



Synthesis of Polyvinyl Alcohol-Chitosan Composite Film using Nanocellulose from Coconut Fibers (*Cocos nucifera*)

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ABSTRACT

In this research, polyvinyl alcohol (PVA)-chitosan composite films were produced using nanocellulose from coconut fibers (*Cocos nucifera*) in an Indonesian plantation in order to enhance mechanical properties and biodegradability. The process began by separating lignin and hemicellulose by delignification, bleaching, and then cellulose hydrolysis to produce nanocellulose. The PVA was mixed with chitosan with specific compositions and added the nanocellulose in 0%, 1%, 3%, and 5% concentrations, respectively. A tensile test was conducted to obtain tensile strength and elongation break. Biodegradability test was also carried out to determine the level of mass losses. Based on SEM observations, addition of nanocellulose appears to increase the reactivity of the formation of PVA-chitosan composite films, which are characterized by a reduction in film thickness. Addition of 5% nanocellulose resulted in a high quality of nano-composite. The tensile strength, fracture elongation and biodegradability of the composite film were 31.50 MPa, 39.9% and 9.04%, respectively.

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NOMENCLATURE

W_0	Initial mass of sample	W_t	Mass of sample after 30 days
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1. INTRODUCTION

In recent time, the community became very interested in fresh food of good quality and long shelf life. Plastic-based packaging also became a public concern because of its quality and cleanliness [1]. In the meantime, plastic is a synthetic polymer of long-chain hydrocarbons derived from petroleum. It consists of a polymerization of a similar monomer in long chains [2]. The majority of monomers used in manufactured food packaging, such as ethylene and propylene, are fossil fuel-based compounds. They are widely used for their advantages, including strength, lightness and stability. However, it is difficult to decompose by microorganisms in the environment, caused serious environmental challenges [3, 4].

The development of biodegradable plastic is known as a composite, composed of several materials having

different superior properties [5, 6]. Research on composites for biodegradable plastics, such as polyvinyl alcohol (PVA)-chitosan, has received considerable attention due to its nature as an ecological polymer [7, 8]. Chitosan is one of the most suitable materials for coating and food packaging due to its good film-formation and high antimicrobial properties against pathogenic microorganisms and bacteria (both gram-positive/negative) [9]. The films have disadvantage of poor resistance to humid air, which limits their use for food packaging [10]. The strength and thermal stability of chitosan films were improved by a number of biodegradable synthetic polymers, including polyvinyl alcohol (PVA), polycaprolactone, and polylactic acid [11, 12]. However, there are limitations to PVA-chitosan films, such as their poor mechanical properties [13]. As a result, addition of other materials to PVA-chitosan films,

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such as nanometric fillers, is essential for improving the physical properties of the composite polymer [14].

Cellulose is among the lignocellulosic polymers, widely examined for its biodegradability, low density, and good mechanical properties [15-17]. Several types of research have also been carried out on cellulose to convert it into a material with many superior values, including conversion to nanocellulose [18-20]. Meanwhile, researchers have focused more on nanocellulose in the technology sector due to its high mechanical strength (high strength and modulus), large surface area, good aspect ratio, environmental friendly nature, and low-cost requirements [21-23].

Agroindustrial waste, such as coconut fibers (*Cocos nucifera*), contains a large amount of cellulose with a percentage of 43.44%. This cellulose enhances the value of the fiber because waste is generally not reused [24]. Coconut fiber has a tensile strength of 7.9 MPa to 11.6 MPa, which may improve the mechanical properties of composite films [25].

Previous research that isolated nanocellulose from coconut fibers discovered that it could be used as a reinforcing agent in composites [26]. Wu et al. [27] have blended PVA with nanocellulose from coconut coir fiber (China), increasing the composition of nanocellulose in composite films from 1% to 3% increases tensile strength from 55 to 60 MPa. Arun et al. [24] added 2% of nanocellulose from a coconut shell (India) into PVA, a resulting tensile strength of 6.35 ± 0.37 N/mm². Wang et al. [28] prepared nanocellulose from waste coconut shell (Sri Langka) and mixed it with cement. Increasing nanocellulose content increases flexural strength and compressive strength. Li et al. [29] isolated nanocellulose from a coconut shell (China) and mixed it with PVA-chitosan. Nanocellulose content increased from 0 to 3%, resulted in an increase in tensile strength from 25 MPa to 34 MPa. Unfortunately, increasing nanocellulose content to 5% decreased tensile strength. Poornachandhra et al. [30] investigated the alkali-acid hydrolysis method and resulted in nanocellulose from coconut coir fiber (India) with a diameter < 40 nm under conditions of 45% acid, 50 °C for 60 minutes. Nurdiana et al. [31] isolated nanocellulose from coconut husk (Malaysia). Based on the regression equation, the optimum preparation condition of the nanocellulose (sulphuric acid is 64.61 wt.%, the reaction temperature is 44.55 °C, and the reaction time is 58.54 minutes), resulted in 44.84% of yield.

