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# Improvement of Biocomposite Properties Based Tapioca Starch and Sugarcane Bagasse Cellulose Nanofibers

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**Keywords:** Sugarcane bagasse fiber, cellulose nanofibers, tapioca starch, biocomposite, tensile properties

**Abstract.** Biocomposite based tapioca starch (TS) and sugarcane bagasse cellulose nanofibers (SBCN) was made through casting method. SBCN was prepared by chemical and ultrasonication process. It was successfully displayed by transmission electron microscope (TEM) in range 20 - 45 nm. Meanwhile, particle size analysis (PSA) also supported the distribution diameter of SBCN for  $59.75 \pm 10.84$  nm. SBCN and glycerol were used as reinforcement and plasticizer, respectively. The amount concentration of SBCN was varied from 0 to 8 wt%. Biocomposite was characterized by using scanning electron microscopy (SEM) and tensile test. SEM image displays SBCN is in good interfacial bonding with the matrix. The highest tensile strength of biocomposite was in TS/4SBCN sample for 20.84 MPa. These results showed that SBCN fiber become potential candidate as reinforcement in biocomposite application.

## Introduction

The development of biodegradable materials from renewable sources is increasing due to environmental awareness. Among of natural polymers, starch is considered as one of the most promising candidates because its advantages such as, availability, low cost and good performance [1-2]. Tapioca (*Manihot esculenta*) is an important source of starch in several countries such as Thailand, Malaysia, Indonesia and some African regions. In addition, using of tapioca starch for bioplastics composite has been developed by many previous researchers [3-5]. In its application, starch has several limitations such as low tensile strength and moisture resistance. One solution to overcome this limitation is the addition of with organic and inorganic fillers in starch matrix [6-7].

Cellulose nano fibers (CNF) is a new type of filler which shows high efficiency in improving the physical and mechanical properties of starch-based biocomposite. Nano particle-sized fillers have good compatibility with matrix due to the high contact surface area [8]. One of the fiber plants which has a high cellulose content is sugarcane bagasse. Sugarcane bagasse fiber has high  $\alpha$ -cellulose content approximately 85%. Other advantages are good mechanical properties, low density, low cost and abundant in earth. Therefore, sugarcane bagasse fiber has potential to reinforce starch biocomposite [9].

Several previous studies have explained that sugarcane bagasse cellulose has a good bond with the starch matrix [9-10]. This is indicated by the hydroxyl bond formation between cellulose and starch resulting in improvement of mechanical properties [11]. Meanwhile, the fiber size of sugarcane bagasse is also play important factor due to its function in filling the void fraction in starch matrix. Previous studies reported that nano-sized cellulose sugarcane bagasse was effective in increasing the properties of biocomposite. Nano size fiber can spread evenly into the starch matrix. Even distribution makes less voids formation [8, 12].

In this study, the synthesis of SBCN was carried out by the chemical-ultrasonic method. The SBCN was added into tapioca starch matrix as reinforcement. The addition of SBCN to the matrix is expected to improve the tensile properties of biocomposite. According to the best our review, there is no research reported about SBCN reinforced tapioca starch matrix. We state that the research about sugarcane bagasse cellulose fiber in nanoscale is limited information. The synthesis of SBCN was produced by chemical and ultrasonication method namely pulping, bleaching, sulfuric acid hydrolysis and ultrasonication. The characterization of SBCN was carried out by using particle size analyzer (PSA) and transmission electron microscopy (TEM), while biocomposites were characterized by using scanning electron microscopy (SEM) and tensile test.

## Materials and Methods

**Materials.** Sugarcane bagasse was obtained from local sugarcane ice seller at Jember, Indonesia. Sodium hydroxide (98% NaOH), potassium hydroxide (KOH), sodium chlorite (NaClO<sub>2</sub>), acetic acid (CH<sub>3</sub>COOH), sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) and glycerol were purchased from CV. Aneka Kimia located at Jember, Indonesia. Tapioca starch was supplied by Laboratory of Material Testing, Department of Mechanical Engineering, University of Jember, Jember, Indonesia.

