POTENTIAL OF RICE STRAW FIBER AS A NATURAL FIBER MATERIAL FOR APPLICATIONS IN COMMERCIAL PRODUCTS

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ABSTRAK

**POTENSI SERAT JERAMI PADI MENJADI BAHAN *NATURAL FIBER* UNTUK APLIKASI PADA PRODUK-PRODUK KOMERSIAL**. Selulosa merupakan bahan yang bisa dijadikan serat alam yang lebih ramah lingkungan daripada serat sintetis. Limbah jerami padi mengandung banyak selulosa, untuk itu jerami padi memiliki potensi untuk dijadikan serat alam. Serangkaian proses harus dilalui sebelum mendapatkan serat alam selulosa dari jerami padi. Banyak metode proses yang bisa diterapkan, seperti menggunakan zat kimia atau menggunakan radiasi, terlebih pada proses pendahuluan. Serat alam yang diperoleh dimanfaat untuk menjadi serat sintesis sebagai bahan membuat beberapa produk komersial. Ulasan ini menerangkan metode proses yang bisa diterapkan untuk pembuatan serat alam dari limbah jerami padi serta produk komersial yang dapat dibuat dari serat alam selulosa.

Kata kunci: selulosa, jerami padi, serat alam, metode proses, produk komersial

ABSTRACT

**POTENTIAL OF RICE STRAW AS A NATURAL FIBER MATERIAL FOR COMMERCIAL PRODUCTS.** Cellulose is a material used in producing natural fibers, which is more environmentally friendly than synthetic fibers. Rice straw waste contains much cellulose and has potential as natural fiber. However, before the natural cellulose fiber is extracted from the rice straw, it must pass through several processes, such as chemicals or nuclear radiation, especially during the pretreatment process. Furthermore, the resulting natural fibers are utilized to replace synthetic fibers for use as raw materials in manufacturing several commercial products. This review describes a process that can be applied to manufacture natural fibers from rice straw and commercial products made from natural cellulose fibers.

Keywords: cellulose, rice straw, natural fiber, process method, commercial product

INTRODUCTION

The Fourth Industrial Revolution (4IR) has begun in many sectors worldwide, one of which is the agricultural sector. Unfortunately, this sector produces much waste known as agro-industrial waste. Subsequently, rice (Oryza sativa) is one of the essential staple food in Indonesia, and extentsively produced throughout the regions. The estimated total of rice production in 2018 was 32.42 million tons [1]. However, the number of rice farms is directly proportional to the amount of waste generated. According to research by Puspa (2014), rice production in Indonesia in 2014 amounted to 70.83 million tons of dry milled grain (GKG), while the quantity of rice straw produced reached 50% of the harvested grain, approximately 35.46 million tons [2].

Rice straw contains lignocellulose, which is chemically lignocellulosic biomass. It’s main components are cellulose (35-50%), hemicellulose (20-35%), and lignin (10-25%) [3].

Cellulose is an organic compound with the formula (C6H10O5), which is the main component of lignocellulose. It is a polysaccharide composed of linear (elongated, unbranched) chains with several hundred to thousands of linked D-glucose units [5-6]. The utilization is preceded by hydrolysis into glucose, but this process is complicated because polymers accumulate/bond together to form strong and long fibers [7-8]. Meanwhile, hemicellulose is a group of polysaccharides that contains many variations of sugar monomers. These monomeric sugars are made up of pentoses (xylose, rhamnose, and arabinose), hexoses (glucose, mannose, and galactose), uronic acid, and acetyl groups [9].

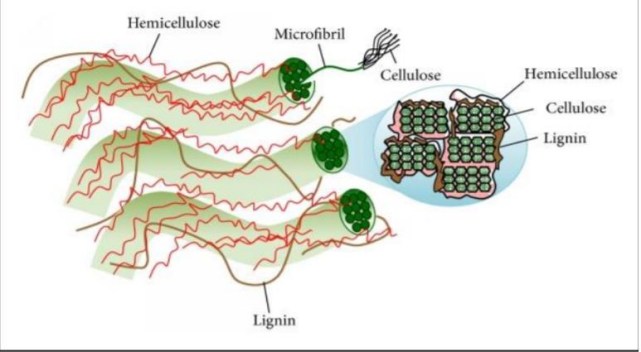


Figure 1. Plant cell walls, composed of lignocellulosic structures [4]

Subsequently, lignin is a complex structure in the primary cell wall that supports lignocellulosic structures. The building block is a phenylpropane polymer consisting of guaiacol, syringyl, and p-hydroxyphenyl linked by ether (β-O-4) or C-C bonds [5]. It is also one of the main factors that make it difficult for enzymes to degrade lignocellulose. In addition, lignin is the main barrier in accessing cellulose and hemicellulose. The hydrophobic interactions of lignin with enzyme molecules create bonds that reduce the enzymes’ ability to hydrolyze cellulose [10]. The content of the cell wall, particularly lignin, increases with the age of the plant [11].