Based on the mentioned above, no research has been conducted on composite film (nanocellulose from coconut husk) with the main objective of investigation on mechanical properties and biodegradability. Li et al. [29] isolated nanocellulose from coconut shell (China) and mixed with PVA-chitosan only to investigate the mechanical properties. For this reason, this research synthesized a biodegradable PVA-chitosan film with

nanocellulose derived from coconut fiber (*Cocos nucifera*) in Indonesian plantation to improve mechanical properties and biodegradability. Nanocelluloses were characterized by FTIR, SEM and XRD. Moreover, PVA-chitosan with nanocellulose was characterized with FTIR. A tensile and a biodegradable tests were also carried out.

2. EXPERIMENTAL METHOD

2. 1. Material The coconut fiber was obtained from a local plantation. NaOH, NaClO, chitosan (66000 g/mol of molecular weight and 92% of deacylation degree), acetic acid, acetate buffer and sulphuric acid were purchased through Sigma-Aldrich and Merck. The PVA was purchased from Gohsenol (Molecular weight: 22000 g/mol). Deionized water was applied to all experiments.

2. 2. Extraction and Purification of Nanocellulose The coconut husk was pre-washed and dried to separate fiber and bran. The fiber was cut and sieved into a 40 mesh size [27], mixed with water for 2 hours at 50 °C and dried with oven for 24 hours at 50 °C. After drying, the fibers were heated to 80 °C with a 2% NaOH solution for 2 hours for the delignification process with a repetition and then dried [32].

Furthermore, the dried fibers were bleached using 1.70% NaClO and acetate buffer at 60 - 70 °C with 2 repetitions, which were also washed and dried [33]. The dried fibers were hydrolyzed using 55% sulphuric acid at 45 °C for 45 minutes [34, 35]. The resulting nanocellulose was centrifuged with deionized water at 5000 rpm until the pH was neutral [35]. Then, the precipitate was dialyzed to obtain a constant pH due to the removal of excess sulphate and dissolved sugar due to hydrolysis to sulphuric acid. A centrifuge tube was used to conduct the dialyzed process for 10 minutes at 5000 rpm [36].

2. 3. Preparation of PVA-Chitosan Solution The PVA 3% solution was prepared by dissolving it in deionized water (90 °C) and continuously stirring for approximately 2 hours [37]. A 1.5% chitosan solution was prepared by dissolving with 2 v/v% acetic acid at 100 °C and continuously stirring for approximately 1.5 hours [38]. Both solutions were cooled at room temperature, mixed in a 7:3 ratio, then sonicated for 15 minutes [11].

2. 4. Preparation of Composite Films The composite film was made by adding nanocellulose (0%, 1%, 3%, and 5%) based on the percentage of the total mass [39]. Then the mixture was poured into a plastic mould. After 72 hours, the mixture was de-bubbled and transferred to an oven (60 °C) for around 24 hours for

drying. Afterwards, the mixed films were vacuumed at 80 °C for 24 hours to remove excess water [40].

Composite film samples were made by adding 0%, 1%, 3% and 5% nanocellulose identified as 0-NC, 1-NC, 3-NC and 5-NC, respectively.

2. 5. Characterization The nanocellulose was characterized by FTIR (SHIMADZU Prestige-21 FTIR), SEM (JSM-6510LA), and Panalytical EMPYREAN X-ray diffractometer (XRD) using Cu K α radiation with $\lambda = 1.5406 \text{ \AA}$ at a 2θ range from 10° - 90°. The mechanical properties of composite films were determined using a Stograph universal test machine. Each sample was tested under ASTM D1882. Triplicate measurement was conducted.