**Preparation of sugarcane bagasse cellulose nanofibers (SBCN).** The overall isolation of SBCN was in accordance previous method and modified in hydrolysis process [13-14]. Hydrolysis was carried out before the ultrasonication process. Hydrolysis process used 30% H<sub>2</sub>SO<sub>4</sub> for 60 min with ratio fiber and solution (1 : 8.75). After hydrolysis, sugar cane bagasse fiber was washed by distilled water until neutral pH. Then, it was ultrasonicated by using sonicator (Ultrasonic 750W) at 70 °C for 150 min to obtain SBCN.

**Fabrication TS/SBCN biocomposites.** The composition of biocomposite from SBCN and tapioca starch was presented in Table 1. Tapioca starch was dissolved in distilled water (% w/v) and SBCN (% w/w based tapioca starch) with different concentrations. Glycerol as a plasticizer (30% w/w from tapioca starch) was added in mixing solution. Then, the biocomposite solution was heated at 65-75 °C with constant stirring (200 rpm) until gelatinized, poured into an acrylic mold (11 cm x 9.5 cm x 0.3 cm). To remove air bubbles, the mold was placed in an ultrasonic bath for 15 min [15-16]. After that, it was dried in drying oven at 40 °C for 17 h. Biocomposite was stored in the desiccator for 24 h before characterization.

Table 1. The composition of the biocomposite from tapioca starch reinforced SBCN

Biocomposites code	Glycerol (w/w dry starch basis)	TS, w/40 ml aqudest	SBCN (% dry starch basis)
TS (Control)	0.3	2	0
TS/2SBCN	0.3	2	2
TS/4SBCN	0.3	2	4
TS/8SBCN	0.3	2	8

*\*This composition is similar with previous report but difference in the addition of % fiber content and glycerol volume [17].*

**SEM and TEM.** The surface morphology of biocomposite was observed using SEM (Model JSM 6510 LA from JEOL) with a voltage and flow at probe for 15 kV and 8 mA, respectively. The tested sample was placed on the SEM stub sample. The preparation sample was previously coated with carbon followed by coating with gold to reduce electron charge. SEM images were enlarged to get image clarity. Furthermore, the morphology of SBCN was observed using TEM-Tecnai T20 at 200 kV for microstructure observation. The suspension of SBCN after ultrasonication process was dripped a few drops over the holley carbon grid and dried at room temperature for 4 h. The dried SBCN solution was directly observed by TEM instrument.

**Tensile strength.** The tensile strength of biocomposite sample was determined using a tensile machine at room temperature conditions of 25 °C. Tensile specimen was formed according to the American Standard Testing Material (ASTM) D-638 type IV. The test was maintained on crosshead speed of 2 mm/min using a load cell of 5 kN load. Five samples were tested for each biocomposite variation as stated in previous report [17].

## Results and Discussions

### Morphological of SBCN

PSA and TEM images of SBCN suspension are shown in Figures 1a and 1b, respectively. The average size of SBCN produced by the chemical-ultrasonication method is  $59.75 \pm 10.84$  nm. This SBCN diameter is smaller in size compared to the hydrolysis-homogenization process which carried out by previous report about isolation of nanocellulose from sugarcane bagasse for 95 nm [18]. This proved that the hydrolysis treatment with  $H_2SO_4$  and ultrasonication had successfully broken the hydrogen bonds between cellulose [13-14]. This is supported by the SBCN morphology by TEM (Figure 1b) which shows SBCN are disintegrated and spread evenly.

