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Characterization of Waste Cooking Oil Purified by Crushed and Sliced *Zingiber Officinale* (Ginger)

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The rapid growth in the human population and the frying methods in preparing food resulted in significant amounts of waste cooking oil (WCO) being generated globally. The excessive piling of the waste has become an alarming problem because the WCO disposal method is inefficient. People tend to dispose of WCO via irrigation systems by simply discarding it. Most WCO has been disposed of in sewage which has created various problems such as water pollution and soil pollution and has unfavorable consequences for the environmental system. From previous studies, it is reported that ginger can treat WCO. This research aims to investigate the effect of the surface area of ginger to treat WCO. For the methodology, the first step, the surface area of ginger (crushed and sliced) needs to be investigated. The ginger is crushed and sliced before WCO purification. The crushed and sliced ginger sample is then analysed using scanning electron microscopy (SEM) to examine the structure of ginger that affected WCO treatment. For the characterisation study of the purified WCO, the sample is studied using Fourier transform infrared spectroscopy (FTIR) to identify the functional group and composition present in the purified WCO. The SEM images of ginger before and after the WCO treatment show a significant difference, demonstrating that ginger has the potential to treat WCO. The highest percentage difference between WCO purified with sliced ginger is 3.33 % from alkane $(CH_2)_n$. In the WCO purified with crushed ginger, the glycerol group O-CH_2 stretching band displayed the greatest percentage variation, at 2.22 %. In conclusion, the surface area of ginger plays an important role in WCO treatment. This research may be an essential requirement for WCO treatment before converting into other valuable products.

1. Introduction

WCO is one of the second-generation wastes that is abundantly generated across the world, with an estimated yearly output of 190 million tons (Mannu et al., 2020). Malaysia produces roughly 0.5 million tons of WCO yearly as the world's second-largest producer and first exporter of palm oil. The growing consumption of fried foods among Malaysian has contributed to a rise in the amount of waste cooking oil (Kamilah et al., 2015). In both developed and developing countries, handling these massive volumes of WCO has recently become a major concern. WCO and other used domestic edible oils and fats are now commonly dumped off with municipal garbage or simply thrown into drains. In the long term, this behavior adds to water and soil pollution, disrupts marine life, causes sewage system clogs and overflows, raises water treatment and waste management expenses, and has unfavorable consequences for the overall environmental system.

When WCOs interact with water, they elevate the water’s chemical oxygen demand (COD) and pollute, making the water hazardous (Yacob et al., 2015). As a result, aquatic life ingested harmful substances from polluted water, which were ultimately returned to humans via the food chain. In terms of the health consequences of WCO reuse, it has been stated that continuous consumption of WCO is extremely hazardous to human health. Using WCO continuously for meal preparation raises the risk of cardiovascular illness, liver disease, and cancer, when cooking oil is heated over an extended period, the concentration of hydrocarbons in the oils develops,

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making it unsafe to be consumed. The management of WCO is a distinct field of waste management because there are particular issues to be handled due to its physical structure and features (Matušinec et al., 2020). At low temperatures, WCO solidifies and only melts at high temperatures.
WCO utilization has increased the efficiency of waste material and energy recovery processes, which is in keeping with the circular economy idea. The two main types of WCO treatments available are chemical treatments such as esterification, transesterification, and saponification and physical treatments such as distillation, extraction, and filtration. The chemical functional groups present in WCO are exploited through the chemical treatment for the synthesis of value-added products. Removing undesired products from WCO is fundamentally the aim of physical treatment.