The biodegradation test was performed using the soil burial method. The ground was collected at the Universitas Negeri Jakarta in Indonesia. The soil was dried at room temperature (three days) and complemented with urea for 6 g/kg to resulting an active microbial flora. The composite films were dehydrated under vacuum at 50 °C to obtained constant mass (W_0). The composite films were then coated with synthetic net and buried in the mixed soil-urea. The biodegradability test was conducted under aerobic conditions (25 °C) at 50% relative humidity for 30 days. After 30 days, the samples were washed and dehydrated under vacuum until they obtained a constant mass (W_1). Triplicate biodegradation test measurement was conducted. Percentage mass loss was calculated by following equation [41, 42].

$$\% \text{ Mass loss} = \left[\frac{W_0 - W_1}{W_0} \right] \times 100 \quad (1)$$

3. RESULT AND DISCUSSION

3. 1. FTIR Results of Nanocellulose The FTIR characterization results on the delignified, bleached, and untreated coconut fibers are shown in Figure 1. A wavenumber 3296 cm⁻¹ showed the stretching vibration of the O–H group [43], the wavenumber 2970 cm⁻¹ did not show, but the peak at this wavenumber showed C–H stretching from the alkyl groups [11]. The wavenumber 2898 cm⁻¹ showed the vibration of the C–H group [44]. Meanwhile, a wavenumber 1736 cm⁻¹ showed stretching vibrations in the C=O group owned by hemicellulose and lignin, where the peak was lost in the delignification and bleaching spectra due to this process [45]. Similar behaviour was also found in Julie Chandra's report due to chemical treatment [46].

At 1655 cm⁻¹, there was a peak, which showed the bending of the O–H group in the H₂O molecule [47]. While the wavenumbers 1606 cm⁻¹ and 1512 cm⁻¹ were absent, the peak at this wavenumber revealed vibrations

of the C=O group on the aromatic framework of lignin [48, 49]. A wavenumber of 1425 cm⁻¹ was a bending vibration of the C–H group discovered in lignin and cellulose [50]. The peak at 1371 cm⁻¹ was the bending vibration of the C–H group in cellulose, lignin, and hemicellulose [51], while 1159 cm⁻¹ was C–O–C asymmetric stretching vibration in cellulose, lignin, and hemicellulose [49]. The peak at 895 cm⁻¹ was a stretch vibration in the glucose ring of the cellulose [52].

Results from characterization of hydrolyzed coconut fibers are presented in Figure 2. A wavenumber 3338 cm⁻¹ was the stretch vibration of the O–H group [53], while the C–H group was 2909 cm⁻¹ [54]. The peak at 1636 cm⁻¹ showed the bending vibration of the O–H functional group on the H₂O molecule [55]. Furthermore, a wavenumber at 1362 cm⁻¹ was the bending vibration of the C–H functional group in cellulose [35], while the S=O group contained in the SO₄²⁻ ion was 1200 cm⁻¹. This ion was generated through the use of sulphuric acid in cellulose hydrolysis. Consequently, the sulphate ion forms hydrogen bonds to the hydroxyl groups in cellulose [56].

Chandra et al. [46] reported that the absence of a peak may occur as a result of chemical treatment. Based on Figures 1 and 2, chemical treatment could disappear a wave number of 1736 cm⁻¹. This condition means hemicellulose and lignin have been removed. In addition, after bleaching, a wavenumber 1655 cm⁻¹ which showed the bending of the O–H group in the H₂O molecule, also disappeared.

3. 2. SEM Image of Nanocellulose Figure 3 shows the morphology of the nanocellulose. It shows the cylindrical rods, which tend to form agglomerations. The nanocellulose's diameter ranged from 66.97 nm – 144.70 nm, with a length of 1046 nm – 1267 nm. Those sizes were resulting when treated with 55% sulphuric acid at 45°C for 45 minutes.

