

Comparative analysis of banana pseudostems and banana stems as adsorbents for reducing peroxide content and free fatty acids (FFA) in used cooking oil

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ABSTRACT

Background: the increasing production and consumption of palm oil in Indonesia have led to arise in used cooking oil (UCO), classified as hazardous waste due to its high content of free fatty acids (FFA) and peroxides, which are toxic and difficult to degrade. To address this, the use of natural adsorbents such as banana pseudostems and banana stems has gained attention due to their cellulose content, which can effectively absorb harmful compound like FFA and peroxides, improving UCO quality.

Method: This experimental study employed a pre-experimental design with a one-group pretest-posttest approach to evaluate the effectiveness of banana pseudostem and banana stem powder, of different mesh size (60, 100, and 200 mesh), in reducing FFA and peroxide levels in UCO. Samples of UCO were obtained from a street food vendor, while the banana plant (*Musca acuminata*) were collected locally. After immersing the adsorbents in UCO for 72 hour, FFA and peroxide values were analyzed using titration methods. Statistically analysis was performed using a Paired Sample T-Test.

Results: The results showed a significant reduction in FFA levels, with the most effective reduction observed with 200-mesh adsorbents, where the FFA content decreased from 0.67% to 0.16% for pseudostem adsorbent and to 0.20% for stem adsorbents. Peroxide levels were also reduced, with the stem adsorbent reducing peroxide values from 49.60mg/L to 12.92 mg/L, while pseudostem adsorbent reduce it to 14.61 mg/L. Statistical analysis confirmed a significant reduction in FFA ($p=0.03$), but the reduction in peroxide values was not statistically significant.

Conclusion: the particle size of banana pseudostem and banana stem significantly influences the effectiveness of reducing peroxide and FFA levels in UCO. Adsorbents with a particle size of 200 mesh were most effective, with banana pseudostems performing slightly better than banana stems. This study high light the potential of banana plant material as inexpensive and environmentally friendly adsorbents for UCO management.

Keywords: Adsorbents; Peroxide; FFA, Banana Stem; Banana Pseudostem; Used Cooking Oil

INTRODUCTION

Used cooking oil (UCO) is a significant environmental concern, particularly due to its hazardous nature and difficulty in degradation. The growing pal oil production in Indonesia, which increased from 37.97 liters per capita per year in 2016 to 49.71 liters in 2021, directly contributes to the rising amount of UCO waste (1).

This surge in production and consumption has resulted in significant used cooking oil waste, which poses environmental challenge due to it hazardous nature and difficulty in degradation (2).

The disposal of UCO is problematic because it contains harmful substances,

including high levels of saturated fatty acids and peroxide compounds, which are toxic and difficult to degrade naturally (3)(4).

UCO is classified as hazardous waste (B3) due to its chemical composition, particularly the formation of free fatty acids (FFA) and peroxides during repeated use (5). These compounds are free radicals that can pose health risks, making UCO unsuitable for direct disposal into the environment (6). Therefore, there is a need for effective treatments, such as refining processes, to purify UCO by removing harmful compounds like FFA and peroxides (7).

One promising solution is the use of

environmentally friendly adsorbents for the purification of UCO. Adsorption is an effective method for removing impurities, as adsorbents with smaller particles offer larger surface areas, allowing for greater absorption (8).

There are various types of adsorbents that potential to be used in the purification of UCO, such as sugarcane bagasse, activated charcoal banana peels and banana stems (9).

Banana stems, an underutilized part of the banana plant, can be used as an adsorbent for treating UCO. Despite Indonesia being one of the largest banana producers, banana stems are typically discarded or used as animal feed or for making rafts. They are also used in food applications as well as non-food uses like wastewater treatment, biofertilizers, textiles, and composites materials (10)(11). However, this study will use adsorbents from banana plants, as banana are easily available and produce fruit only one, which may lead to the accumulation of banana plant waste if not properly managed.

Banana stems contain cellulose, which can be used as an adsorbent for absorbing FFA with the addition of activator substances (12). The chemical composition of banana stem fiber consisted of 5-10% lignin, 60-65% cellulose, 6-8% hemicellulose, and 10-15% water. The highest potential lies in the cellulose, which can be used as an adsorbent material (8).