1.1 Ginger

The earliest recording of ginger was mentioned in Chinese herbals, and it is also well known by ancient Greek physicians in 40-90 AD (Anno Domini) (Semwal et al., 2015). Today, abundant studies have been carried out to understand this herb's potential fully. Some of the benefits that ginger can gain include its anticancer properties (Vemuri et al., 2017) and its antioxidant properties (Menon et al., 2019). A study by Lu et al. (2018) investigated the polycyclic aromatic hydrocarbon (PAHs) formation in food prepared by using the deep-fried method with a spice mix including ginger, garlic, onion, red chilli, paprika, and black pepper. The authors concluded that adding ginger has a significant result to remove the PAHs in WCO compared to other spices. They discovered that the ginger's antioxidant capacity was a primary contributor to its inhibitory efficacy.
A study by Razak et al. (2021) reported the main disadvantages of the WCO treatment method including high investment and maintenance costs, complex operating procedures, and extra time consumption. WCO treatment with ginger is preferable because it operates at a low cost, simple method, and little time-consuming when compared to other chemical and physical WCO treatments. The usage of ginger in this work is a pioneering step and solely to notify the effect of ginger in WCO purifications. Ginger waste could be improvised from this study however it might yield a different outcome. It is of great interest to consider employing the ginger waste for future work later.
Therefore, in this study, ginger is used because there is presently insufficient research on ginger from WCO treatment. The objective of this paper is to investigate the effect of crushed and sliced ginger to treat WCO.

2. Materials and methods

2.1 Materials

WCO samples were all collected from local household kitchen in Durian Tunggal, Melaka. The samples were palm cooking oil used for frying. The collected WCO samples were filtered, labeled, and stored in a plastic bottle container at room temperature. A ginger (Zingiber Officinale) was purchased from the local supermarket in Durian Tunggal, Melaka. The fresh ginger was cleaned, and their thin outer skin was scraped out. A part of the ginger was sliced using a knife, and the other was crushed using a domestic food blender. The sample was labeled separately as sliced ginger and crushed ginger. Figure 1 shows the picture of sliced ginger and crushed ginger. It can be seen clearly that the sliced ginger was cut in a long rectangular shape whereas the crushed ginger was in a small cubic shape.

Figure 1: Macroscopic picture of sliced ginger and crushed ginger

2.2 WCO treatment with ginger

10 g of sliced ginger and crushed ginger were weighed using an analytical balance. The filtered WCO sample and ginger were mixed well. The mixture was heated using a hotplate magnetic stirrer, and the time started when the mixture reached 80 °C. The pH of the mixture was tested and it is at pH 5. After 10 min, the samples were cooled at room temperature (27 °C to 32 °C) and filtered using filter paper to remove the ginger. The ginger residue and purified WCO were labeled and stored in a sample test tube at room temperature. Under these conditions, the ginger residue was observed by using SEM to study the characteristic of the structure. The purified WCO obtained in this study was further analyzed using FTIR for the characterization analysis of the purified WCO to determine the functional group and composition present in the purified WCO. The whole process was simplified in the flow chart, as illustrated in Figure 2.

2.3 Ginger characterization

Before and after WCO treatment, the ginger was dried in an oven (Memmert UF55) at 150 °C for 30 minutes. These materials, denoted as dried ginger, were packed in zipper bags and kept at room temperature. The structure and size of the dried ginger were analysed using SEM (JEOL JSM-6010PLUS/LV) at an accelerating potential of 10 kV and zoomed by *x*100 magnifications. Samples were applied on a circular aluminium stub with double sticky tape, and the sample was coated with a thin layer of platinum using a fine auto coater (JEOL JEC 3000FC). This analysis was implemented in the Materials Science Laboratory, Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM).

