larger scale such as for biogasoline feedstock, while reducing UCO waste pollution in the environments.

## 2. MATERIALS AND METHODS

This study was conducted through batch method on a laboratory scale. The primary materials used were bagasse and Used Cooking Oil (UCO). The UCO was obtained from household waste around South Sumatra, while the bagasse was obtained from sugarcane juice seller. The bagasse obtained can be seen in **Figure 1**.

**Figure 1.** Bagasse obtained from sugarcane juice seller

The secondary materials used as support for this study were 95% technical ethanol and NaOH solution. The 95 % technical ethanol and NaOH solution were used in the titration process.

The titration process was conducted using phenolphthalein (PP) as indicator. Laboratory equipments used includes a blender, 80-mesh sieve, beaker glass, stirring rod, volumetric pipette, thermometer, hotplate, retort stand, clamp, and oven. The product parameters analyzed from this study was Free Fatty Acid (FFA) levels. The functional groups of chemical compounds analysis were performed using Fourier Transform Infrared (FTIR) spectroscopy.

### 2.1. The Preparation of Raw Materials

Bagasse is dried, smoothed, and then sieved using an 80-mesh sieve. The sieved bagasse was then weighed 10 g per sample. The natural adsorbent from bagasse can be seen in **Figure 2**.


**Figure 2.** The weighed natural adsorbent from bagasse

UCO is filtered first, then measured into a beaker glass in quantities of 600 mL, which is then divided into nine samples as detailed in **Table 1**. These nine samples are then heated. The initial FFA content of the UCO is then measured before soaking it with bagasse.

### 2.2. The Pre-treatment of UCO

10 g of bagasse are then added to each sample and heated at varying temperatures (70, 85, and 100 °C), while stirring the sample with a magnetic stirrer at different speeds (0, 150, and 200 rpm) for 90 minutes. The pre-treatment process of UCO can be seen in **Figure 3**. The mixture of bagasse and UCO is then filtered and pressed to separate the UCO from the bagasse.


**Figure 3.** The Pre-treatment process of UCO

### 2.3. The Analysis of Free Fatty Acid (FFA) Content

The soaked UCO is then analyzed for its Free Fatty Acid (FFA) content by dissolving 5 g of the soaked UCO in 25 mL of 95 % ethanol. The solution is heated and phenolphthalein (PP) indicator is added. The solution is titrated with 0.5 M NaOH until a pink color appears and remains unchanged for 30 s. The volume of NaOH used is then recorded, and the FFA content is calculated using equation (1).

$$\% \text{ FFA} = \frac{\text{Normality of NaOH x NaOH Titration Volume x 256}}{\text{Sample Weight}} \quad (1)$$

## 3. RESULTS AND DISCUSSION

This study involved an adsorption process using bagasse as an adsorbent added to UCO to reduce its FFA content, aiming to obtain UCO with lower FFA levels. The bagasse used as the adsorbent was first smoothed using a blender and sieved through an 80-mesh sieve to achieve uniform particle size. The adsorption process was facilitated using a hotplate and magnetic stirrer. During the adsorption process, variations in adsorption temperature and stirring speed were applied. The data analysis method applied in this research is descriptive analysis, whereas the data obtained from calculations using formula (1) was processed using Microsoft Excel software on computer. The data then subsequently represented in tables and graphs to identify the maximum and minimum values of each category. The overall results of the study are presented in **Table 1**. The initial FFA content of the UCO before pre-treatment was 5.50 %. The lowest FFA content obtained after adsorption using bagasse was 1.49 %, observed in the product stirred at 200 rpm and adsorption temperature of 100 °C.

**Table 1.** Result of UCO Pre-treatment Process using Bagasse

| Product | Stirring Speed (rpm) | Adsorption Temperature (°C) | FFA Content (%) | FFA Reduction (%) |
|---|---|---|---|---|
| $A_1$ | 150 | 70 | 2.30 | 58.14 |
| $A_2$ | | 85 | 1.84 | 66.67 |
| $A_3$ | | 100 | 1.54 | 72.09 |
| $B_1$ | 200 | 70 | 1.92 | 65.12 |
| $B_2$ | | 85 | 1.75 | 68.22 |
| $B_3$ | | 100 | 1.49 | 72.87 |
| $C_1$ | 0 | 70 | 3.24 | 41.09 |
| $C_2$ | | 85 | 3.07 | 44.19 |
| $C_3$ | | 100 | 2.56 | 53.49 |
| $D_1$ | 0 | 0 | 5.50 | 0 |