Similarly, the cellulose in the banana stem can bind to harmful compounds such as FFA and peroxides, thus improving the quality of used cooking oil. Additionally, the adsorptive effectiveness of banana stems can influence by factors such as particle size, with smaller particles providing greater surface area for adsorption (13). Therefore, both banana stems and pseudostems present a promising alternative to synthetic adsorbents for the purification of peroxides and FFA in used cooking oil.

This research aims to compare the effect of adsorbent size from banana pseudostems and banana stems on the

reduction of FFA and peroxide levels in UCO. By utilizing banana stems, an easily accessible and abundant resource, this study seeks to provide an environmentally friendly and sustainable alternative to synthetic adsorbents in UCO purification.

METHOD

This study is experimental in nature, employing a Pre-experimental research design with a one-group Pretest-posttest approach. In this design, a pretest is conducted before applying the treatment. The research aims to determine the effectiveness and comparison of FFA and peroxide values in used cooking oil before and after treatment by immersing it with banana stem and banana pseudostem powder of varying mesh sizes using mesh size of 60, 100 and 200.

Preparation of adsorbent samples

This research was conducted by collecting used cooking oil samples from a street food vendor selling pecel lele around Jalan Tuanku Tambusai, while samples of banana pseudostems and banana stems were obtained from areas near the researcher's residence with the species *Musca acuminata* is abundant.

The samples of banana stems and pseudostems were cleaned thoroughly to remove any dirt or impurities. Afterward, the samples were dried at varying temperatures to determine the effect of drying temperature on the adsorbent's efficacy. The drying process was carried out at temperatures of 40°C, 60°C, and 80°C, and the samples were left to dry for 24 hours. The dried materials were ground into powders, which were sieved into mesh size 60, 100 and 200 microns to test the influence of particle size on the adsorption process.

Adsorption Process and Variable Control

During the adsorption process, several variables were carefully controlled to ensure reliable results. The immersion time was 3x24 hours with a consistent oil volume of 100 mL was used for all trials to maintain uniformity in the experiment. The adsorbent mass was kept constant at

10 grams per trial to ensure that the only variable influencing the results was the type of adsorbent and its mesh size.

Analysis Method Validation

To ensure the accuracy of the FFA and peroxide value measurements, the analysis methods were validated through repeat titration tests. For each sample, titration was performed in duplicate, and the average values were used for further analysis. The repeat tests helped to confirm the consistency and reliability of the titration procedure, providing confidence in the results.

Statistical Analysis

Data analysis was conducted after completing the laboratory research. The effectiveness of the adsorbents in reducing FFA and peroxide values was evaluated using bivariate analysis with the Paired Sample T-Test (dependent sample T-Test). This statistical test was chosen because it allows for the comparison of two related samples—in this case, the FFA and peroxide values before and after the treatment. The paired design ensures that the variability within each sample is accounted for, providing a more accurate measure of the adsorbent's effectiveness.

RESULTS

The procedure testing in this research was conducted at the Chemistry Laboratory of Riau University in August 2023 until February 2024.

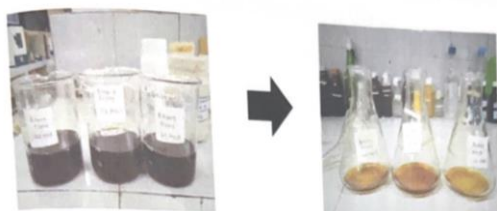


Figure 1. Results of Immersion Using Banana

Pseudostems and Banana Stems

The banana pseudostems and banana stems were blended into powder to achieve the desired particle size. Before blending, the pseudostems and stems were cut into small pieces and sun-dried for one week. Sieving was performed using mesh size of 60, 100 and 200 to obtain banana pseudostems and banana stems powders of uniform sizes. The powders were then immersed in used cooking oil for 72 hours (3x24 hours). After the 72-hour immersion, the following results were obtained :

Figure 1 shows that immersing used cooking oil with banana pseudostems and banana stems powder resulted in a physical change, as the color of the oil transformed from dark brown to yellowish-brown. This indicates a reduction in free fatty acid (FFA) content and peroxide value in the used oil. The theory suggests that darker oil signifies a higher degree of rancidity and damage.