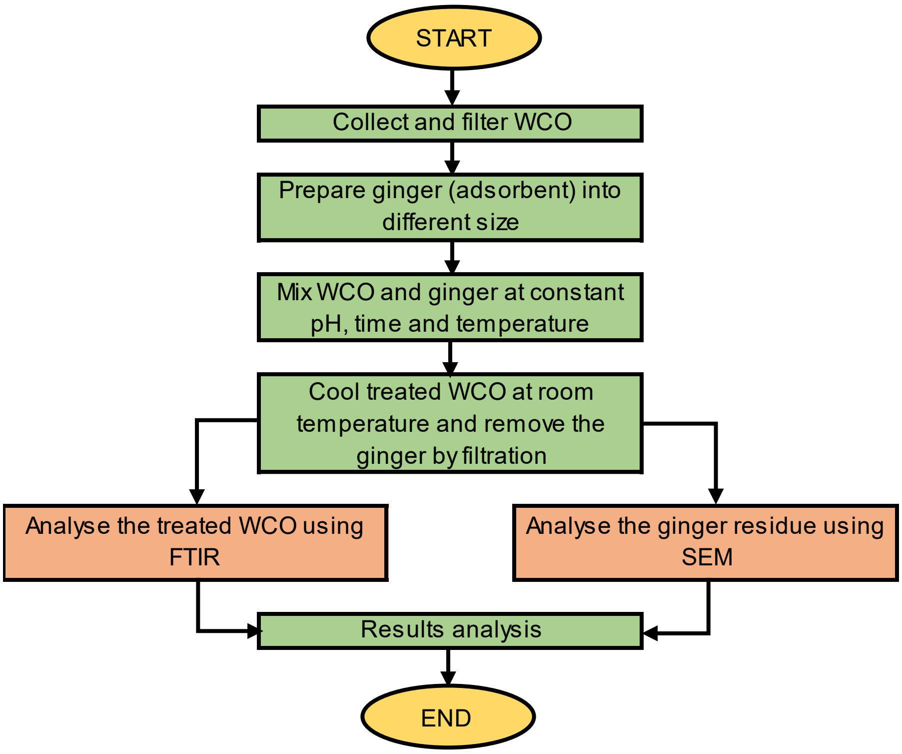

Figure 2: Process flow chart for the study

3. Results and discussions

3.1 SEM analysis

The dried ginger was examined employing SEM. Figure 3 shows the SEM image of crushed dried ginger before and after WCO treatment and Figure 4 shows the SEM image of sliced dried ginger before and after WCO treatment. All experiments are conducted at *x100* magnifications. For the SEM image of dried ginger before WCO treatment, the crushed ginger and sliced ginger have irregular pores with thick walls. They also show the disarrangement suffered by the cellulosic structure due to the pressure applied during the cutting process. The cellulosic walls are mostly round for crushed ginger, and on the other hand, the sliced ginger has rectangular cellulosic walls.

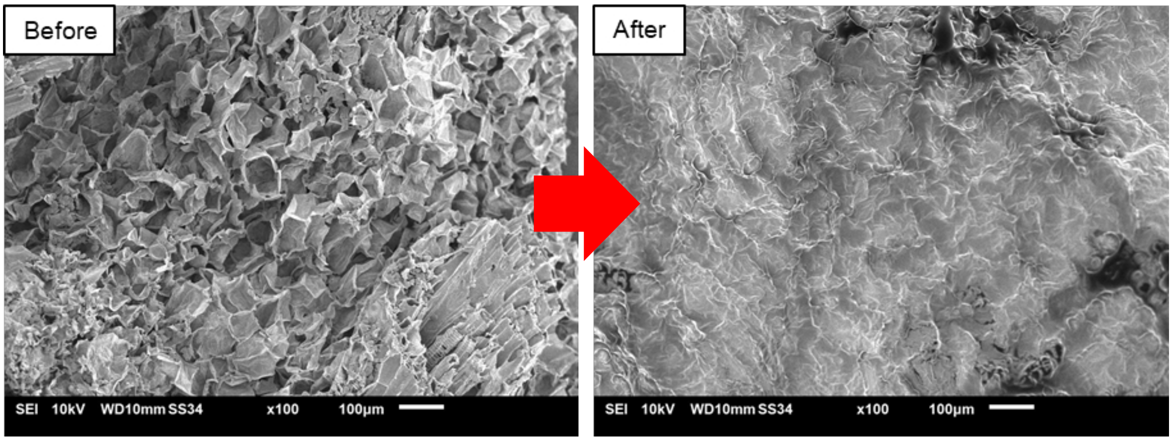

Figure 3: SEM of crushed dried ginger before and after WCO treatment by x100

For the SEM image of dried ginger after WCO treatment, its structure appeared to have changed because all pores have been covered by oil through the heat treatment despite the difference in cutting size. The single pore before the treatment can also be seen clearly, and after the treatment, it is hard to distinguish a single pore because the pore wall has also become thin throughout the WCO treatment. Both figures show that ginger can trap WCO in their pore wall which implies the mechanism of WCO treatment. The elements that have been trapped will be tested by Gas Chromatograph Mass Spectroscopy (GCMS) and High-Performance Liquid Chromatography (HPLC).

