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Kapok (Ceiba Pentandra (L.) Fiber for Removal of Spilled Oil

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Abstract: Kapok is a natural cellulosic fiber with unique characteristics. It is often considered the most effective method for cleaning up and collecting oil spills. A critical investigation was conducted to study the potential of kapok fiber as sorbent material. This research aims to analyze the surface properties of kapok fiber for the ability of kapok fiber to absorb oil and evaluate the interaction mechanisms of kapok fiber in oil/water as oil sorbent. Therefore, the surface properties of kapok fiber were characterization and analyzed using Scanning Eelectron Microscope, Fourier Transform Infrared and contact angle. To investigate the selectivity nature and the sorption capacity of 5 g kapok fiber and different types of oil were used. The types of oil used are 60ml of original palm oil, 60ml of used palm oil, 60ml of original coconut oil and 60ml of used coconut oil. Kapok fiber was able to absorb all the types of oil, with original palm oil, the oil absorbs the shortest time with a record of 15 minutes compared to other oils. Scanning electron microscopy (SEM) was used to examine the morphology of raw kapok fiber. In this study, kapok fiber was shown to have a porous hollow lumen structure and a waxy coating on the surface. Other than that, for the contact angle analysis show that the kapok fiber had high water contact angle up to 137.30˚. The water droplet was stood on the kapok fibers surfaces before and after absorption with the range of contact angles from 102˚ to 137˚. In contrast, the oil droplet had disappeared from the surfaces of kapok fiber within a few seconds. This review discusses the recent papers on the use of natural fiber sorbent for removal of oil from water. With their excellent oil removal properties, environmental friendliness, easy availability, and feasibility, natural fibrous sorbents are an attractive alternative for oily wastewater treatment.

Keywords: Kapok Fiber, Absorption, Oil Spilled

1. Introduction

The extremely serious effects of the marine environment pollution due to oil spill [1], oil slick [1] and toxic heavy metals [1] on the human, ecosystem, and society are clearly seen [1]. When an oil spill happens in water, the leaked oil might produce an oil-water emulsion or floating films, which prevent

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sunlight from penetrating the water and killing living organisms [2]. Spilled oil accidents have a serious impact on ecological and environmental systems [3]. The oil spilled can have an effect such as harming sea creatures, ruining a day at the ocean and beach, and making seafood unsafe to eat or cook [4]. Besides, tens of thousands of people have died because of various diseases that are connected to environmental pollution. For instance, the Deepwater Horizon drilling rig exploded in the Northern Gulf of Mexico which resulted in 3.19 million barrels of oil spilling and several hundred thousand hydrocarbons leaking into the water [2]. To overcome this problem, need to come up with a something that can remove the oil spill. There have been several strategies used to reduced oil spill. One of the methods used by using an absorbent material such as kapok fiber, cotton and others. A variety of oil absorption materials, including natural inorganic materials, natural fibre materials, and synthetic materials, have been used to clean up oil spills [5]. Natural fibre materials including cotton fiber, kapok fiber, wood, straw, milkweed, and wool have gotten extending consideration as a cost-effective eco-friendly absorbent for oil removal from industrial sewage due to their versatile properties such as, biocompatibility, biodegradability, and non-toxicity compared with the preeminent manufactured sorbents [5]

1.1 Objective of study

The objective for this study are:

a) To characterization and analyse the surface properties of kapok fibre.
b) To evaluate the interaction mechanisms of kapok fibre in oil/water as oil sorbent.

1.2 Additional introduction subheadings

Subheadings in the introduction are usually limited to 2-3 topics. Contents should be brief; more detailed information should be discussed in the methodology section. The subheadings should not go beyond the second level.

2. Materials and Methods

This section otherwise known as methodology, describes all the necessary information that is required to obtain the results of study.

2.1 Materials

Material is the essential things that we need to take into consideration before starting any experiment. A systematic approach to a material selection process is necessary to select the proper material for any application. Choosing the right material requires carefully identifying the application requirements in terms of sample surface structure, sample qualities, chemical content, and other application. This experiment only consists of two types of material which are:

a) kapok fiber
b) palm oil
c) coconut oil.

