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A comparison of nanocellulose extracted from coconut (*Cocos nucifera*), sugarcane (*Saccharum officinarum L.*) and lemongrass (*Cymbopogon*)

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Abstract

The agricultural residues that are not well-managed will cause environmental deterioration. In fact, they can be used as alternative sources for production and application in various industries due to their attractive properties such as absorption ability, mechanical properties and biodegradability. In recent advancements, agricultural residues are broadly used to form nanocellulose. In this study, nanocellulose was extracted from plant leaves of coconut (*Cocos nucifera*), sugarcane (*Saccharum officinarum L.*) and lemongrass (*Cymbopogon*) which are abundant agricultural waste. Chemical pre-treatment was carried out by boiling dried leaves at 80°C in NaOH. The extraction was conducted under homogenous conditions using high pressure homogenization with speed at 1000 rpm for 30 mins to produce nanocellulose. The samples were characterized for surface morphology, UV-Vis spectrum, Fourier transmission using FTIR and water absorption. The properties displayed by the formed nanocellulose were analysed and compared for further recommendation. These materials have a high potential to be used in different fields towards a sustainable future.

1. Introduction

Nanocellulose is a novel and promising natural chemical that is generated from common biomass. It has become the most environmentally friendly, technologically feasible, and cost-effective material that produces the least amount of effluent (Trache *et al*., 2020). Nanocellulose possesses unique characteristics such as high strength, dimensional stability, low thermal expansion coefficient, excellent reinforcing potential and transparency. Nanocelluloses are also biodegradable, biocompatible, and renewable because they are natural materials (Jin *et al*., 2014).

Nanocellulose generated from diverse agricultural wastes is becoming a great magical particle that has gotten a lot of attention in recent years. With its excellent reinforcing potential, dimensional stability and high strength, it is added as an additive in composite manufacturing, paper modification, and biological products (Borjesson and Westman, 2015). On the other hand, nanocellulose is used in food in a variety of ways, such as food stabilisers, dietary fibres, thickeners, flavour carriers, suspension stabilisers, and as a way to reduce calorie content. Additionally, it may be used to make soups, puddings, chips, wafers, cream, ice cream, fillings, crushes, biscuits, *etc.* (Perumal *et al*., 2022). Nanocellulose helps to widen the range of potential applications by integrating cheap cost, lightweight, electric conductivity, eco-friendly materials, and excellent resistance (Salah, 2013). Nanocellulose also has the potential to be used in drug delivery applications, due to its high surface area to volume ratio and great polymerization. These characteristics give nanocellulose an increased loading and binding capabilities for active pharmaceutical ingredients, enabling the control of the drug release (Hasan *et al*., 2020).

In the agriculture industry, there are many plants grown to supply food from their fruits including coconut and oil palm meanwhile stems from some plants are used in the food industry such as sugarcane and lemongrass. The waste from the agriculture industry or food industry after getting the useful parts from the plants is commonly thrown, degraded, and burnt resulting in environmental deterioration such as water pollution and air pollution

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(Do *et al*., 2022). Moving towards a sustainable world, researchers are thinking of transforming agriculture waste from recyclable and reusable resources, namely cellulose. In recent studies, researchers discovered that plant leaves which are high in lignin can be extracted and fabricate cellulosic materials that are in high demand for commercial exploitation across the world to bring advantages in various fields (Trache *et al*., 2020). From the experimental trial in the lab, our research team noticed that leaves with linear shapes performed well in cellulose extraction.

Cellulose is mechanically separated into nanofibrillated cellulose by applying a significant shear force to split the fibres along their longitudinal axis (Abdul Khalil *et al*., 2014). The most widely used mechanical processes are high-pressure homogenization, ultrasonication, and ball milling. The cellulose industry uses ball milling the most frequently. This approach does have some important disadvantages, though. Erosion of the mill balls is a frequent occurrence because of the vigorous mixing forces in the vessel. The erosional remnants raise the possibility of product contamination (Patchiya *et al*., 2016). Sonication is a method of cell disruption that shatters tissues and cells using sound energy. Heat is produced more by sonication than by homogenization. Therefore, it is essential to perform sonication in a cool environment. Furthermore, unlike homogenization, sonication works best with samples that are smaller than 100 mL in volume.