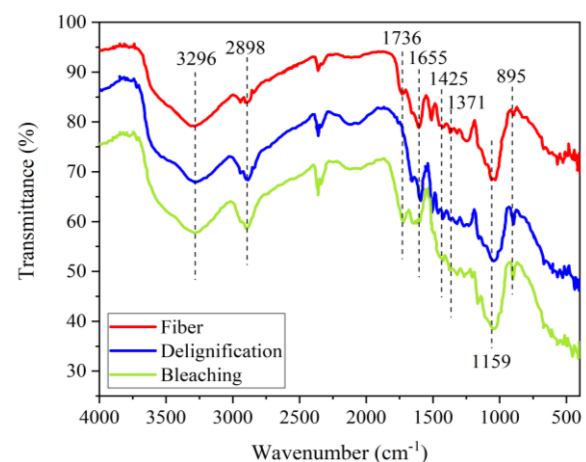


Figure 1. FTIR spectrum of coconut fibers

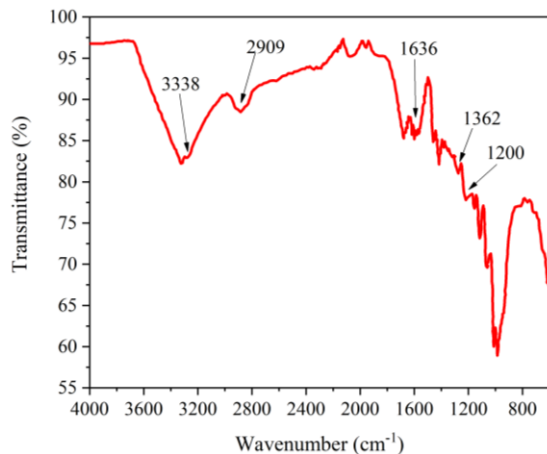


Figure 2. FTIR spectrum of nanocellulose

Lu et al. [57] treated sweet potato residue in 65 wt.% sulfuric acid (120 minutes and 55 °C), resulting in nanocellulose with a diameter of 20–40 nm. Pereira et al. [58] treated bleached banana pseudostem fiber in 62 wt.% sulfuric acid (70 minutes and 45 °C), resulting in nanocellulose with a diameter of 7.2 ± 1.9 nm and length 135 ± 12 nm. Ogundare et al. [59] treated discarded cigarette filters in 55 wt.% sulfuric acid (45 minutes and 45 °C), resulting in nanocellulose with a diameter of 8 nm and length 143 nm. Gan et al. [60] treated empty fruit bunch in 62 wt.% sulfuric acid (60 minutes and 45 °C), resulting in nanocellulose with a diameter less than 50 nm. Yang et al. [61] treated corn husk in 55 wt.% sulfuric acid (1.5 hour and 45 °C), resulting in nanocellulose with a diameter 26.9 ± 3.35 nm. Chen et al. [62] treated alpha cellulose in 0.8 M sulfuric acid (1 hour and 82.2 °C), resulting in nanocellulose with a diameter of 18.36 ± 7.34 nm. Wulandari et al. [35] treated sugarcane bagasse in 50 wt.% sulfuric acid (10 minutes and 40 °C), resulting in nanocellulose with a diameter 95.9 nm. Kouadri and Satha [63] treated *Citrullus colocynthis* in 40 wt.% sulfuric acid (4 hours and room temperature), resulting in nanocellulose with a diameter less than 100 nm. Sampath et al. [64] treated microcrystalline cellulose in 64 wt.% sulfuric acid (60 minutes and 45 °C), resulting in nanocellulose with a diameter of 40 nm to 50 nm and length 200 nm to 300 nm.

Based on mentioned above, the source of the cellulose, sulfate concentration, time, and temperature are factors which affect the size of the nanocellulose [65].

3. 3. XRD Result of Nanocellulose Figure 4 shows the nanocellulose diffraction pattern. Most of the cellulose phase is found to be semi-crystalline or amorphous, according to the diffraction pattern. Although the peak of the cellulose phase at the indexed plane (200) appears at an angle of $2\theta = 22.64^\circ$, the peak intensity is quite low and broad [66–68]. Through intra-

molecular and inter-molecular hydrogen bonding, cellulose molecules combine to form the semi-crystalline peak in this plane [68]. This is depicted in the insert in Figure 4, which shows the magnified diffraction pattern over the angle range of $2\theta = 15\text{--}40^\circ$. Kamal et al. [69] also stated that X-ray diffraction investigations revealed the existence of the amorphous cellulose phase.

3. 4. Results of Nanocomposite Films FTIR analysis was used to detect changes in functional groups or the formation of new bonds due to the addition of nanocellulose as a filler in the PVA-chitosan matrix. The results of FTIR characterization of composite films with various concentrations of nanocellulose are shown in Figure 5.