2.2 Methods

Prior to carrying out the work, a flowchart should be produced as a guide or work step to do during this experiment. The flowchart is shown in Figure 1. the flowchart is to make sure the process can be done as planned the objectives of this experiment have been achieved.

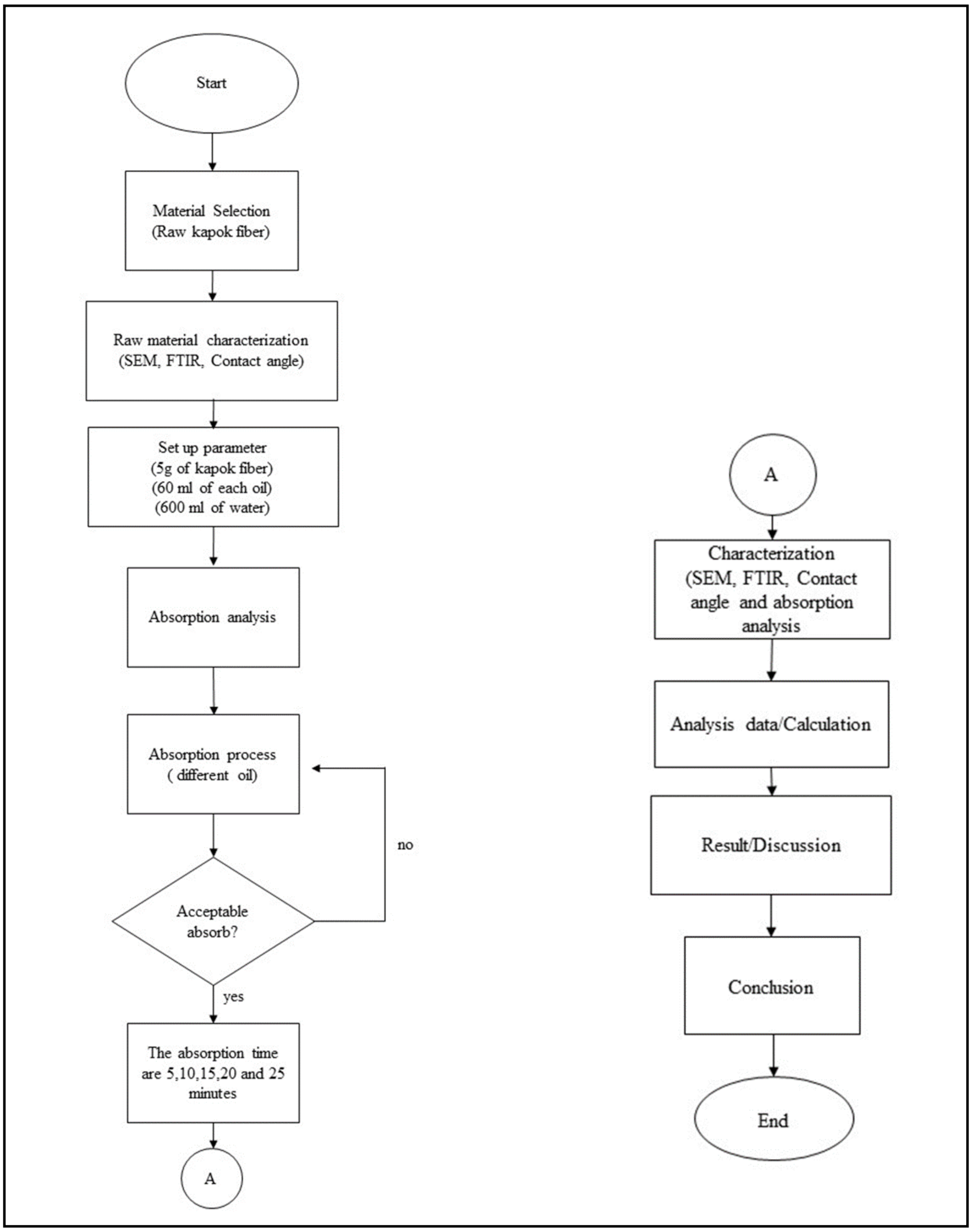

Figure 1: Research flowchart

2.3 Parameter setup

In this experiment, the parameter that must be fixed for sample of kapok fiber, oil and water. Table 3.2 and Figure 3.3 below showed the set of parameter use in this experiment. In addition, the sample of kapok fibre were test with different type of oil which are palm oil, coconut oil, used palm and used coconut oil.

