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RESEARCH PAPER

Effectiveness test of microfilter mask based on straw waste cellulose fiber biopolymer

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Abstract: Straw waste, which is often underutilized, contains abundant cellulose that holds potential as a raw material for environmentally friendly filtration technologies. The conversion of agricultural waste into value-added products, such as mask microfilters, aligns with the increasing demand for sustainable materials, particularly in the context of public health protection. Harnessing cellulose from straw offers a promising alternative to synthetic fibers commonly used in mask production, while simultaneously addressing waste management challenges. This study aims to determine the characterization of microfilter masks from straw waste and the effectiveness of straw microfilters used in cloth masks. Cellulose from straw waste can be used as a mask microfilter by going through several stages, such as: preparation, extraction, delignification, bleaching, characterization, and making mask microfilters and effectiveness tests. The characterization of structure, morphology and topology from the straw waste cellulose has not been fully degraded from lignin as shown from the aromatic C = C stretching vibrations on lignin at wave numbers 1638.34 cm^{-1}, 1648 cm^{-1}, and 1583.56 cm^{-1} of FTIR also SEM tools at 3600 times magnification. The effectiveness of the microfilter mask is 94% and 91% as evidenced by each bacterial filtration test and the decreasing data of the dust filtration test.

Keywords: Microfilter Mask, Cellulose, Straw Waste

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INTRODUCTION

1. Introduction

The increasing awareness of environmental sustainability and public health protection has driven the search for alternative, environmentally friendly materials for various applications, including air filtration technology [1,2]. Agricultural waste, especially straw, is one of the abundant yet underutilized biomass sources [3]. Straw is mainly composed of cellulose, hemicellulose, and lignin, with cellulose being a particularly valuable component due to its structural strength, renewability, and biodegradability [4]. Converting straw waste into value-added products not only promotes sustainable waste management but also supports the development of environmentally friendly alternatives to synthetic materials [5].

The use of cellulose extracted from straw waste as a microfilter in cloth masks is a promising innovation. Traditional mask filters usually rely on synthetic polymers, which are often non-biodegradable and contribute to environmental pollution after disposal [6]. In contrast, cellulose-based filters offer a biodegradable solution without compromising filtration performance, thus aligning with global efforts to reduce plastic waste and promote green technologies [7].

The production of cellulose-based microfilters involves several critical steps, including preparation, extraction, delignification, bleaching, and characterization [8]. A comprehensive understanding of the chemical structure, morphology, and topology of the extracted cellulose is essential to optimize filtration efficiency. Characterization techniques such as Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) are used to assess the lignin removal efficacy and evaluate the physical structure of cellulose fibers [9,10].

In addition to its abundance, the utilization of straw waste presents a more scalable and accessible solution compared to other agricultural residues such as pineapple leaves [11]. While pineapple leaf fibers have demonstrated promising filtration performance, their availability is relatively limited in certain regions of West Nusa Tenggara [12]. In contrast, rice straw is generated in much larger quantities as a byproduct of the dominant agricultural activity in Lombok [13]. Leveraging this locally available resource could not only reduce environmental pollution caused by unprocessed straw disposal but also provide a sustainable raw material for the production of biodegradable microfilter masks [14]. Furthermore, the high cellulose content in straw, coupled with the substantial silica composition, offers structural advantages for microfilter applications by enhancing mechanical stability and filtration capacity [15]. Therefore, utilizing straw waste for the development of cloth mask microfilters represents an innovative and regionally appropriate strategy to improve community-level health protection while simultaneously addressing agricultural waste management challenges [16].

MATERIALS AND METHODS

Straw waste was obtained from a farm located in Central Lombok, West Nusa Tenggara, Indonesia. Distilled water (H_2O), hydrogen peroxide (H_2O_2) (5%), sodium hydroxide (NaOH) (20%), toluene ($C_6H_5CH_3$) (85%), ethanol (C_2H_5OH) (96%), phosphate buffered saline (PGBP) diluent, and sterile liquid *Plate Count Agar* (PCA). This research also involved instruments such as Microbial Air Sampler (MAS 100-NT) (Merck) to microbial monitoring of ambient air in controlled environments, colony counter and inhibitors (35^{o}C) to bacterial filtration test, and analytical balance to dust filtration test, also Fourier Transform-Infra Red (FTIR) (Parkin Elmer), Scanning Electron Microscope (SEM).

Cellulose Isolation

To obtain cellulose from straw waste, sample preparation, extraction, delignification, and bleaching were carried out.

In the sample preparation, the wet straw waste was cleaned and then dried for ± 3 days in the sun until dry. The dried straw waste was then cut into ± 2-4 cm pieces and then smashed and filtered with a 40 mesh sieve. Extraction stage: Straw powder was reacted with toluene: ethanol 2:1 (v/v) then stirred until mixed then macerated for 8-24 hours. The mixture was filtered and the precipitate was washed with distilled water until the pH of the filtrate was neutral and then dried. Delignification: The residue was added to a 20% NaOH solution, in a ratio of 1:10 then the mixture was heated at 80 ºC and stirred using a *magnetic stirrer* for 2 hours.