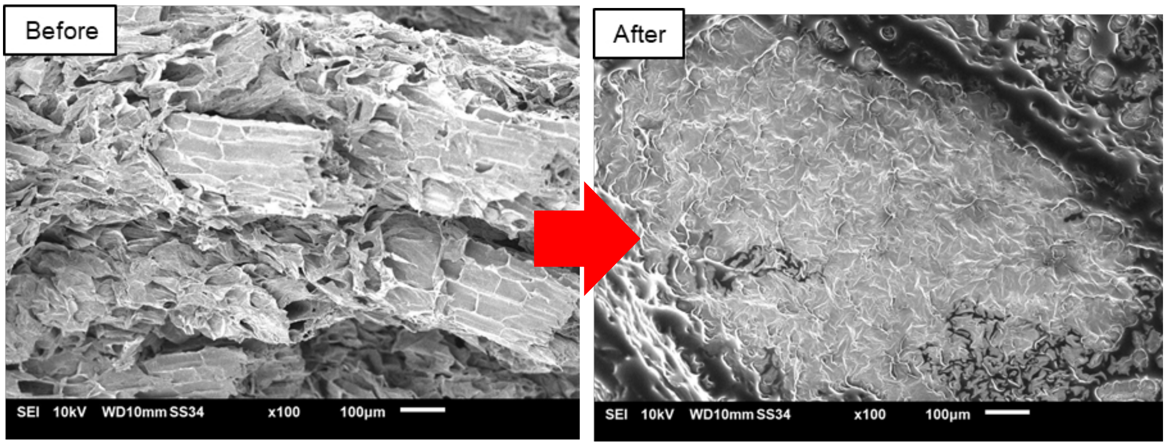

Figure 4: SEM of sliced dried ginger before and after WCO treatment by x100

3.2 Effect of ginger cutting size

FTIR is an instrumental analysis method for identifying functional groups in organic and inorganic substances by measuring their infrared radiation absorption over a variety of wavelengths (Berna, 2017). The infrared spectrum of absorption of the WCO sample is obtained using the FTIR technique. The FTIR spectrum for the non-purified WCO, WCO purified with crushed ginger, and WCO purified with sliced ginger were displayed in Figure 5. The FTIR spectrum was analyzed from 400 cm^{-1} to 4000 cm^{-1}. The functional group remains unchanged before and after WCO treatment, and the results are consistent with the previous study by Lamichhane et al. (2020). The alkane component exists in the WCO at the absorption peak 2,911 cm^{-1} and 2,790 cm^{-1}. The peak for typical esters, which is the stretching band of C=O, was observed at 1,701 cm^{-1}. It can also be seen in Figure 5 that the glycerol group, O-CH_2 group is present in the WCO at 1338 cm^{-1}. Glycerol is a flexible renewable raw material that may be refined or distilled. It is mostly employed in the chemical industry, but it can also be found in foods and drinks as a humectant and solvent (Harabi et al., 2019).

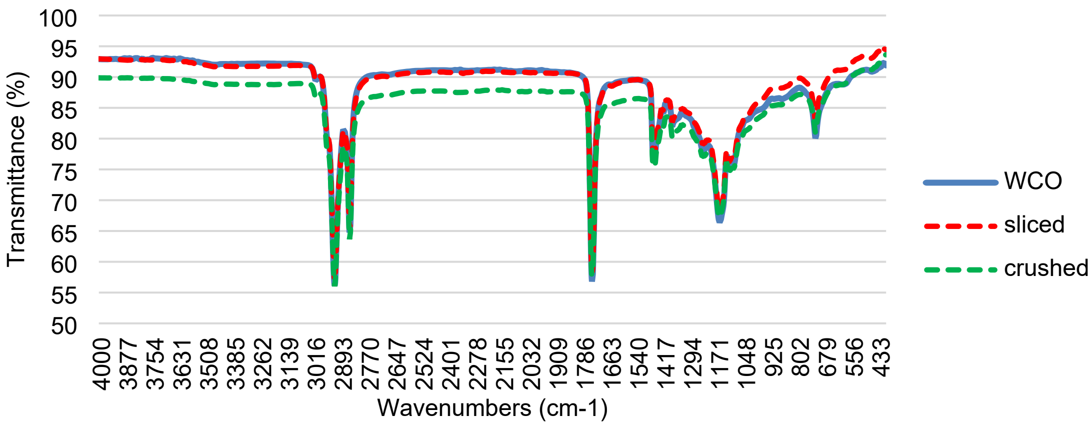

Figure 5: Comparison of FTIR spectrum between unpurified WCO, WCO purified with sliced ginger, and WCO purified with crushed ginger