Homogenization can be used to generate nanocellulose from the cellulose which is micron-sized and high crystallinity after chemical treatment. During the homogenization process, cellulose's intermolecular and intramolecular hydrogen bonds were broken, resulting in a reduction in crystallinity. High-pressure homogenization (HPH) treatment is an effective approach for biomass processing because of its simplicity, efficiency, and absence of requirement for organic solvents (Keeratiurai and Corredig, 2009). Samples can produce shear rates, disintegrate amorphous areas, shrink the size of the cellulose fibres, and eventually release cellulose nanofibrils when they pass through a homogenization chamber (Lee *et al*., 2009; Saelee *et al*., 2016).

In this study, the leaves from *Cocos nucifera* (coconut), *Saccharum officinarum L.* (sugarcane) and *Cymbopogon* (lemongrass) were used as biomass sources in nanocellulose extraction. All these leaves are multicellular and lignocellulosic agriculture waste products from food manufacturers. The samples are characterized and compared for their properties. The fabrication of these nanocellulose is aimed to suggest potential applications in various fields and capture interest for further study moving towards a green sustainable future.

2. Materials and methods

The leaves of coconut (*Cocos nucifera*), sugarcane (*Saccharum officinarum L.*) and lemongrass (*Cymbopogon*) were collected from food stalls and housing areas in Nilai, Negeri Sembilan, Malaysia. The leaves were cut into small pieces and ground into powder. A total of 100 g of leave powders was soaked in a 2% (w/v) NaOH solution for 3 hrs at 80°C for each leaf on the hot plate to digest and to remove lignin in the sample. The treatment of bleaching was done by adding 35 mL of 5.25% (w/v) sodium hypochlorite to the sample at 70°C for 2 hrs. The homogenization step was carried out using a homogenizer (WiseTis HG-15D) with a speed set at 1000 rpm. The homogeneous solution was then added five times as much hot distilled water, and the combination was agitated for 10 mins on a magnetic stirrer to precipitate nanocellulose from the homogeneous system. Subsequently, the flask was allowed to cool down to room temperature and the mixture was filtered in a conical flask. The mixture was washed with distilled water and oven-dried overnight at 60°C. The samples were then ground to be fined powder after drying.

The physical surface of the dried samples was observed using a light microscope (Olympus CK21). The characterization of the samples was carried out based on absorbance spectra which are plotted from the collected data using a UV-Vis spectrometer. The bonding of nanocellulose was characterized using Fourier-transform infrared (FTIR) transmittance spectra while the absorption abilities of the samples were compared based on the water absorption measurement. The water absorption test was conducted by measuring the weight gain of the sample before and after soaking in the distilled water for 24 hrs. The percentage of weight gain (wt.%) during the immersion in distilled water was calculated as in (Evyan *et al*., 2017):

$$W\% = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100\% \quad (1)$$

where W_{wet} is the weight of sample after immersion into distilled water for 24 hrs, and W_{dry} is the weight of sample before immersion into distilled water.

3. Results and discussion

The dried nanocellulose of coconut, sugarcane and lemongrass were characterized using Fourier Transmission of infrared (FTIR) spectrum. The spectra in Figure 1 show all three samples have the same FTIR pattern after treatment with the peaks that are stated in

Table 1. Absorption peaks of FTIR spectra and their functional groups for different leaves of: (a) coconut; (b) lemongrass and (c) sugarcane.

Peaks (cm^{-1})			Functional groups
Coconut	Lemongrass	Sugarcane	
1003	985	997	C-O stretching; C-H vibration in cellulose
1028	1038	1034	C-O; C-C stretching; C-OH bending
2914	2914	2918	C-H stretching
3296	3288	3284	O-H stretching

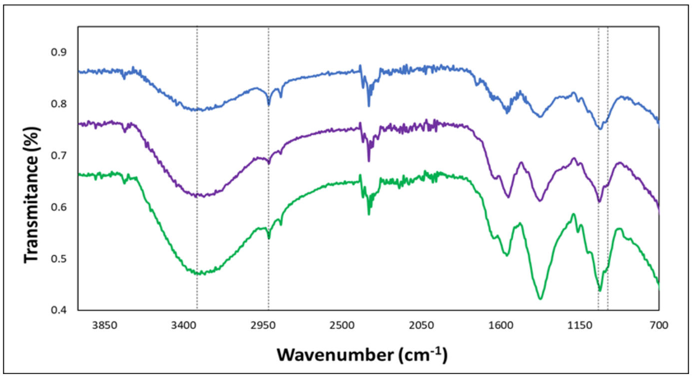

Figure 1. FTIR spectra of nanocellulose extracted from leaves of: (a) coconut, (b) lemongrass and (c) sugarcane.