Afterwards, the mixture was filtered and the precipitate was washed with distilled water about 500 mL until the pH of the filtrate was neutral. The residue was dried at 50 ºC to constant weight. Then the *bleaching* process was carried out by adding 5% H_2O_2 solution, pH 12 in a ratio of 1:10, then heated in a water bath at 70 ºC and stirred using a magnetic stirrer which was kept constant for 3 hours. The mixture was treated with the same methode until the pH was neutral.

Cellulose Characterization

Cellulose produced from straw waste was characterized by FTIR to determine and analyze the vibrations of its functional groups, while SEM analysis was used to determine its morphology and topology.

Microfilter Making from Straw Cellulose

Cellulose is put into a tub containing clean water then put into a 40mesh sieve and then shaken until flat. Cellulose that has been flat and printed on the sieve is dried using a hair dryer until it is separated from the sieve and then dried in the sun.

Microfilter Mask Effectiveness Test

Bacterial filtration test*:*

The sterile microfilter was placed in MASS 100-NT at the top and bottom of the bag and then turned on MASS 100-NT with a suction speed of

500 m/s for 2 minutes. The microfilter was then inserted into the diluent and then homogenized. Serial dilutions were carried out with dilutions of 10^{-1}, 10^{-2}, 10^{-3}, and 10^{-4} using PGBP (phosphate buffered saline diluent) then poured sterile liquid count agar plate (sterile liquid PCA) while leveled. The plate was incubated at 35.5 ºC for 2x24 hours then read and counted the number of bacterial colonies.

Dust filtration test: Sterilized microfilters were weighed with an analytical balance and then placed in a *Portable high-air sampler* for 10 minutes with a control speed of 70 m/s. After 10 minutes the sample was weighed with an analytical balance to determine the weight of dust obtained before and after filtration.

RESULTS AND DISCUSSION

X-Ray Diffraction (XRD)

Cellulose Isolation of Straw Waste

Straw waste that has gone through the preparation and extraction produces straw powder with a yield of 50.2 grams. The last stage of delignification and bleaching produces white cellulose. The average cellulose yield produced was 14.2 grams (Figure 1). The success of the straw waste cellulose isolation stage can be seen from the white cellulose [17].

The spectrum of straw cellulose shows a wide absorption at wave number 3445.84 cm^{-1} which indicates the stretching vibration of a hydroxyl group (O-H) of cellulose [18]. The absorption at wave number 2905.34 cm^{-1} indicates the stretching vibration of the aliphatic C-H group of cellulose. Wave numbers 1638.34 cm^{-1}, 1648 cm^{-1}, and 1583.56 cm^{-1} show aromatic C=C stretching vibrations on lignin, meaning there is lignin in straw cellulose [19]. The absorption region of 1423.49 cm^{-1} identifies the presence of CH_2 bending and bending absorption of C-H groups seen at wave numbers 1376.35 and 1316.52 cm^{-1} [20]. The wavenumber 1159.49-1027.94 cm^{-1} is the area of C-O-C vibrations [21].

FTIR Characterization

Analysis of functional groups using FTIR characterization is carried out to determine the functional groups contained in the straw cellulose produced based on the wavenumber where a peak appears. The results of FTIR spectroscopic characterization show data on the structure of the compounds contained in straw cellulose (Figure 2).

Figure 1. Cellulose powder

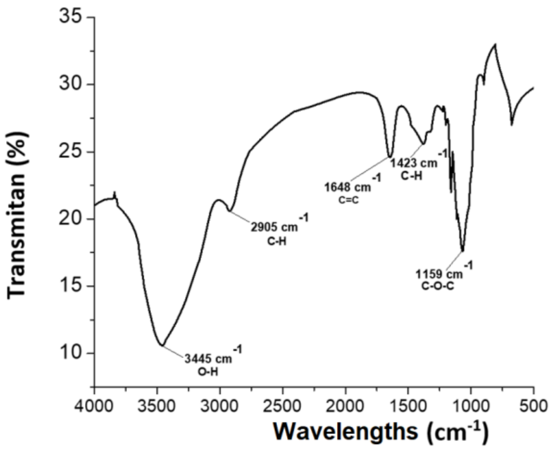
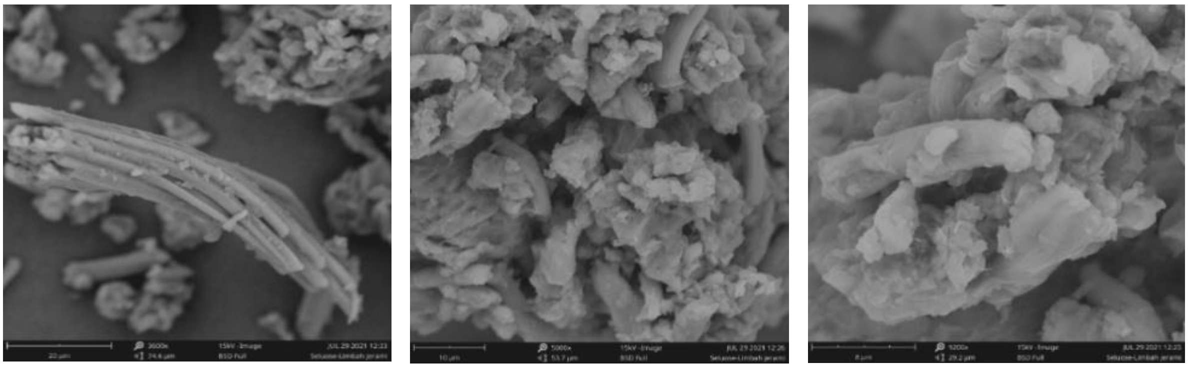