Peaks are widening at wavenumbers from 3100 cm^{-1} to 3550 cm^{-1} in the four PVA-chitosan film spectra due to the vibrations of 2 different functional groups, namely the stretching vibration of the O–H group together with PVA and the N–H group in chitosan [70]. Furthermore, wavenumber 1648 cm^{-1} was a stretching vibration of C=O from acetate [71]. The wavenumber 1564 cm^{-1} was the vibration of the N–H group in chitosan, which shifted from literature [72], indicating the presence of intermolecular bonds of chitosan with the SO_4^{2-} group on

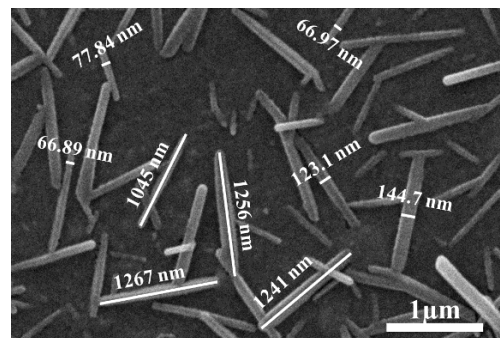


Figure 3. SEM image from nanocellulose

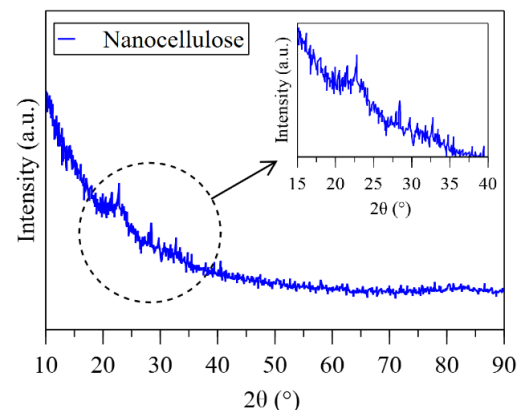


Figure 4. XRD spectrum of nanocellulose. Inset image shows the magnification at $2\theta = 15 - 40^\circ$

nanocellulose surface. Meanwhile, peak at wavenumber 1433 cm^{-1} was the bending vibration of the C–H group on CH_2 in the nanocellulose [73]. The wavenumber of 1126 cm^{-1} was a stretching vibration of the asymmetric C–O group in PVA during the peak at 924 cm^{-1} for the C–C structure of the saccharides in chitosan and cellulose [74, 75]. Furthermore, the wavenumber of 851 cm^{-1} was a bending vibration of the C–O group on the monosaccharide ring in chitosan [76].

The characteristic spectral peaks of PVA-chitosan are due to the presence of good miscibility and chemical interaction between amino-hydroxyl group in PVA and the hydroxyl group in chitosan [11]. Furthermore, the presence of nanocellulose in composite films results in the disappearance or reduction of a certain intensity of FTIR peaks [77]. Wavenumber at $3500\text{--}2750\text{ cm}^{-1}$ reduced with a presence nanocellulose indicating the formation of intermolecular hydrogen bond between PVA-chitosan-nanocellulose in composite films [75]. Presenting nanocellulose in the composite films exhibit wave numbers 1648 cm^{-1} , 1564 cm^{-1} , 1433 cm^{-1} , 1126 cm^{-1} , 924 cm^{-1} , and 851 cm^{-1} . With increasing nanocellulose content, the vibration of the N–H group in chitosan wave number at approximately 1564 cm^{-1} and the stretching vibration of the asymmetric C–O group in PVA wave number at approximately 1126 cm^{-1} are decreased.

3. 5. Results of SEM Cross-section of Nanocomposite Films

The results of the SEM cross-section of nanocellulose added PVA-chitosan films showed that the mixture of PVA and chitosan produced homogeneous films. This showed a good interaction between PVA, chitosan, and the addition of nanocellulose as a filler. The results for SEM films are presented in Figure 6. Adding 1% nanocellulose, the thickness was reduced from $38.9\text{ }\mu\text{m}$ to $17\text{ }\mu\text{m}$. In contrast, adding 3% nanocellulose, the thickness