Table 1: The fix parameter set up for kapok fiber

Weight (g)	Diameter (cm)	Height (cm)
5	8	5

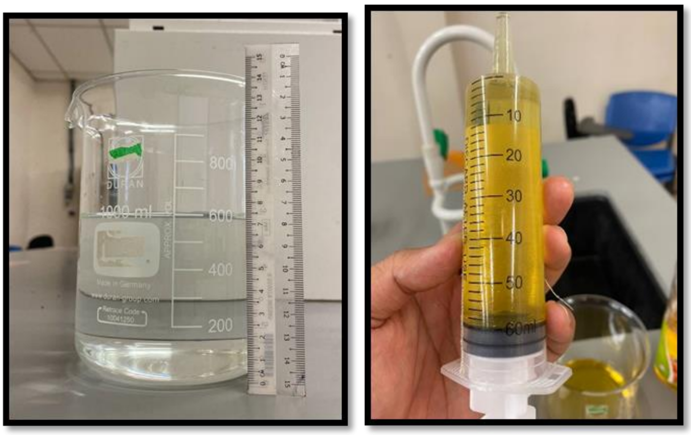

Figure 2: Parameter setup for oil and water

2.4 The apparatus setup for oil absorption

The experimental arrangement has been design to replicate the practical use of kapok fibre to absorb free-phase oil floating on water. The experiment has been prepared by combining oil and water. An approximate quantity of each of the three types of test oil will be mixed into tap water in a series of three beakers. After the oil and water mixture has reached a steady state, kapok fibre in a loosened form has been placed across the whole liquid surface in each beaker. Take the time when the kapok starting absorb the oil. Then, the kapok fibre has been pull out from the beaker.

Figure 3: Design of absorption study

2.5 Oil absorbing measurement

To determine the oil sorption ability of kapok fibre, the suitable method to evaluate the capacity of oil in the sample is to measure time the sorption of oil. Therefore, the mass of the model will take before and after immersion into the solution. In this experiment, the testing of the sorption behaviour of kapok fiber will be done by using a mixture of oil and water. Firstly, 60ml of oil and 600ml of water will pour into a 1000ml beaker. After the oil and water in a steady state, 5g of kapok fiber will immerse horizontally in the solution for 5, 10, 15, 20, 25 and 30 minutes to ensure that the sorption reaches until not have any oil on the water. Then, the weight of the sample will be taken after being lifted out of the beaker.

2.6 Characterization of Kapok Fiber

2.6.1 Surface Morphology of Kapok Fiber using SEM

Kapok's surface morphology was analyzed using Scanning Electron Microscope (SEM) from JEOL JSM-6380LA. Kapok fiber was coated in platinum to increase the conductivity. Sample of kapok was placed on steps using sticky carbon steps. The camera position was adjusted using two knobs that control the x-axis movement and y-axis movement.

2.6.2 Surface Analysis of Kpaok Fiber Using Contact Angle

The contact angle of kapok fiber were studies using the sessile drop method where a drop of water is placed on the surface of material. This was done by using contact angle analyzer from VCA Optima, AST product. The contact angle of the liquid was shown on desktop. Image of the droplets on kapok fiber were taken by the analyzer.

2.6.3 Fourier Transform Infrared Spectroscopy

The stage of the FTIR machine is cleansed with alcohol to remove impurities. Small pieces of kapok fiber are placed on the stage. Wavelength ranging from 4000 cm^{-1} – 600 cm^{-1} was set and for each spectrum 32 tests were run.

