Oil/Water Separation Study of Synthesized Cellulose Aerogel

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ABSTRACT

Despite our country experiencing some of the highest rainfall levels globally, achieving water security and sustainability remains a challenge compared to first-world nations. The expenditure on water remediation constantly be the main rationalization, however the adoption of our lignocellulosic biomass at the highest level might provide the light at the end of the tunnel. Still, the vital challenges on the utilization of biomass are the hygroscopic in nature, which was a drawback on its wide application of water remediation. Therefore, the main objective was to enhance the surface area of regenerated cellulose by the formation of polymeric to separate cooking oil for water remediation. Briefly, augmentation of cellulose surface area and roughness was achieved by converting the cellulose-to-cellulose aerogel through the dissolution of the green solvent of alkaline urea system and freeze-drying process. The selectivity of oil uptake towards the aerogel was performed. The chemical and morphological analysis were conducted and the results showed that this cellulose aerogel was successfully separate oil from waste cooking oil and further can be used as compost piles, where it can be broken down by microorganisms over time. Hence, this project is expected to expand the chain of high value-added products and green growth for sustainability, which is in line with the Sustainable Development Goals 2030 by United Nations.

Keywords: Cellulose aerogel, oil absorption, porous structure, waste cooking coil, water remediation

INTRODUCTION

The growing demand for cooking oil in the expanding food and beverage industry leads to increased waste, contributing to oil pollution. Cooking oil waste contains harmful substances, such as carcinogenic polycyclic aromatic hydrocarbons, which can contaminate water sources (Zhao et al., 2021). Improper disposal of used oil, particularly when poured down drains, causes it to solidify and block sewage systems, leading to obstructions. These environmental and health risks highlight the need for better waste management in addressing the global issue of oil pollution (He et al., 2013; Jiang et al., 2013).

Various methods are used to manage cooking oil waste, such as filtration, biodiesel production, and thermal decomposition. However, oil-water separation is the most common technique. Recent studies highlight the effectiveness of superhydrophobic cellulose beads in selective oil absorption due to their microporous, hydrophobic structures (Allaoui et al., 2023; Wang et al. 2022).

Therefore, this study aims to synthesis regenerated cellulose beads which then transform into cellulose aerogel through freeze drying method introduce porous structure which allow oil to be absorbed. The samples were characterized and investigated on their chemical and morphological properties using Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy and scanning electron microscopy,respectively.

METHODOLOGY

Materials

Sulfuric acid 96% (R&M Chemicals), sodium hydroxide pellet (Bendosen) and urea (HmBG Chemicals) were purchased and used as cellulose solvent. Commercial cellulose fibre powder (pure cellulose plant fibre) with average fibre size of 200 microns was purchased from Multifilla.

Preparation of Regenerated Cellulose and Cellulose Aerogel

The cellulose solvent was prepared by mixing NaOH, urea, and distilled water, pre-cooled at -20°C, and thawed to -13°C before adding 4% cellulose. The solution was stirred until transparent cellulose solution formed, then injected into a 5% H_2SO_4 coagulant to form beads. These beads were filtered, washed, neutralized, and freeze-dried to produce cellulose aerogel, which was stored in a sealed container for later use. This process effectively creates cellulose beads using a dropping technique for subsequent applications.

Oil/water Separation Cellulose Aerogel

The oil/water separation were conducted through kinetic study of oil uptake that was performed by immersing cellulose aerogel (CA) in waste cooking oil at various time intervals until they reached equilibrium. Afterward, CA was removed from the oil, dried with filter paper, and weighed. The percentage of oil uptake was then calculated using Eq. 1.

$$\text{Oil Uptake (\%)} = (W_{wet}-W_{dry})/W_{dry} \times 100 \qquad \text{(Eq.1)}$$

where W_{wet} is the weight of absorbed CA and W_{dry} is the weight of the dried CA (Kaco et al., 2015).

Morphological Characterization

The surface morphology of cellulose and cellulose aerogels were studied using scanning electron microscope (SEM LEO 1450VP). The samples were sputter-coated with gold before the observation.

RESULTS AND DISCUSSION

Oil Absorption Test

Figure 1 shows the kinetics of oil absorption by CA after freeze dried. The oil absorption at higher cellulose content (4% cellulose) is lesser compared to a lower cellulose content (3% cellulose). The graph shows that the rate of oil absorption is higher at the first 3 min and increase gradually until 10 min and above 10 min of exposure, the increasing of oil absorption has reached the equilibrium point in which the CA structure has absorbed maximum of oil. Increase the time after the saturation process will not increase the percentage of oil absorption.

Morphological Analysis

Figures 2(a) and 2(b) display SEM images of cellulose and the cross-section of cellulose aerogel (CA), respectively. The CA, which has been freeze-dried, exhibits a highly porous structure. During the freeze-drying process, the water trapped within the hydrogel forms crystals, leading to phase separation, and its subsequent sublimation creates voids (Druel and Budtova, 2023). The porous structure of CA contributed to the oil absorption in in CA. Compared to the cellulose structure, the surface morphology of cellulose reveals individual fibers arranged in a linear fashion, white layers, a nail-like morphology, and tiny discontinuous sections, which characteristic of cellulose fibers respectively (Thandavamoorthy et al., 2023).

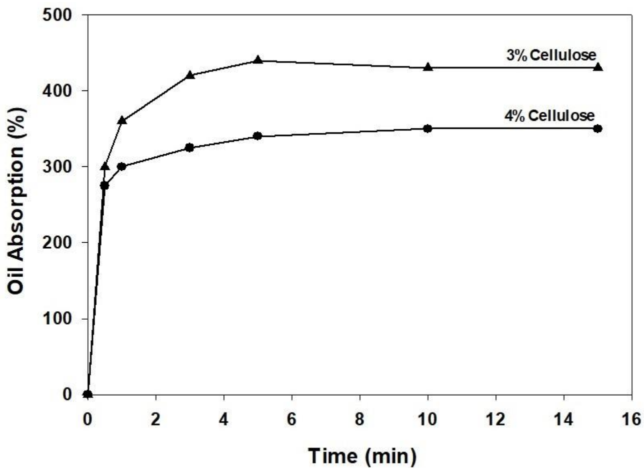
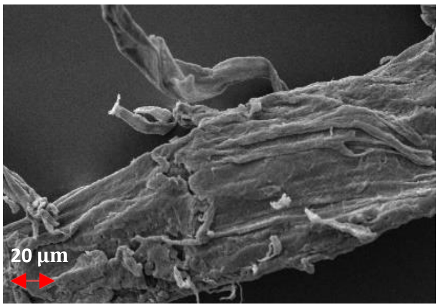
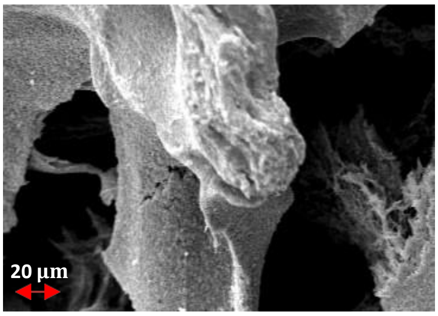


Figure 1. Kinetic study of oil absorption of CA at different cellulose content.



(a)



(b)

Figure 2. SEM images of (a) cellulose and (b) cellulose aerogel.

CONCLUSION

The oil absorption capacity of the cellulose aerogel (CA) was evaluated, revealing that it successfully absorbed up to 440% of its weight in waste cooking oil within just 5 minutes. This result correlates with morphological analyses, which confirmed that the porous structure of the aerogel plays a key role in its high oil absorption capacity.

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