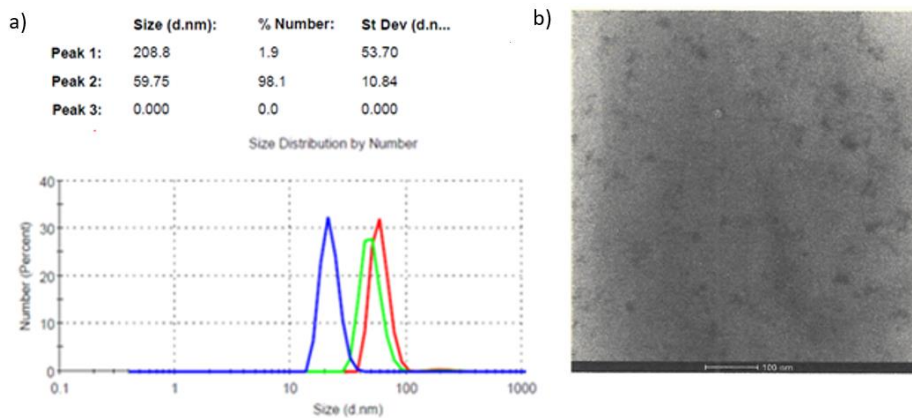


Figure 1. SBCN distribution by different characterization: a) PSA and b) TEM

According to previous researchers, the ultrasonication process was very effective for breaking the hydrogen cellulose chain in the liquid medium. The ultrasonication emits ultrasonic waves and form cavitation in a liquid medium. The cavitation formed will collide with each other to break the bond. However, this process has a disadvantage such as high-power electricity consumption [15, 19].

### Morphology SEM of TS/SBCN biocomposite

Figure 2 shows the fracture surface morphology of a TS/SBCN biocomposite. Figure 2a displays the control sample (pure TS film). It can be seen that fracture surface looks smoother than biocomposite samples. This phenomenon is caused by good mixing between glycerol and tapioca starch during gelatinization process [8]. Good mixing and dispersion able to make homogeneous film. A similar phenomenon was also reported by previous studies of films from yam bean starch [6, 12]. The addition of SBCN in the tapioca starch matrix displays a rougher surface. The addition

of 2% SBCN into TS matrix (Figure 2b) showed less dispersion of SBCN particles than 4% and 8% SBCN in TS matrix. This fracture is also accompanied by cracks in various parts. This is due to the bad preparation of biocomposite samples [20].

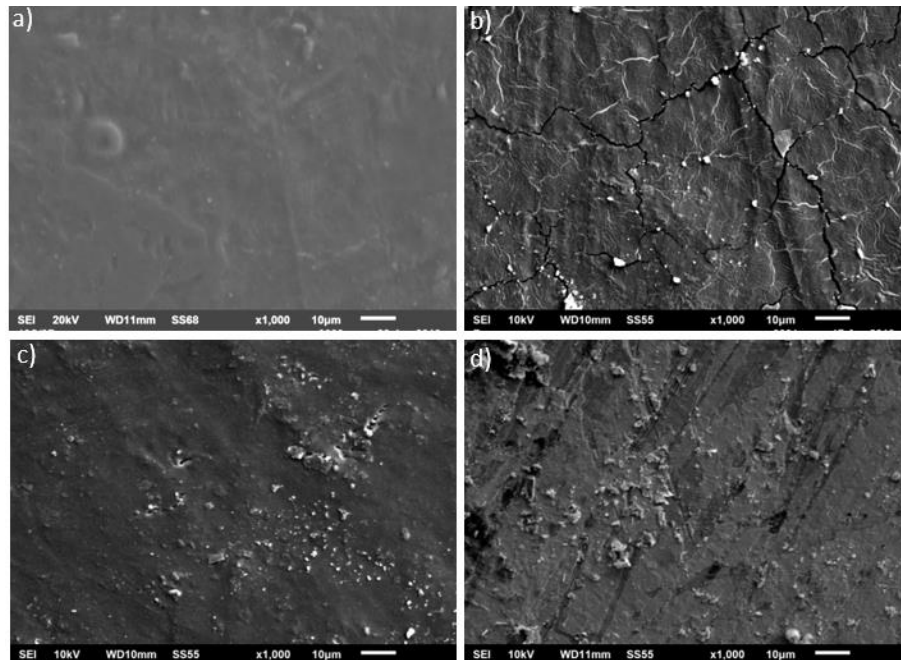


Figure 2. Fracture morphology by SEM image: a) 0% (control), b) 2%, c) 4%, d) 8% of SBCN

Meanwhile, the addition of 4% SBCN in TS matrix (Figure 2c) shows a more homogeneous surface and it has denser structure. The SBCN particles look evenly dispersed in various parts of the matrix. This results in a good bond between the fiber and matrix resulting in higher tensile strength [16]. Different phenomena are shown by 8% SBCN in the TS matrix (Figure 2d). This sample shows porosity in several parts. In addition, clot formations are formed in these samples. This is due to the ineffective transfer of stress from fiber to matrix [15, 21]. This factor affected in decreasing mechanical properties. This result is also supported by the tensile strength which shows a decreasing up to 200% compared to the addition of 4% SBCN in TS matrix.