Percentage transmittance is the intensity measured from the infrared radiation concerning the reference. the transmittance of purified WCO was expected to be lower than that of the unpurified WCO. The variation of the transmittance results between WCO purified with sliced ginger and crushed ginger is due to the difference in the surface area of the different cutting sizes of ginger that make the ginger affect WCO differently.

The stretching band is the vibrational mode of the functional group molecule. Bending, scissoring, rocking, and twisting is the other example of vibrational modes (Lin-Vien et al., 1991). Figure 5 shows the trend of all the transmittance results. The trend shows that unpurified WCO has the highest transmittance value followed by WCO purified with sliced ginger and crushed ginger accordingly. The crushed ginger has a bigger surface area contacting with the WCO it has the highest efficiency towards the WCO treatment, so the transmittance is lower. All the spectra results and the percentage difference of the transmittance of WCO purified with sliced ginger and WCO purified with crushed ginger from the non-purified WCO were tabulated in Table 1. The significant percentage difference from the WCO purified with sliced ginger is 2.65 % C=O, 2.48 % C-O-C both of stretching band ester, and the highest difference is 3.33 % of $(CH_2)_n$ of alkane. C_2H_4 is an example of alkane and small hydrocarbons that is responsible and contribute to the PAHs and soot formation (Hanafi et al., 2018). The largest percentage difference of the WCO purified with crushed ginger is 2.22 % of the glycerol group O-CH_2 stretching band. In addition, the FTIR result of crushed ginger has a significant decrease in intensity compared to the sliced ginger. This result proved that crushed ginger has a more noticeable effect on WCO treatment.

Table 1: FTIR spectrum of unpurified WCO, WCO purified with sliced ginger, and WCO purified with crushed ginger

Frequency (cm^{-1})	Functional group	Vibrations type	Transmittance of non-purified WCO (%)	Transmittance WCO purified with sliced ginger (percentage difference) (%)	Transmittance WCO purified with crushed ginger (percentage difference) (%)
2,922	Alkane	CH_2 stretching	56.09	57.01 (1.64)	56.04 (0.09)
2,853	Alkane	CH_2 stretching	64.41	64.89 (0.75)	63.37 (1.61)
1,744	Ester	C=O stretching	56.60	58.10 (2.65)	57.45 (1.50)
1,464	Alkane	C-H bending	76.66	77.38 (0.94)	75.20 (1.90)
1,377	Glycerol	O-CH_2 stretching	81.90	82.59 (0.84)	80.08 (2.22)
1,161	Ester	C-O-C stretching	66.40	68.05 (2.48)	67.07 (1.01)
722	Alkane	$(CH_2)_n$ rocking	79.94	82.60 (3.33)	80.93 (1.24)

4. Conclusions

In the present work, the effect of ginger cutting size; crushed and sliced WCO treatment was being investigated. The technical limitation of this work has been encountered specifically during the sample preparation for SEM analysis. The sample ginger after the WCO treatment must be completely dry from the oil to get an accurate and clear image of the SEM. Besides using the oven to dry out the oil from the ginger, oil paper was used to absorb excess oil from the surface of the ginger.

The experimental results showed that ginger has a significant effect on the WCO treatment. The SEM image of ginger before and after the WCO treatment is completely different to prove that ginger has the promising ability to treat the WCO. This result is supported by the FTIR result of the purified WCO. The highest percentage difference between the WCO purified with sliced ginger is 3.33 % from $(CH_2)_n$ of alkane. The glycerol group O-CH_2 stretching band had the greatest percentage difference in the WCO purified with crushed ginger, at 2.22 %.

From the SEM image results, some elements that have been trapped will be tested and identified by Gas Chromatograph Mass Spectroscopy (GCMS) and High-Performance Liquid Chromatography (HPLC) later. This study is relevant for WCO utilization to enhance the energy recovery measures and develop waste material efficiency in the future.

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