### 3.1. Bagasse as a Natural Adsorbent

Bagasse is an organic waste primarily composed of cellulose fibers, pentosan, and lignin. The finely ground bagasse was analyzed for its functional groups using FTIR equipment. The obtained Infrared (IR) spectrum can be viewed in **Figure 4**. Based on the spectrum, wavelengths ranging from 600 $cm^{-1}$ to 4000 $cm^{-1}$ indicate the presence of functional groups such as silica, oxygen, and hydrogen. This corresponds with research conducted by Ameram et al. (2019) which state that bagasse consists of carbon, oxygen, sodium, magnesium, and silica elements. Generally, adsorption kinetics occurs through two main steps. Initially, the adsorbate transfers from the bulk solution to the adsorbent surface, passing through a solid-fluid boundary layer known as the film. This surface diffusion process is influenced by hydrodynamic factors, such as stirring speed and fluid flow rates. It occurs rapidly and leads to the chemical entrapment of chemical elements on the functional groups of bagasse (Iwuozor et al., 2021).

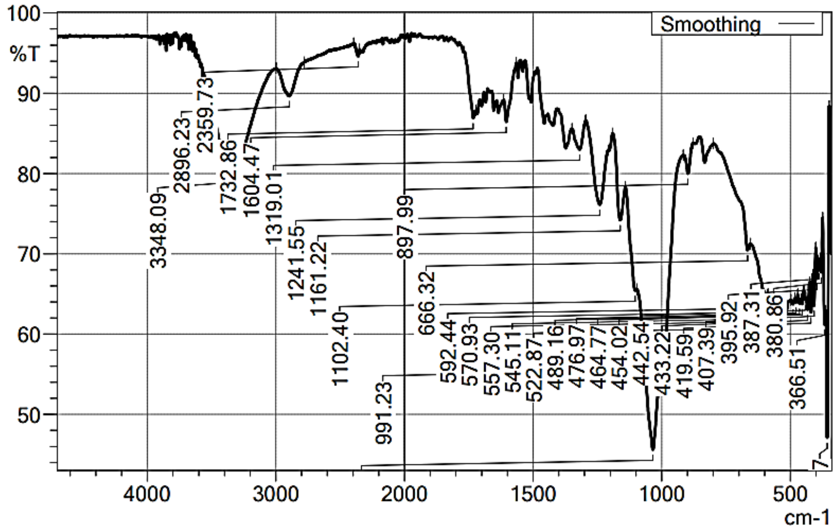


**Figure 4**. The Obtained IR Spectrum of Bagasse

Bagasse consists of lignin, hemicellulose, and cellulose compounds. Lignin itself can be categorized into four groups depending on how it is isolated, including alkaline lignin (also known as kraft lignin), lignosulfonate, organosolv lignin, and soda lignin. Lignin in bagasse belongs to alkaline lignin/ kraft lignin (Berghuis et al., 2023). The cellulose component itself contains a high concentration of carboxyl (-COOH) and hydroxyl (-OH) group, which significantly influence the adsorption capacity of various chemical compounds in a liquid medium (Gorgulho et al., 2018). In the IR spectrum of bagasse, the highest adsorption peak appears at a wavelength of 1034.27 $cm^{-1}$, indicating the presence of C-O bonds as ester functional group. Additionally, the IR spectrum shows peak at a wavelength of 1241.55 $cm^{-1}$, indicating C-O bonds in acetyl and ester group of lignin, hemicellulose, and pectin (Kumar et al., 2014). At a wavelength of 3348.09 $cm^{-1}$, a broad adsorption peak indicates the presence of hydroxyl (-OH) functional group. The -OH group in lignin act as adsorbent. Bagasse contains a relatively high amount of hemicellulose, approximately 35-40 % (Ferdian et al., 2022). The hemicellulose content in bagasse can bind water molecules. Furthermore, the plasticity and large molecular contact surface of hemicellulose in bagasse are known to enhance the bonding (Trisnaliani et al., 2019).

### 3.2. The Effect of Adsorption Temperature on The FFA Content of UCO

Adsorption is a process that occurs when a fluid adheres to a solid and forms a thin layer (film) on the surface of the solid. Adsorption occurs due to the unbalanced attractive forces between atoms or molecules on the surface (Sera et al., 2019). The adsorption process can be influenced by several factors, such as the type of adsorbent, surface area of the adsorbent, and temperature. Temperature variations applied during the adsorption process include 70, 85, and 100 °C. The temperature set during the UCO adsorption process using the adsorbent will affect the quality of UCO, especially in terms of the percentage of FFA content. The rate of adsorption in chemical adsorption increases with temperature because it enhances the transfer rate of materials into the adsorbent pores. The adsorption process is endothermic, so an increase in temperature will increase the amount of adsorbate adsorbed.