After the adsorption process using banana pseudostem and banana stem powders, the FFA content and peroxide value were measured. A total of eight used cooking oil samples were analyzed. The FFA content was measured by titration with 0.1 NaOH standardized until a persistent pink color appeared for 30 seconds. The peroxide value was analyzed using a titration method with sodium thiosulfate solution until the blue color disappeared.

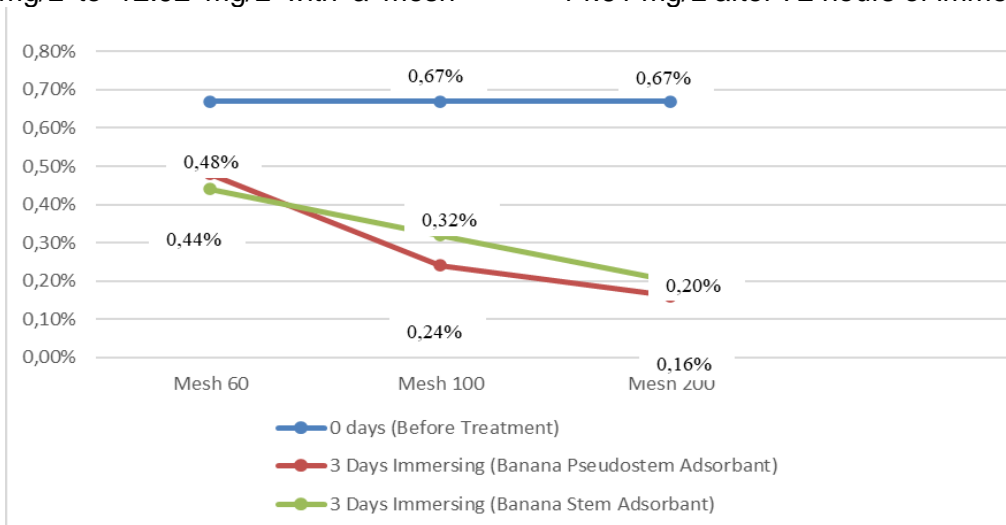
The research results, which compared the samples with treatment and without treatment, show a significant difference, as can be seen in the graphic 1 and graphic 2 :

The research results shown in Graph 4.1 indicate a significant reduction in FFA after immersion using banana pseudostem and banana stem powders with different mesh sizes. The most effective mesh size for reducing FFA was mesh 200, where the initial FFA content of 0.67% dropped to 0.16% with pseudostem adsorbents and to 0.20% with stem adsorbents.

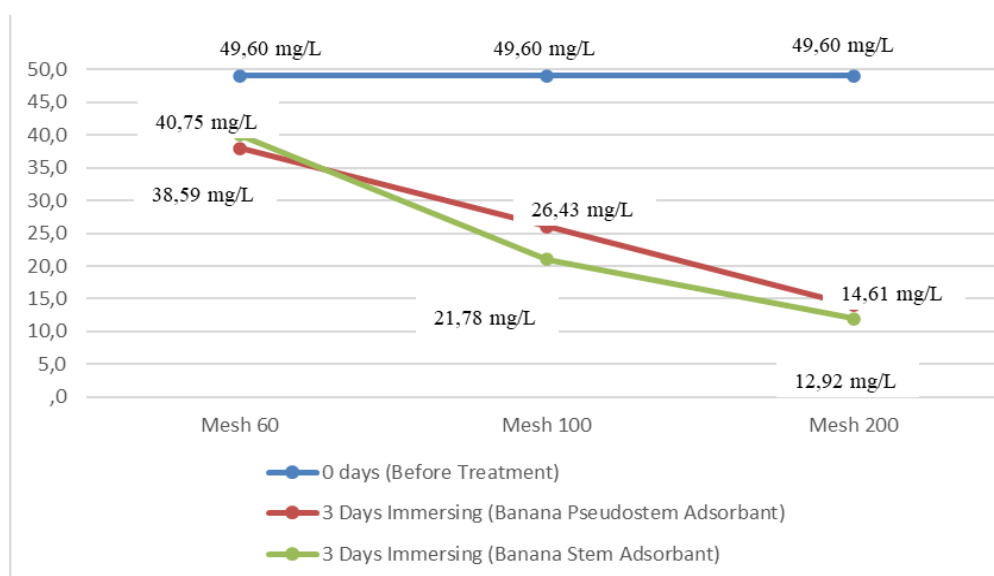
The analysis of peroxide value absorption revealed that the banana

adsorbent was the most effective, reducing the initial peroxide value from 49.60 mg/L to 12.92 mg/L with a mesh

size of 200. In contrast, the pseudostem adsorbent reduced the peroxide value to 14.61 mg/L after 72 hours of immersion.