3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Oil Sorption Analysis

From the Figure 4 it can be seen that the original palm oil absorb shorter time compared to other oils. Then, the weight will be taken according to the appointed time as shown in Figure 4 and Figure 5.

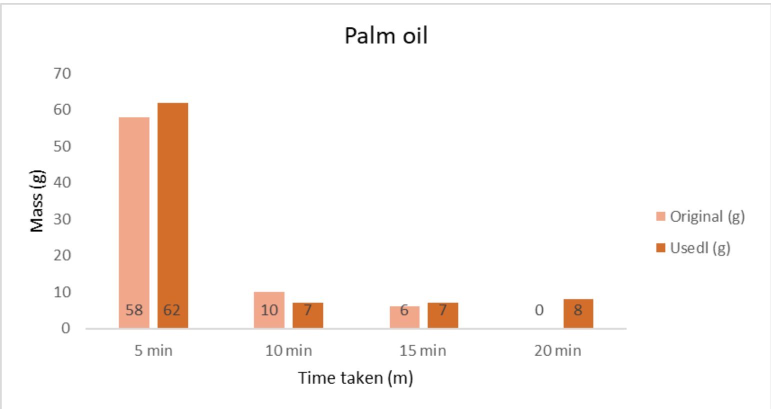

Figure 4: Oil absorption of palm oil on kapok fiber

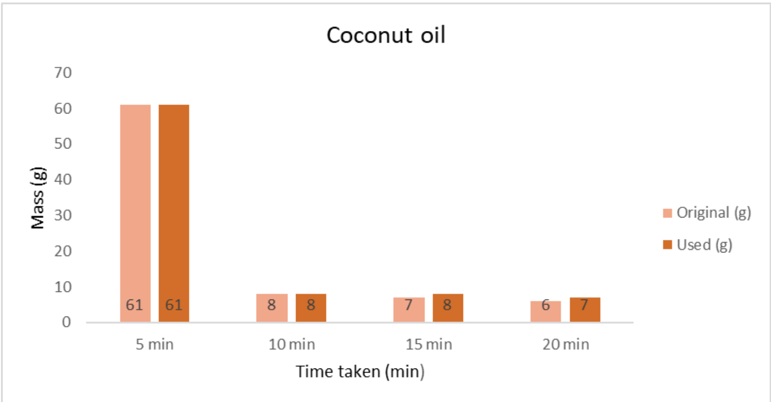

Figure 5: Oil absorption of coconut oil on kapok fiber

3.2 Surface morphology analysis of Raw Kapok Fiber using SEM

Raw kapok fiber surface structures were analyzed using by Scanning Electron Microscope (SEM). Figure 4.3 shows the SEM image of surface morphologies of raw kapok fiber. The raw fiber has a smoother surface and the orifice of hollow lumen is nearly closed. The surface of kapok fiber is smooth with the size of ca. 12-20 µm in diameter. Raw kapok fiber exhibits a smooth surface without any ripple due to the coverage of plant wax, while the surface of treated samples is rough along with different degree of wrinkles and grooves. This suggests that the surface wax of kapok fiber is removed and the hydrophilic surface is exposed. The statement was supported by a research study from [6]. The excellent oil absorption capacity was found in the kapok fiber largely because oil can easily enter the hollow cavity through the open ends of the fiber wall and through the multi-level buckling microspores on cells [7]. The fibres are coated with a highly water-resistant waxy. It has a thin wall with an air filled lumen. The kapok fibre is lustrous and extremely light. This statement was supported by a research study from [8].