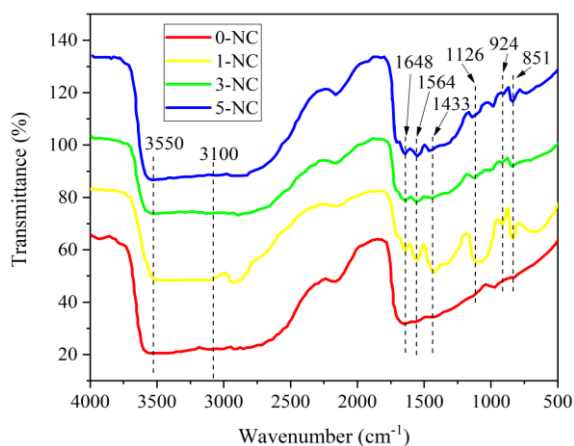


Figure 5. FTIR spectrum of composite films containing different percentages 0%, 1%, 3% and 5% of nanocellulose

increases from $17\text{ }\mu\text{m}$ to $24.6\text{ }\mu\text{m}$. This behaviour needs further investigation. Moreover, by adding 5% nanocellulose, the thickness was reduced from $24.6\text{ }\mu\text{m}$ to $12.1\text{ }\mu\text{m}$. Generally, the addition of nanocellulose can reduce the thickness compared to the absence of the nanocellulose. Smaller thickness is found on addition of nanocellulose to 5%.

Hajji et al. [11] found pure chitosan and PVA thicknesses of $80\text{ }\mu\text{m}$ and $30\text{ }\mu\text{m}$. Due to the increased solubility, exhibiting PVA in the blended films would decrease the thickness. PVA-chitosan with a ratio of 70:30 resulting thickness $30\text{ }\mu\text{m}$. This result is slightly different from the present study, probably because of different preparation. In the present study, the PVA solution was stirred at $90\text{ }^\circ\text{C}$ for 2 hours. The chitosan solution was also stirred in the meantime for 1.5 hours at $100\text{ }^\circ\text{C}$. Both solutions were naturally cooled to room temperature. PVA-chitosan was mixed in a 7:3 ratio, and then subjected to a 15-minute sonication process. Whereas Hajji et al. [11] conducted a stirring of the solution for 6 hours at $80\text{ }^\circ\text{C}$ (PVA) and stirred the solution for 24 hours at $25\text{ }^\circ\text{C}$ (chitosan). Based on chitosan weight, glycerol was added to the chitosan solution at 10% (w/w). Both solutions were mixed in a 7:3 ratio [11].

3. 6. Results of Tensile Analysis of Nanocomposite Film

The tensile strength results obtained from the films tested are presented in Figure 7. PVA-chitosan films demonstrate a tensile strength of 22.43 MPa , which increased to 24.78 MPa when nanocellulose was added at 1%. Tensile strength was 28.05 MPa by adding 3% nanocellulose and 31.50 MPa by 5%. As a result, the increase in nanocellulose concentration increases tensile strength due to had a high surface area. This led to the formation of intermolecular interactions through hydrogen or ionic bonds in the PVA-chitosan polymer matrix at nanocellulose fillers [77]. Hydrogen bonds are

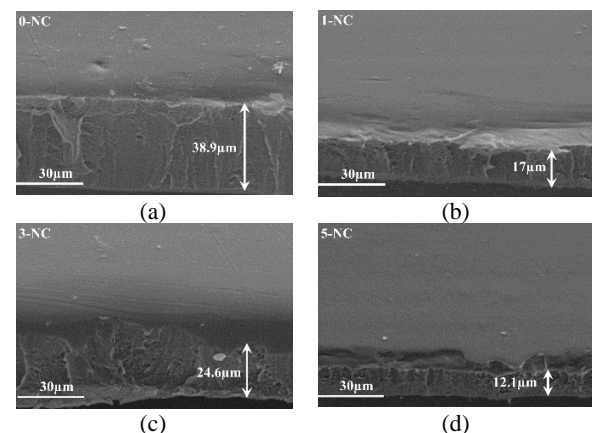


Figure 6. SEM images of nanocomposite film containing different percentages (a) 0%, (b) 1%, (c) 3% and (d) 5% of nanocellulose