Table 1 for different samples.

The relevant functional groups were identified in Table 1 (Alemdar and Sain, 2008). The extracted nano cellulose is free from non-cellulosic components such as lignin and hemicellulose after treatment with sodium hydroxide and bleaching in agreement with the study by Priyanka *et al*. (2019). Coconut leave was taken to study the removal of lignin and hemicellulose as in Figure 2. From the FTIR spectra in Figure 2, the aromatic C ≡ C stretching at the peak of 1505 cm^{-1} in lignin (Sain *et al*., 2006) and C-H stretching at the peak of 1371 cm^{-1} in hemicellulose (Li *et al*., 2012) of coconut leaves in the spectra (a) was removed after NaOH treatment and bleaching process as in spectra (b). The pattern of FTIR spectra remains unchanged after homogenization as in (c).

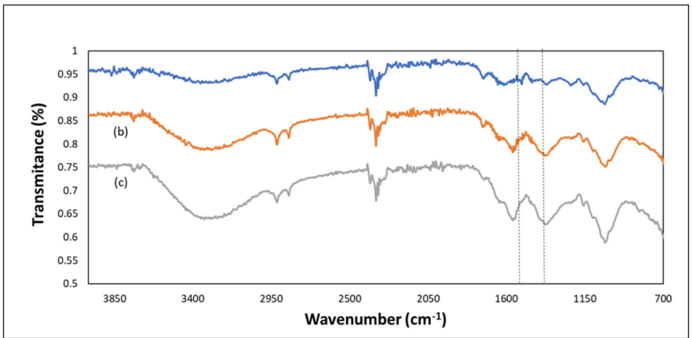

Figure 2. FTIR spectra of: (a) grinded coconut leaves, (b) treated cellulose from coconut leaves and (c) homogenized coconut leaves.

The surface morphology was examined under a light microscope before and after to identify the differences. Figure 3 illustrates the light-microscope images of the cellulose before and after homogenization. From the images in Figure 3, all the cellulose extracted from the leaves obviously shown finer and smaller physical sizes under the same magnification after homogenization. Homogenization is the mechanical process of transforming matter into smaller sizes or more uniform in physical organization (Rohde *et al*., 2015). Larger physical sizes of cellulose were displayed by coconut leaves if compared to sugarcane and lemongrass due to the natural physical structure of the leaves being much harder. The cellulose from the leaves is defibrillated due to shears and decompression forces applied to the cellulose under high pressure homogenization (Dufresne, 2013). The nanocellulose which are in nano-sized will have better crosslink (Rohde *et al*., 2015).

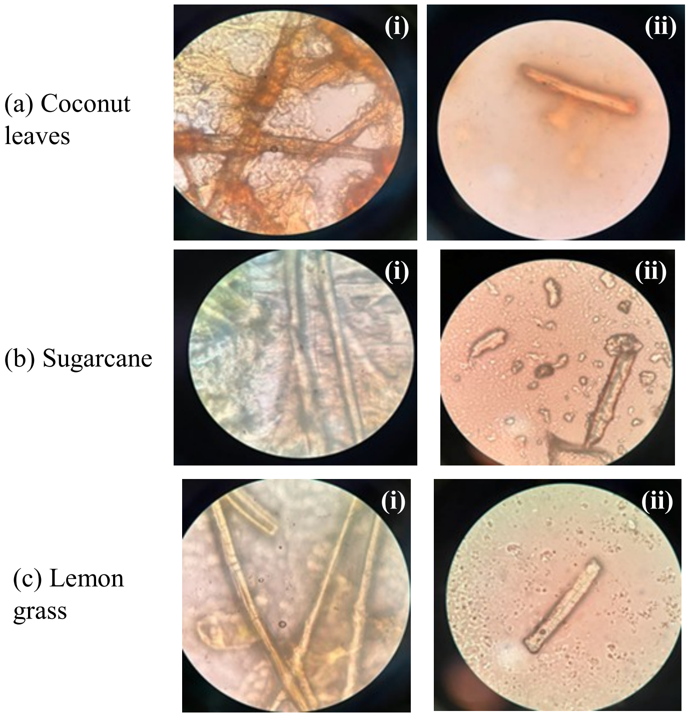

Figure 3. Images of the samples before and after homogenization at 100× magnification: a) coconut leaves, b) sugarcane, c) lemongrass with (i) before homogenization and (ii) after homogenization.