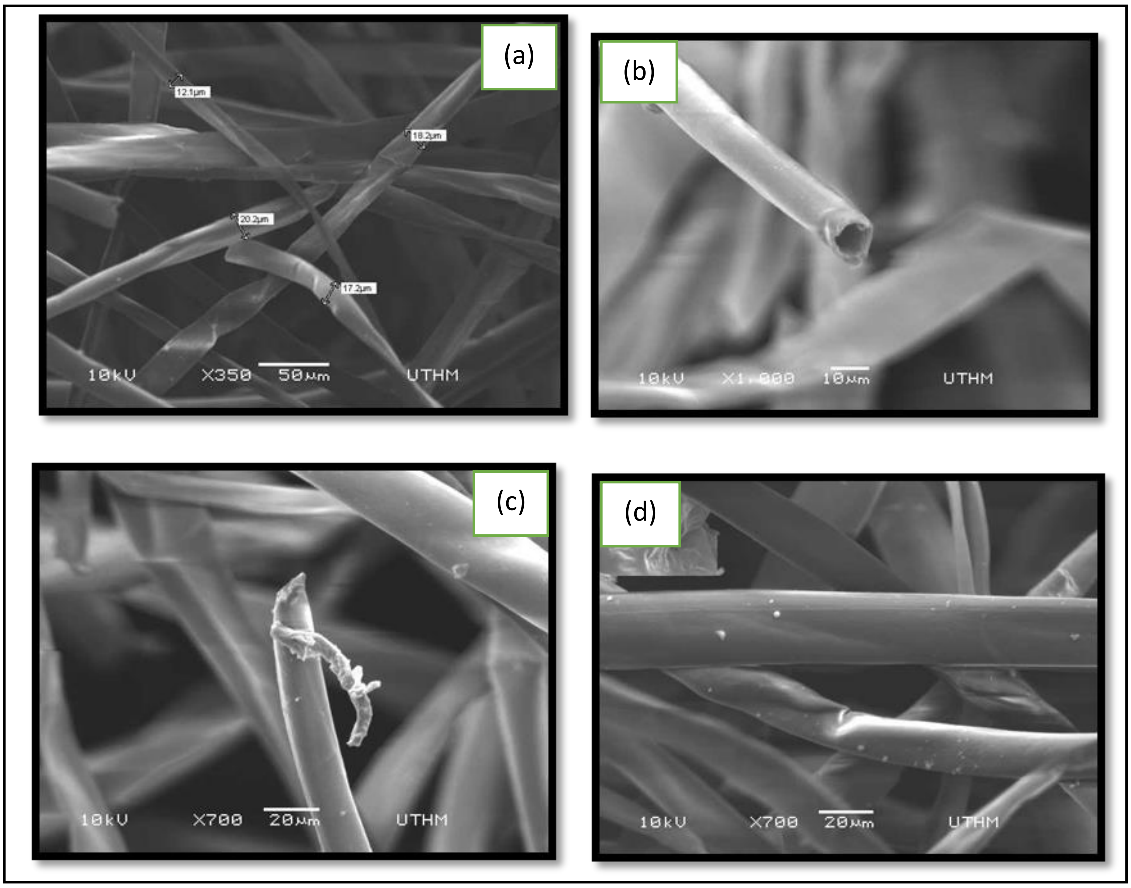

Figure 6: SEM image of kapok fiber (a) average diameter (b) large lumen and hollow structure (c) end of the kapok (d) smooth surface

3.3 Element and Functional Group Analysis of Kapok Fiber using FTIR

FTIR spectra are commonly used to identify the groups involved in the reaction process. Figure 7 demonstrates the result from FTIR for all sample. For the raw kapok fiber, the following primary absorption peaks can be observed: the strong and broad peak at 3338 cm−1 was assigned to non-free O-H stretching vibration, the strong peak around 2914 cm−1 was assigned to asymmetric and symmetric stretching vibration in CH2 and CH3 [6]. Other than that, the FTIR result for kapok fiber was lignocellulosic and had a hydrophobic waxy covering.