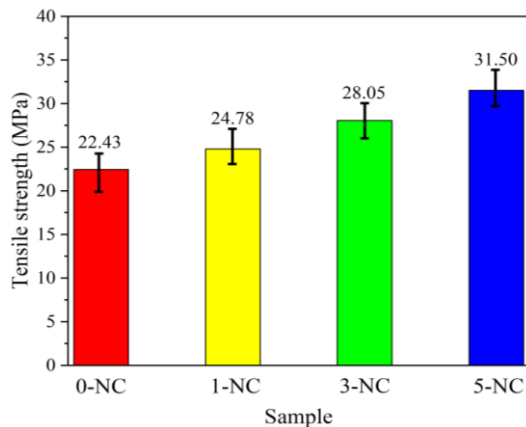


Figure 7. Effect of nanocellulose addition on the tensile strength

formed in order to increase the strength of the polymer [78]. Yudhanto et al. [79] has found that increasing nanocellulose composition from 2 to 5% lead to an increase in tensile strength. Moreover, Perumal et al. [80] blended PVA-chitosan-nanocellulose and resulting tensile strength increase with an increase in nanocellulose composition (1, 3 and 5%).

The present research has less tensile strength than another report due to acetic acid at PVA-chitosan synthesis. Abdolrahimi et al. [81] reported that an increase in acetic acid concentration in the composite promoted decreased tensile strength. Compared with Wu et al. [27], this research resulting less tensile strength due to the presence of chitosan (30%) in the composite films. Hajji et al. [11] found the tensile strength of pure PVA and chitosan to be 53.4 and 3.75 MPa, respectively. An increase in chitosan composition results in a reduction in tensile strength. Yu et al. [13] mixed PVA with chitosan in a 3:2 ratio. The PVA-chitosan mixture reportedly has a tensile strength of 27 MPa.

Another factor influence tensile strength is size of the nanocellulose. Modified cellulose to nanometer size induce the mechanical properties as regard to common cellulose fiber due to surface area and active interface [82]. In the present research, nanocellulose's diameter ranged from 66.97 nm – 144.70 nm, with a length of 1046 nm – 1267 nm which is higher than other research (Figure 3) [65]. Wu et al. [27] have blended PVA with nanocellulose with size 5.6 ± 1.5 nm, increasing the composition of nanocellulose in composite films from 1% to 3% increased the tensile strength from 55 to 60 MPa.

Compared with synthetic packaging, the present research has more or similar tensile strength. Su and Zhang [83] reported tensile strength of high-density polyethylene is 29.3 MPa. Rhim et al. [84] found polypropylene is 31 -38 MPa. Boldt et al. [85] and AlMaadeed et al. [86] found low-density polyethylene is 20 MPa.

Figure 8 shows that adding nanocellulose as a filler increased the elongation at the break of the PVA-chitosan films, which is similar to other report [79]. Hajji et al. [11] found elongation at break pure PVA and chitosan are 38.4 and 454 %. Yudhanto et al. [79] have found that increasing nanocellulose composition from 2 to 5% lead to an increase in elongation at break from 51 % to 110 %. Zhou et al. [87] found that exhibit 10% nanocellulose would increase elongation at break from 6 to 11 %. Moreover, Mandal and Chakrabarty [82] also found similar behaviour, by increasing nanocellulose content from 2.5 to 5 wt.% would increase elongation at break from 160 to 190 %. It seems that tensile strength and elongation at break have a linear relationship, which perfectly agrees with another result [29].

3. 7. Result of Biodegradable Test of Nanocomposite Films

The biodegradation test was carried out using the soil burial method. When buried, this is a direct contact test between the films and the soil. This condition could degrade the films by action of microorganism, fungi, bacteria, or other in soil [88]. The mass loss (%) amount results of the biodegradation test were calculated by Equation (1) is presented in Figure 9. Based on Figure 9, the nanocellulose filler addition affected the composite films mass degraded during soil burial. In nanocellulose-free PVA-chitosan films, the degradation mass during the biodegradation process was 2.11%. Furthermore, at the 1% nanocellulose addition, the degraded mass was 4.80%, and it was 8.62% at 3% of nanocellulose. In addition to 5%, the highest percentage of mass degradation was 9.04%. This behavior could due to denser structure of the PVA-chitosan restricted the destructive enzymatic activity, therefore, by increasing nanocellulose content, would increase mass loss.