### Tensile strength and strain of TS/SBCN biocomposites

The tensile strength and tensile strain of TS/SBCN biocomposites are shown by Figures 3a and 3b, respectively.

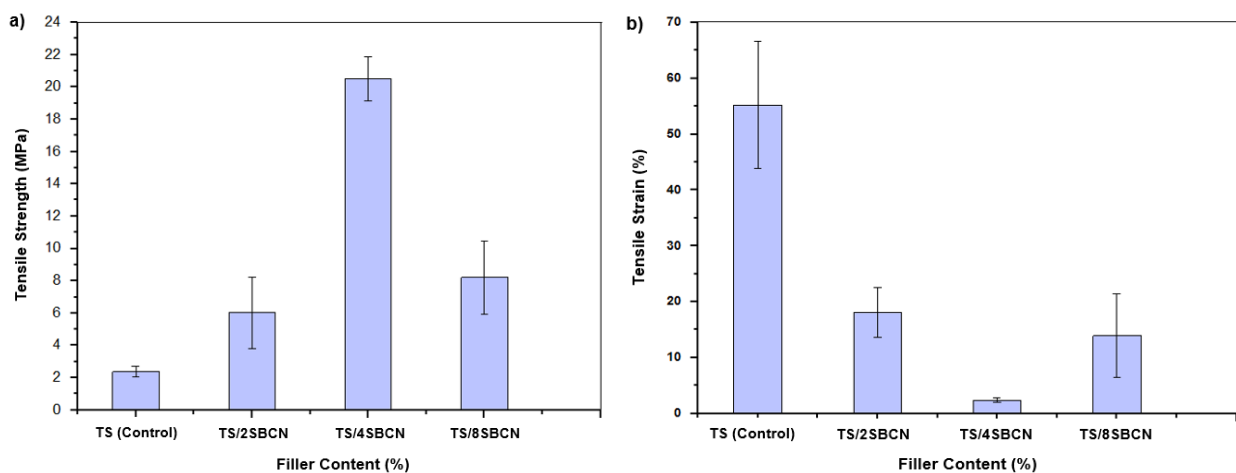


Figure 3. Tensile properties of all samples tested: a) tensile strength and b) tensile strain of all biocomposites tested



It can be seen that the tensile strength increased significantly from  $2.37 \pm 0.34$  MPa to  $20.51 \pm 1.37$  MPa with the addition of 4% SBCN in starch matrix (Figure 3a). This tensile strength is higher than the previous research as conducted by [Abral \*et al.\* \(2018\)](#) for 6.68 MPa (10% fiber in starch matrix) [22]. Conversely, there was a decrease in tensile strain 4% SBCN biocomposites from 55.27% (control) to 2.37% (Figure 3b). This indicates that the SBCN particles are distributed evenly in tapioca starch matrix for 4% SBCN samples. In addition, good adhesion bonding between matrix and fiber is also become supporting factor in increasing tensile strength [12, 22]. This result was supported by SEM imaging (Figure 2c). The addition of SBCN to the TS matrix makes the sample become brittle (strain reduced). It is affected by the present of SBCN in TS matrix which results in the prevention mobility of starch chain. Similar results were reported by previous studies [15].

## Conclusion

SBCN was successfully synthesized by chemical-ultrasonication method with a diameter of  $59.75 \pm 10.84$  nm. This SBCN has potential used as reinforcement in biocomposite based starch due to its nanosized fiber. The SBCN was found in good dispersion in biocomposite based tapioca matrix. Beside that, the mixing SBCN and tapioca starch resulting in good adhesion bonding. This is affected in highest tensile strength of 4% SBCN in TS matrix for 20.84 MPa. This improvement in biocomposite properties proves that SBCN might have potential as a reinforcement in biopolymer matrix-based packaging material.

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