Graphic 1. Results of Free Fatty Acid Absorption in Used Cooking Oil with Banana Pseudostem and Banana Stem Adsorbents



Graphic 2. Results of Peroxide Absorption in Used Cooking Oil with Banana Pseudostem and Banana Stem Adsorbents

The statistical analysis of FFA content using Paired Sample T-Test, the results are considered effective if the *P* value is < 0.05 is presents in table 1.

Table 1. Analysis of Free Fatty Acid Content in Used Cooking Oil Using Banana Pseudostem and Banana Stem Adsorbents

No.	Parameter	Description	Mean	SD	SE	95% CI		Sig.
						Lower	Upper	
1	FFA ₀	0 Days (Before Treatment)	0,670	0,000	0,000			
2	FFA ₃	3 Days (After Treatment)	0,320	0,120	0,692	0,051	0,648	0,03

From Table 1, a significant difference in the average FFA content was observed, the statistical test yielded a significance value of 0.03, indicating a significant difference in FFA levels before and after immersion with banana pseudostem and banana stem.

Table 2. Analysis of Peroxide Content in Used Cooking Oil Using Banana Pseudostem and Banana Stem Adsorbents

No.	Parameter	Description	Mean	SD	SE	95% CI		Sig.
						Lower	Upper	
1	Peroxide ₀	0 Days (Before Treatment)	49,60	0,000	0,000			
2	Peroxide ₃	3 Days (After Treatment)	25,15	14,217	8,208	10,868	59,768	0,09

From table 2 indicate that, while there was reduction in the peroxide value of the used cooking oil treatment with banana pseudostem and banana stems adsorbents, this reduction was not statistically significant. This means the the observed changes might not highly effective in reducing peroxide levels or their effect is marginal.

DISCUSSION

Free Fatty Acids (FFA) Value

The research results indicate that adsorbents derived from banana pseudostem and banana stem, with particle size of 60 mesh, 100 mesh and 200 mesh, effectively reduced the free fatty acid (FFA) content in used cooking oil sourced from a local food vendor. This efficiency is likely attributed to the high cellulose and glucose contents present in banana pseudostem and banana stem. According to SNI 01-3741-2002, the maximum permissible FFA level is 0.3%, and the adsorbents in this research successfully reduced the FFA levels to below this standard. Among the adsorbents types, banana pseudostem was the most effective and the 200-mesh size was the most effective, achieving up to a 70% reduction in FFA content.

This research result demonstrates that the particle size of the adsorbent significantly influences its adsorption efficiency. Several factors affect the adsorption rate and the amount of adsorbate that adsorbents can absorb.

These findings align with previous research that the potential of banana-based adsorbent in reducing FFA level in used cooking oil. For instance (14) investigated the isotherm adsorption in FFA in waste cooking oil using activated carbon derived from banana peel

biomass that found that activated carbon from banana peel effectively adsorbed FFAs.

Similarly, (15) examined the potential of *Musa acuminata balbisiana* Colla in reducing FFA levels in used cooking oil, showed a significant decrease in FFA content after treatment with banana peel powder, suggesting its efficacy as a natural adsorbent improving the quality of used cooking oil.

A recent study by (16) examined the use of activated charcoal derived from *Leucaena leucophala* wood is significantly reduce FFA content in UCO in 1,5 hours.

This aligns (17), these factors include the adsorbent's surface area, particle size, and chemical composition, with specific surface area and particle size being the most dominant factors.

As noted (18), smaller adsorbent granules provide a larger surface area, enabling better absorption of contaminants. Generally, adsorption speed is determined by the rate at which solutes transfer into the pores of the adsorbent particles.

This finding aligns with research (6), which demonstrated that banana stems are effective in reducing FFA content in used cooking oil due to their high cellulose and lignin content.