All the nanocellulose performed water absorption capabilities that are higher than 100% which indicated they are good absorbent materials. The water absorption ability of the sugarcane is the highest among the three types of leaves which achieved 152%. The 2nd highest absorbance was lemongrass followed by coconut as

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displayed in the bar chart (Figure 4). The finer physical structure after homogenization results in better crosslink and improve the ability of water absorption of the cellulose. Water molecules can be stored in between the porous structures of the cellulose.

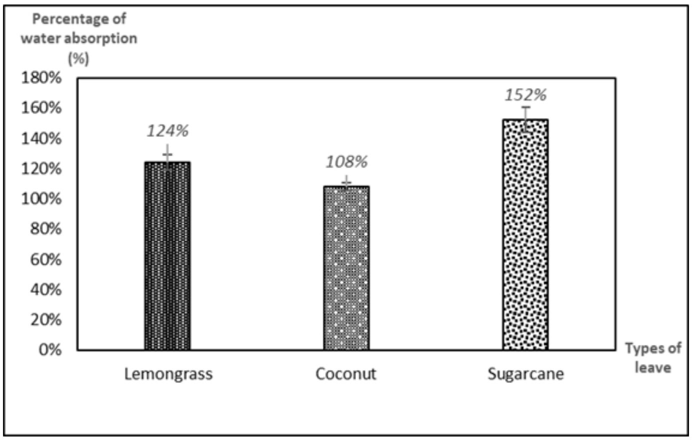

Figure 4. Water absorption capability of lemongrass, coconut and sugarcane leaves.

Referring to the analysis of collected data based on the surface morphology, water absorption ability and FTIR spectra, potential applications of each type of nanocellulose were identified in Table 2. Overall, the cellulose that formed is suitable to be applied in the pulp industry. Nanocellulose extracted from coconut leaves is suitable to be applied as an additive in construction materials due to its tough physical structure (Reddy *et al*., 2010). Sugarcane nanocellulose which is high in water absorption ability can be applied to produce products that require high water adsorbents such as disposable napkins, facial masks, sanitary supplements and other personal care products that act as absorbent (Azadeh *et al*., 2018).

Nanocellulose extracted from lemongrass is widely used in various applications due to its very fine morphology and easy to extract and fabricate nanocellulose. In addition, lemongrass also is a species of herbs with a natural aroma for its pharmaceutical and antimicrobial functions. Thus, its applications spread in products such as biodegradable food packaging as the high demand in the modern lifestyle (Liew *et al*., 2021; Evyan *et al*., 2022). On the other hand, with its antimicrobial activity, it is also widely used to produce wound dressing materials and cosmetics (Priyanka *et al*., 2021).

4. Conclusion

In the study, the leaves of coconut, sugarcane and lemongrass were used as agricultural biomass to fabricate nanocellulose. The properties of each sample were characterized through morphology observation, FTIR, UV-Vis spectrum and water absorption. The fabricated celluloses possess different or similar properties that are beneficial to be applied in different industries, pharmaceutical and construction depending on their specific requirement, e.g. high absorption ability, antimicrobial, chemical and physical stability. Further study can be carried out on the potential application of cellulose such as biodegradable food packaging, antimicrobial materials and sustainable products.

Conflict of interest

The authors declare no conflict of interest.

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Table 2. Potential applications of the extracted nanocellulose from leaves of coconut, sugarcane and lemongrass.

Nanocellulose	Properties	Potential Application
Coconut leaves	• 200-250 tapering leaflets in one leaf • hard physical structure • high in moisture before dying • fine structure after homogenization	• construction materials • pulp and paper • bio-adsorbents
Sugarcane leaves	• can be collected in big amount from food manufacturers • high water absorption ability • moderate in moisture before drying	• bio-adsorbents • pulp and paper • food packaging product
Lemongrass leaves	• easily grow • very fine structure after homogenization • low in moisture before drying • thin linear leaves • natural aromatic herb	• food packaging • pharmaceutical products • cosmetics • pulp and paper • antimicrobial products

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