Rice straw production reaches an estimated 21.75 million tons per year and accounts for 43% of agricultural waste in Indonesia [3]. Out of the available stock of rice straw, 31-32% is used as animal feed, 36-38% is used as fertilizer, and 7-8% is used as raw material for the pulp and paper industry, while the remaining 22-25% left are not optimally utilized [11]. The unused rice straws are usually burnt, which invariably pollutes the air and increases CO2 levels in the environment, thereby increasing global warming. Additionally, burning rice straws on agricultural land leads to soil losses of up to 93% of nitrogen (N) and 20% of potassium (K) [12].

Most natural fibers are commonly made from cotton. However, growing cotton requires land, water, and other beneficial naturally occurring phenomena [13]. However, it is more profitable to utilize rice straws as raw materials. Furthermore, a rival to natural fibers is the synthetic fibers made from petroleum, which are non-renewable and consume more energy in their manufacturing process [9]. Producing synthetic fibers is not environmentally friendly, and the resulting product is also difficult to dispose of after usage. consequently, the efforts and pressure to utilize only natural fibers are intensified every year. [14]. One of the natural fibers is cellulose which is extracted from rice straw. In addition, large amounts of lignin and hemicellulose hinder cellulose production from rice straw. Therefore, it is difficult to access the cellulase enzyme capable of hydrolyzing cellulose to glucose, which invariably decreases hydrolysis efficiency [1, 11].

The pretreatment process of lignocellulosic materials should be carried out to facilitate the hydrolysis process. It opens up the lignocellulosic structure to make enzymes that break down polysaccharides from polymer to monomer form to save and reduce the use of enzymes [15]. Pretreatment is usually carried out using Alkaline-hydrogen peroxide (AHP) reagents. The AHP is selected because, by its nature, it leaves no residue and hardly generates any by-products. [16].

Fermentation is the anaerobic breakdown of carbohydrates and amino acids [17]. Furthermore, the fermentation process of existing rice straw is carried out with the addition of staple probiotics [13]. Also, the use of probion in the fermentation of rice straws reduces crude fibers [18]. Asides probiotics and probions, other potential initiators of rice straw fermentation, are probiotic FM, local micro-organism (MOL), banana weevil, and Mikrostar LA2. The Microstar LA2 is a product of the National Nuclear Energy Agency (BATAN) [19].

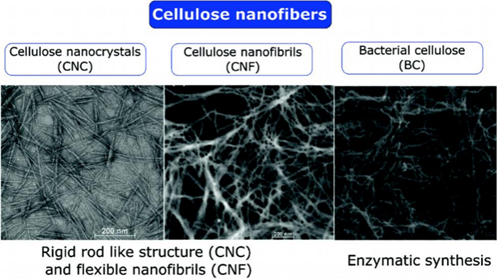


Figure 2. Cellulose Nanofiber

Cellulose nanofibers are linear polymers that exhibit high strength and rigidity due to their extensive intermolecular and intramolecular hydrogen bonding [1].

METHOD

This research was carried out using a descriptive method through studies and careful analysis of related literature and journals. The literature study began with the topic of natural fiber from rice straw, the components, and the processes involved in their extraction. Shortly afterward, an analysis of the commercial products made from natural fibers was conducted [20,21].

results and Discussion

**Potential and Process of Rice Straw Waste into Cellulose Nanofiber Biomaterials**

Cyrocrushing, Sonication, and Solid substrate fermentation produce nanocellulose, which accelerates the process of splitting cellulose molecule chains into amorphous regions, thereby increasing crystallinity. Additionally, cellulose nanofibers with high crystallinity are rigid and possess mechanical strength [1].

According to Graciella (2020), the dry rice straw waste is ground and subjected to a pretreatment process using AHP. Furthermore, the pretreatment precipitate is sent for fermentation to hydrolyze cellulose. The following stage, which is the final or downstream process, consists of 4 stages. The first stage is cryocrushing, where rice straw is pounded in a mortar with liquid nitrogen. The next phases are the agitation and sonification stages, which was carried out for 24 hours and 15 minutes, respectively. Finally, the last stage is centrifugation, which results in the production of cellulose suspension [1]. Furthermore, according to a research conducted by Narendra (2006), it was found that fiber from rice straw is made through a combined chemical and enzymatic extraction process.