However, the absorption peak belonged to C=O stretching vibration of ketones, carboxylic groups, and esters in lignin and acetyl ester groups in xylan at 1740 cm-1 had no obvious change, which indicated that the NaClO2 treatment had no destruction to lignin and xylan [14]. For the kapok fiber after absorption test, it can be seen the abroad at 3338 cm−1 for original palm oil and used palm oil were increasing. Meanwhile, for the absorption bands of original coconut oil and used coconut oil slightly reduced at 3338 cm−1. According to the research study from [9], the absorption peaks between 1602 and 1504 cm−1 practically vanished in NaClO2-treated kapok fiber, indicating the breakage of the aromatic chain in lignin. The NaClO2 process is an efficient method for changing the surface character of kapok fiber [9]. This phenomenon happened due to the kapok fiber had lost their smooth and waxy surface after absorption test. This statement was supported by [10].

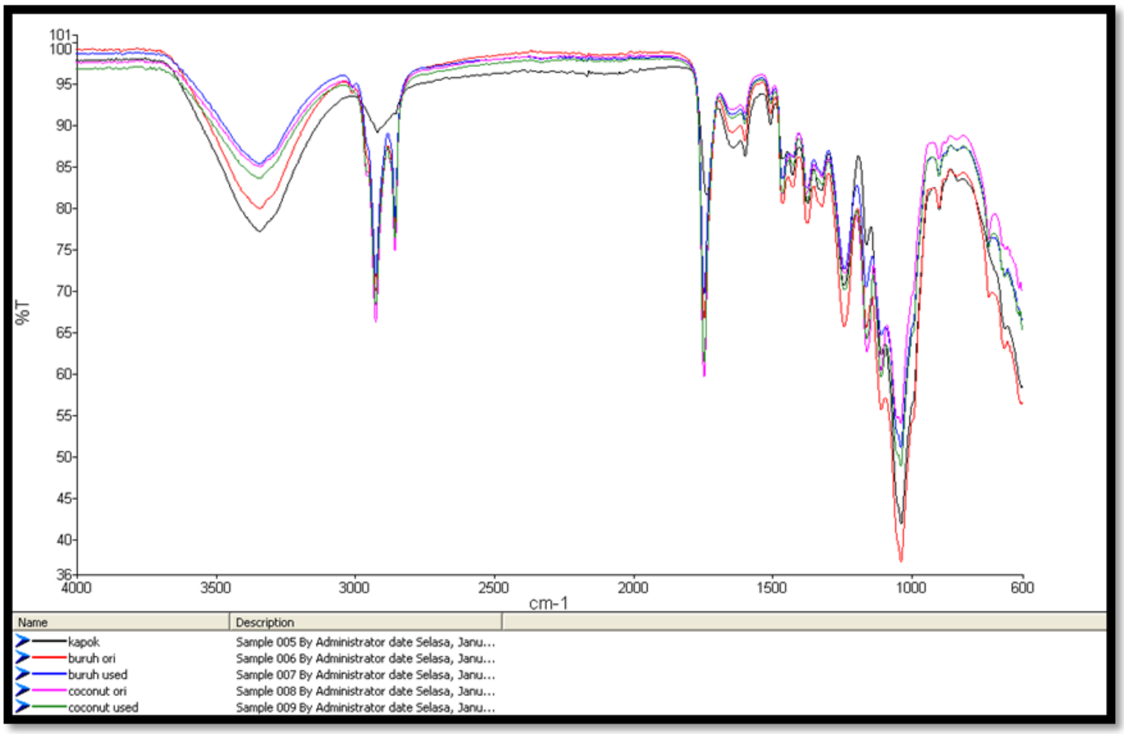

Figure 7: FTIR result for all sample

3.4 Surface Properties Analysis using contact angle

The contact angle was performing to appraise the surface properties of kapok fiber. Therefore, Figure 4.5 shows the contact angle measurement of raw kapok fiber and kapok fiber with four different oils. The kapok with palm oil and used palm oil was absorbed as shows in Figure 8. The surface contact angle of raw kapok fibers was 137.30° and kapok fibers with different oil to 106.90° for original coconut oil, 102.70° for used coconut oil and no angle for the contact angle between water and kapok immersed in original and used palm oil because the water droplets absorb into the kapok with palm oil. The surface wettability of water on the surface of the raw kapok fibre was observed in Figure 4.5 respectively. The water contact angle of the raw kapok fiber was 137.30°.