This research found, banana pseudostems and stems, especially at finer particle sizes, serve as effective natural adsorbents for reducing FFA and peroxide values in used cooking oil. However, to meet stringent quality standards, further treatment or activation of these adsorbents may be necessary to enhance their adsorption capabilities. This also found that banana pseudostem was the most effective part of banana plant for adsorption than banana stem. This effectiveness is hypothesized to results from differences in pore density and cellulose and lignin content between the pseudostem and stem parts.

Peroxide Value

The results of this study demonstrate the efficacy of banana stem adsorbent (200-mesh) in reducing the

peroxide value of the used cooking oil. The peroxide value significantly decreased from an initial 49.60 mg/L to 12.92 mg/L following treatment, representing a reduction of approximately 74%. The banana pseudostem, after being immersed for three days (3x24 hours), showed a reduction in peroxide value to 14.61 mg/L, achieving a 75% decrease in peroxide content. Although, banana pseudostem and banana stem adsorbent effectively lowered the peroxide content, the final values still exceeded the permissible limit set by SNI 01-3741-2002, which is 1.00 mg/L. It is indicating that the current treatment is not sufficient to achieve the desired peroxide reduction.

The reduction in peroxide values can be attributed to the high cellulose content found in both banana pseudostem and stem, which plays significant role in adsorbing and neutralizing peroxides. Cellulose, being a highly polar substance, can adsorb organic compounds such as peroxides, thus reducing their concentration in the oil. Studies have shown that adsorbents with high cellulose content, such as various plant materials, can be effective in lowering peroxide levels in oils (19,20).

The high cellulose content in banana pseudostem and stem contributed to the reduction in peroxide levels. However, further improvements are necessary to achieve peroxide levels below the permissible threshold.

However, while the treatment resulted in a substantial reduction, it did not achieve the required threshold for edible oils as stipulated by the SNI 01-3741-2002 standard. This suggests that further optimization of the process is necessary. Potential improvements could include extending the treatment duration, modifying the adsorbent size, or using additional material to enhance the adsorption capacity (18). Additionally, other factors such as temperature, pH, and oil type may also play a role in improving the effectiveness of the treatment (21).

Enhancing peroxide reduction might involve incorporating additional substances or employing alternative methods. For

example, converting banana pseudostem and banana stem into activated carbon treated with chemical activators such as sulfuric acid (H_2SO_4), hydrochloric acid (HCl), or phosphoric acid (H_3PO_4), could improve adsorption capacity (22).

Aligns to (23), that using activated Ampo as an adsorbent reduced peroxide values in used cooking oil by 93%, meeting standard quality requirements.

But these methods have weaknesses, they reduce the eco-friendly nature of the adsorbent derived from banana pseudostems and stems by introducing non-biodegradable chemicals. So it's recommended to longer immersion times, higher adsorbent quantities of banana pseudostem and banana stem adsorbents.

According to (21), the activation time also affects the adsorbent's quality; longer activation times allow for better removal of organic matter blocking the pores.

In the context of used cooking oil treatment, optimizing the activation time of adsorbents like banana pseudostem and banana stem could lead to more efficient reduction of peroxide values. By extending the activation duration, it is possible to achieve a more thorough removal of organic impurities, thereby improving the adsorbent's performance in purifying used cooking oil.

This study found that the decrease of FFA is more significant than peroxide due to chemical composition and adsorption mechanism in UCO. FFAs are the result of hydrolysis of triglycerides during frying, leading to their accumulation in UCO. Natural adsorbent, such as banana pseudostems and stems, are rich in cellulose and lignin, which have a strong affinity for polar compounds like FFAs. This affinity facilitates the adsorption of FFAs more effectively than peroxides. In contrast, peroxides are formed through the oxidation of lipids and may not interact as readily with the functional groups present in natural adsorbents (25).

It highlights that optimizing particle size and controlling lignin content are critical for maximizing the adsorption capacity of banana pseudostems and

stems, ensuring effective reduction of FFA and peroxide values in UCO.

CONCLUSION

The particle of banana pseudostem and banana stem affect the effectiveness of reducing peroxide and Free fatty Acid (FFA) levels in used cooking oil. Adsorbents with a particle size of 200 mesh show the best efficiency, with banana pseudostems performing slightly better than banana stems. This study demonstrate the great potential of banana pseudostems and banana stems as inexpensive and environmentally friendly natural adsorbent materials for used cooking oil.

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