Based on **Figure 5**, it can be observed that there is a decrease in FFA content as the adsorption temperature increases. The lowest FFA content is shown in product B with a temperature variation of 100 °C. Temperatures exceeding 100 °C can potentially cause the UCO to deteriorate, leading to the reformation of FFA (Rahayu et al., 2014). The increase in temperature accelerates the collision rate between particles, thereby speeding up the adsorption process. At higher temperatures, the kinetic energy of molecules increases, leading to larger collisions that enhance the bagasse's ability to adsorb FFA (Ferdian et al., 2022).

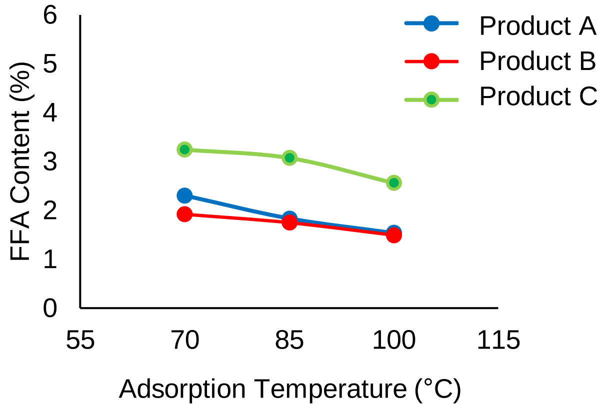


**Figure 5.** The Effect of Adsorption Temperature on FFA Content Percentage Chart

During adsorption at high temperatures, particle movement in the solution becomes faster and they collide more frequently. These collisions break the bonds between the solute and the solvent. As a result, the Van der Waals forces between the solute and the solution surface become lower than the surface tension and media, causing the solute to dissolve and the impurities to be attracted and adsorbed on the surface (Selpiana et al., 2016).

### 3.3. The Effect of Stirring on The FFA Content of UCO

Stirring also influences the FFA content in UCO. Stirring helps to increase the contact area between the adsorbent and UCO. The effect of stirring on the FFA percentage can be seen in **Figure 6**. **Figure 6** illustrates that stirring speed is inversely proportional to the FFA percentage. Higher stirring speeds correspond to lower FFA percentages in UCO. Increasing stirring speed widens the contact area between the adsorbent and adsorbate, optimizing the adsorption process (Sirajuddin et al., 2017).

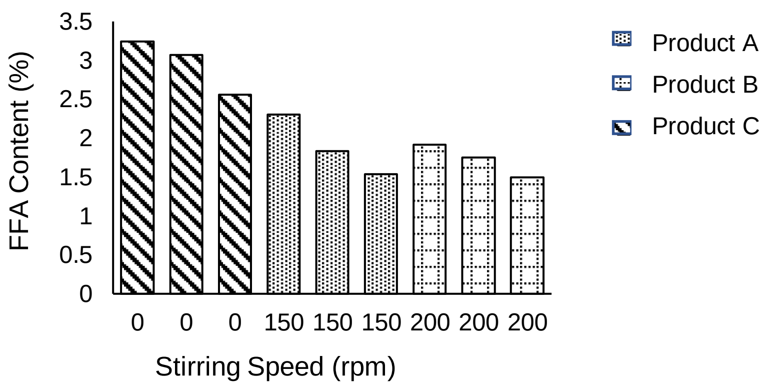


**Figure 6**. The Effect of Adsorption Stirring Speed on FFA Content Percentage Chart

The lowest percentage of FFA content was achieved in product B with a stirring speed of 200 rpm, whereas the highest percentage of FFA was observed in product

C without any stirring treatment. Increasing stirring speed accelerates the diffusion rate of UCO molecules from the liquid phase to the liquid boundary layer around the adsorbent particles due to increased turbulence and reduced thickness of the liquid boundary *layer* (Kuśmierek dan ̄wia¸tkowski, 2015).

## 4. CONCLUSION

The pre-treatment process of UCO using bagasse results in a significant decrease in the percentage of FFA content. The most notable reduction obtained was 1.49 %, compared to the initial FFA content of UCO before pre-treatment which was 5.50 %. Among the various temperature variations tested (70, 85, 100 °C), the optimal adsorption temperature was found to be 100 °C, as it produced the product with the lowest FFA content. Stirring speed of 200 rpm also resulted in the product with the lowest FFA content among the different stirring speeds tested (0, 150, 200 rpm). Higher stirring speeds leads to lower FFA content in UCO. The results indicate that while the use of bagasse on UCO pre-treatment process is suitable for FFA content reduction on UCO, several limitations were identified. These include variability in the quality of UCO feedstock and challenges in maintaining consistent adsorption conditions such as temperature and the stirring speed. Recommendations for further research include optimizing adsorption parameters to enhance the percentage of FFA content reduction, experimenting with smaller adsorbent sizes to potentially achieve better reduction of FFA content, and seeking alternative methods to refine bagasse into adsorbents.

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