In general, wettability uses contact angle measurements which simulate the degree of wetting during the interaction between solids and liquids. A small contact angle of less than 90 degrees corresponds to high wettability or hydrophilicity whereas a large contact angle of more than 90 degrees signifies low wettability or hydrophobicity [11]. For hydrophilic surfaces, s, their receding angle (θR)'s is <90°. These surfaces exhibit strong affinities, as indicated by the residual water droplets in the pull-off experiments, whereas hydrophobic surfaces are shown to have little affinity with water, and their receding angle (θR)'s are >90° [12]. Figure 4.3 shows that the contact angle of raw kapok fiber was higher than that the kapok fiber with different oil. Therefore, the contact angle of raw kapok fiber in this experiment was getting 137.30° and this result was more than enough to prove that kapok fiber was hydrophobic. The hydrophobic–oleophilic properties of oil sorbent are determined by factors such as the chemical constituent of the sorbent, the amount of the surface wax, the physical configuration of the fiber such as the hollow lumen, the twists and the crimps, and the surface roughness and its porosity [13]. According to research from Abdullah also (2010), C. pentandra (L.) Gaertn (kapok) as a natural sorbent exhibited high hydrophobic–oleophilic characteristics, which were attributable to its waxy surfaces and hollow lumens and exhibited stability for prolonged use, with higher saturation time and low bed height reduction at higher packing density and higher oil viscosities [13].