Figure 2. FTIR spectrum of straw cellulose

SEM Characterization

Morphological and topological analysis with SEM characterization was carried out to determine the surface morphology and see the topology on the surface of the straw cellulose produced with various magnifications. The results of cellulose powder characterization using SEM with 2000-4000x magnification obtained the size of straw waste cellulose around 29.2 µm -74.6 µm.

Figure 3 shows the morphology of cellulose with various magnifications on the SEM tool. The morphology of cellulose at 3600 times magnification is in the form of compact chunks with small cavities indicating that the lignin content has not been degraded. The 9200x magnification shows that the fibrils are still attached and some have not been defibrillated, indicating that the alkaline treatment and delignification procedures did not completely disrupt the cellulose structure and remove amorphous areas [22].



A B C

Figure 3. Morphology and topology of cellulose by SEM at magnifications of 3600x; b) 5000x; and, c) 9200x.

Mask microfilter

The mask microfilter of straw waste cellulose is white fibrous with a length of 14 cm, and a width of 9 cm. The weight of this straw waste microfilter is 1 gram which is biodegradable, so it does not cause environmental pollution. Microfilter masks made from cellulose are non-toxic based on a study of feeding rats with cellulose isolated through oral radicals [23]. In addition, cellulose shows a low toxicity impact [24].

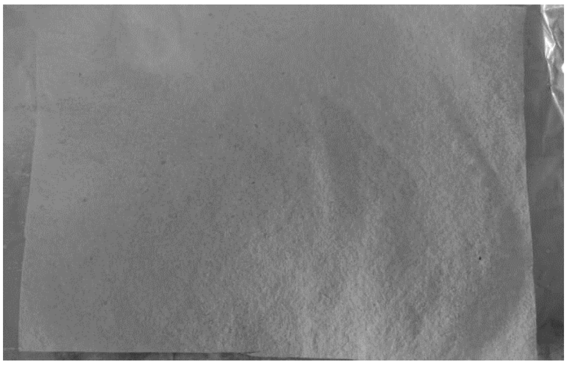


Figure 4. Cellulose fiber microfilter

Mask Microfilter Effectiveness Test

Bacterial filtration test

Based on Table 1. in the bacterial filtration test using 3 controls, the number of bacterial colonies produced is 0, meaning that the three controls are not contaminated with bacteria. In Table 2 the number of bacterial colonies in the three samples decreased after being filtered with the microfilter.

Data in Table 2. shows the percentage of bacterial filtration obtained from the comparison of the difference in bacterial colonies before and after treatment with the number of previous colonies in samples I and II is 92% and 98%. Then, the percentage of bacterial filtration test results after the microfilter is used is obtained at 94%.

Table 1. Bacterial Filtration Results with Control

No	Control	Number of Bacterial Colonies
1	Deluent 9 mL	0
2	Deluent 90 mL	0
3	Deluent and sterile microfilter	0

Table 2. Bacterial Filtration Test Results on Microfilters

S	Treatment	Number of Bacterial Colonies				Bacterial Colony Count Results
		10-1	10-2	10-3	10-4	
I	Before	16	1	0	0	130
	After	1	0	0	0	10
II	Before	1	2	2	0	736.67
	After	1	0	0	0	10

S = sample

Dust filtration test

Table 3 shows the comparison data before and after dust filtration. From the filtration result data after using the microfilter, there was a decrease in dust weight by 91%. Based on the quality standards set in Decree of the minister of environment (Kep-Men LH) No. 13 of 1995 related to the TSP (dust) parameter, the weight of dust that can be inhaled by humans is 35%. So, when viewed from the standard data, this straw waste cellulose fiber microfilter has high effectiveness because the dust filtration value produced by the microfilter is greater than 35%

Table 3. Dust Filtration Test Results

Sample	Microfilter code	Mass I (g)	Mass II (g)	Mass of dust obtained (g)	A-B
I	A	0.05640	0.05687	0.00047	0.00043
	B	0.06202	0.06206	0.00004	
II	A	0.07571	0.07604	0.00033	0.00010
	B	0.06785	0.06808	0.00023	

CONCLUSION

Based on the research that has been done, it can be concluded that the cellulose obtained from straw waste is 14.7% per 100 grams of straw. Microfilters from straw waste cellulose fibers that have been tested for effectiveness with comparative data before and after filtration produce a decrease in the number of bacterial colonies by 94% and a decrease in dust weight by 91%.

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