In this research, a scanning electron microscope (SEM) was also used to examine the morphological properties of fiber strands mechanically extracted from rice straw waste, the fiber extracted with alkali and enzymes, and individual cells in the fiber extracted from the maceration process [14].

Cellulose Extraction Process Using Radiation

One of the chemical processes applied to the pretreatment session involves radiation technology. The advantages are that it does not require recycling, pollute the environment and or generate any residue/waste, and it lasts for just a few hours. Furthermore, this technology can be physically, chemically, and biologically combined with other processes [9]. The impact of the two radiation methods on pretreatment processes are shown in Table 1.

Table 1. Impact of Radiation Method on Pretreatment Process

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***No*** | ***Radiation Method*** | ***Treatment Condition*** | ***Structure Change*** | ***Reference*** |
| 1 | Gamma Radiation | 100 kGy gamma irradiation, continue to warm up 10 grams of rice straw in 100 ml of 2% NaOH for 1 hour | Increase the solubility of hemicellulose and lignin, the access surface, and the enzymatic hydrolysis reaction | [9] |
| 2 | Electron Beam | The sample was immersed in 4% NaOH (30% of the sample weight), then electron beam irradiation at a dose of 50 Mrad. | Cuts cellulose and hemicellulose chains make it easier for enzymes to access cellulose, remove lignin. | [17] |

Rice Straw Cellulose Nanofiber Products

Narendra (2006) research proved that nanofiber produced from rice straw has the same properties as both linen and synthetic fiber in terms of fineness, strength, elongation, and modulus. Subsequently, the modulus is the determining factor in the softness and flexibility of fiber products [14].

Cellulose nanofibers are used as car-body replacement parts, filters, and skin graft donors. For example, the "NCV (Nano-Cellulose Vehicle)" project of the Japanese ministry of environment has developed a sports car made of cellulose nanofiber (CNF). This project aims to replace as many steel body parts of cars as possible with CNF-based parts [22].

Also, nanocellulose-based materials can function as membranes, filters, or adsorbents. Its performance is primarily related to the ability of nanocellulose fibers of large surface areas to absorb contaminants from water streams [1]. Furthermore, NFC (Nano-Fibrillar Cellulose) is a biocompatible treatment for skin graft donors wherein the bandage adheres well to the surface of the wound and detaches itself after skin recovery [17]. Cellulose nanofibers from rice straw are also applied to fabric products such as clothing and pillows.

Cellulose Nanofibers from Rice Straw as Urea Formaldehyde Resin Supplement

Urea-Formaldehyde (UF) resin is used to produce wood-based panels, where the physical and mechanical properties depend on the properties of the adhesive material. The connection quality between wood particles is a decisive factor determined by the amount and type of adhesive used [23]. Cellulose nanofiber (CNF) is one of the adhesives due to its environmental friendliness, large surface area, rigidity, and strength. [24, 25].

Moslemi (2020) stated that incorporating cellulose nanofibers into UF adhesive, significantly improves the mechanical performance of the panels and reduces formaldehyde emissions [26].

Rice Straw for Other Types of Fiber

Fiberglass Reinforced Plastic (FRP) is a composite consisting of fiber and matrix (resin) [27]. This FRP material is considered suitable for manufacturing of ships such as speedboats, patrol boats, fishing boats, and cruise ships due to the improvement in the manufacturing process [28]. In addition, Nuraini (2017) showed that adding natural rice straw fiber to composite materials yields higher tensile strength [29].

The tensile strength of a material indicates the maximum capacity in withstanding loads or stresses without getting damaged or broken. Furthermore, Andi (2018) performed tensile strength and impact tests to determine mechanical properties such as tensile strength, yield stress, and strain, and the influence of the volume fraction and the orientation on the tensile strength of the specimen. The results suggested that an increase in the volume fraction of straw fiber affects the strength of the material [30].

CONCLUSION

Cellulose is extracted from rice straw to produce natural fiber. Before processing, the dry straw goes through a pretreatment process with the addition of chemicals such as AHP or utilizing radiation technology. This natural fiber is used as a substitute for linen fiber. In addition to being used for clothing material, it is also utilized for resin mixture or composite for FRP.

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