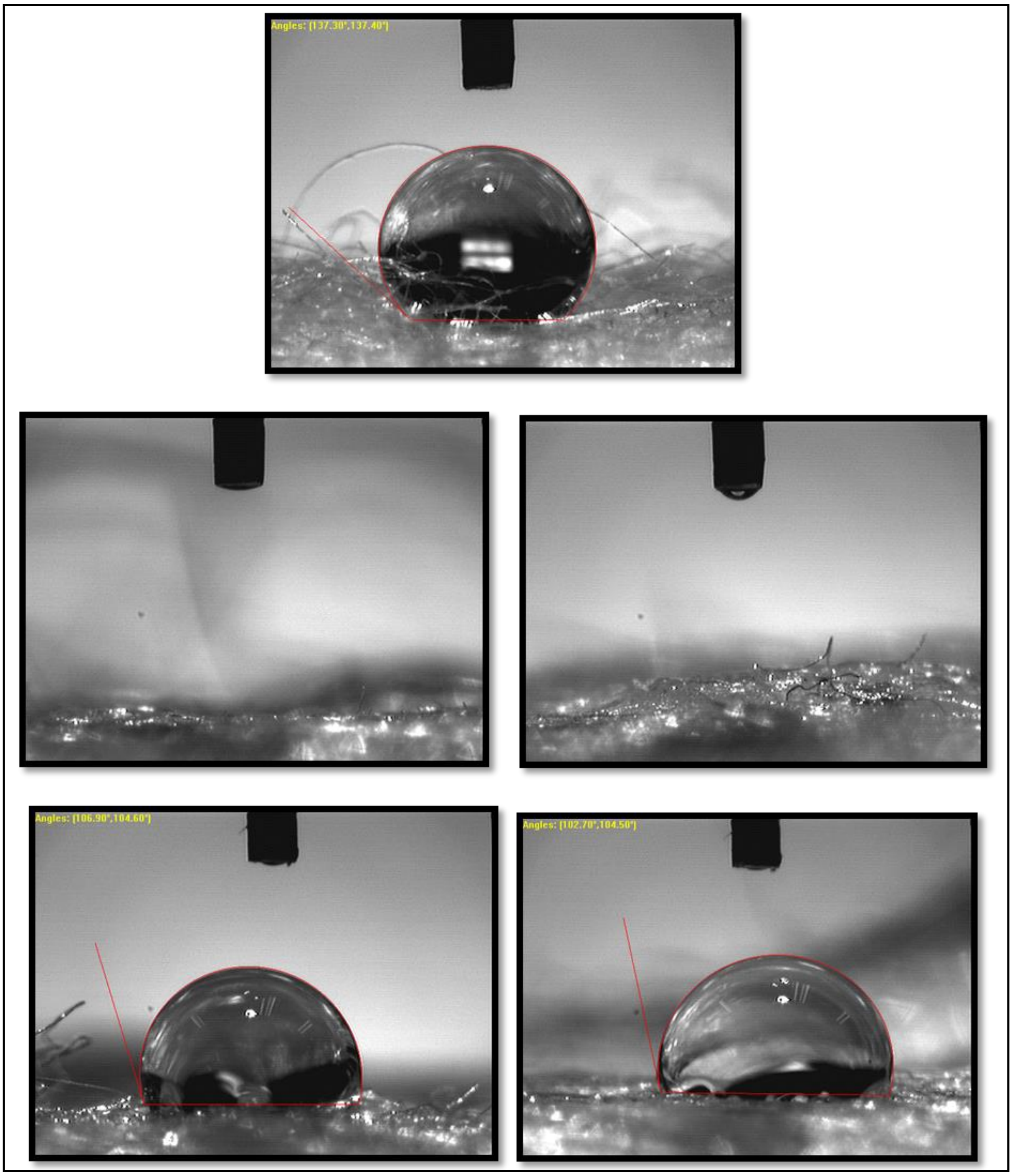

Figure 8: Contact angle of kapok fiber (a) raw kapok (b) palm oil (c) used palm oil (d) coconut oil (e) used coconut oil

4. Conclusion

This study was conduct to investigate the oil sorption behavior of kapok fiber by using two different types of oil. Based on the characterization of kapok fiber that has been analyzed SEM, FTIR, contact angle, and oil sorption analysis, we that can conclude all kapok fiber samples before and after absorption can be successfully analyzed. Using all methods above, we manage to investigated the surface characteristics and sorption mechanisms of kapok fiber in this study.

In this study, the absorption method was able to investigate the kapok fiber's interaction and sorption mechanism between oil and water by obtain the duration of absorption of oil from kapok fiber. Based on the result, kapok fiber with original palm oil has the shortest time of absorption within 15 minute compared to other oil (used palm oil, original coconut oil and used coconut oil). This is because of unique feature such as a porous lumen network with inter-fiber pores, then the kapok fiber can effectively absorb the amount of oil from water and potentially can be used as a sorbent material in absorption to separate oil and water.

The morphology by SEM also proven to be an efficient surface of kapok fiber. The cylindrical hollow lumen structure with a smooth surface without any ripple of kapok fiber given. Besides that, kapok fibers also had a hollow structure with a thin fiber wall and a large lumen filled with air. The presence of lumen structure has been considered a contributing factor in the secure holding of oil after its collection. In addition, by using SEM, it can be seen that raw kapok fiber to have a silky appearance and smooth surface due to the plant wax's covering. This feature made kapok fiber highly water resistant. The structure became completely flattened and similar to a flat ribbon-like shape when examined by using SEM.

Fourier transform infrared spectroscopy (FTIR) was used to analyze the functional group of kapok fiber. Based on the result obtained for kapok fiber before absorption test, the strong and broad peak at 3338.10 cm-1 was assigned to non-free OH stretching vibration. This was believed to be related to the presence of plant wax. However, for the kapok fiber after absorption test, the absorbance peak at 3338 cm-1 were increase. This happened due to the loss of smooth and waxy surface after absorption test.

Contact angle analysis examined the surface properties of kapok fibers by dropping a single drop of water on each sample before and after the absorption test. It can be seen that the water stood on the surfaces of kapok fiber, while oil droplets disappeared quickly from the kapok fibers' surfaces within several seconds. The water contact angle of each sample ranged from 102˚to 137˚as shown in Figure 4.3 at section 4.5. This phenomenon confirming that the kapok fiber sample before and after absorption test has excellent hydrophobic and oleophobic characteristics. Based on the result it can be seen that the kapok fiber was hydrophobic.

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