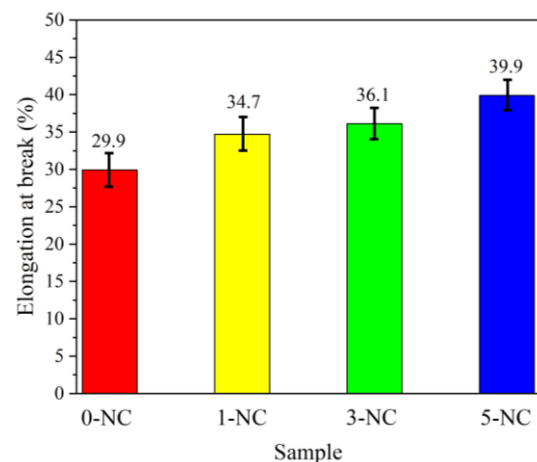


Figure 8. Effect of nanocellulose addition on the elongation at break

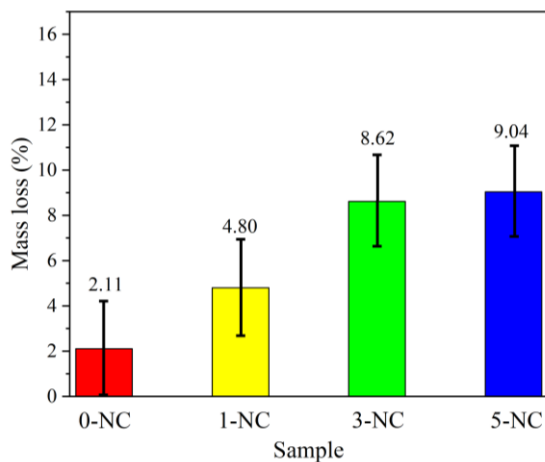


Figure 9. Effect of nanocellulose addition on biodegradation tests

Perumnal et al. [80] have found by adding 5% in PVA-chitosan lead to increase mass loss from 4 to 5% (investigated in 30 days). Van Nquyen and Lee [89] have found, by adding 0.75 g nanocellulose in 3.325 g PVA would enhance degradation rate from 10 % to 19 %. Moreover, Luzi et al. [90] has found the presence nanocellulose increases microbial attack to the surface leading to roughness and formation of crevice.

4. CONCLUSIONS

The PVA-chitosan films with nanocellulose filler from coconut fibers have been successfully fabricated. The morphology of nanocellulose is obtained as cylindrical rods, which tend to form agglomerations. The nanocellulose's diameter ranged from 66.97 nm – 144.70 nm, with a length of 1.046 μm – 1.267 μm . With an increase in nanocellulose content, the vibration of the N–H group in chitosan wave number at approximately 1564 cm^{-1} and the stretching vibration of the asymmetric C–O group in PVA wave number at approximately 1126 cm^{-1} were decreased. Increasing the nanocellulose concentration, increases the tensile strength, elongation at break and biodegradability. Higher the tensile strength, elongation at break and biodegradability is found in the 5-NC sample. Due to its tensile strength and biodegradability, PVA-chitosan-nanocellulose, a product of synthesis, offers a potential replacement for synthetic packaging.

5. ACKNOWLEDGMENTS

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**Persian Abstract****چکیده**

در این تحقیق، فیلم‌های کامپوزیتی پلی‌وینیل الکل - (PVA) کیتوزان با استفاده از نانوسلولز از الباف نارگیل (*Cocos nucifera*) در مزرعه‌ای اندونزی به منظور افزایش خواص مکانیکی و تجزیه‌پذیری زیستی تولید شد. این فرآیند با جداسازی لیگنین و همی سلولز با لایه برداری، سفید کردن و سپس هیدرولیز سلولز برای تولید نانوسلولز آغاز شد. PVA با کیتوزان با ترکیبات خاص مخلوط شد و نانوسلولز به ترتیب در غلظت‌های ۰، ۱، ۳ و ۵ درصد اضافه شد. یک آزمایش کششی برای به دست آوردن استحکام کششی و شکست ازدیاد طول انجام شد. تست زیست تخریب پذیری نیز برای تعیین سطح تلفات جرمی انجام شد. بر اساس مشاهدات SEM، افزودن نانوسلولز به نظر می‌رسد که واکنش‌پذیری تشکیل لایه‌های کامپوزیت PVA- کیتوزان را افزایش می‌دهد که با کاهش ضخامت لایه مشخص می‌شود. افزودن ۵ درصد نانوسلولز منجر به کیفیت بالای نانوکامپوزیت شد. استحکام کششی، ازدیاد طول شکست و زیست تخریب پذیری فیلم کامپوزیت به ترتیب ۳۱/۵۰ مگاپاسکال، ۳۹/۹ درصد و ۹/۰۴ درصد بود.