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Isolation of Nanocellulose from Jatropha Waste: An Overview

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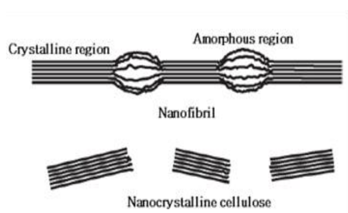
Graphical abstract



Abstract

Nanocellulose widely used as an additive to improve the quality of composite for medical appliances, electronic and many other applications. The structure can be found in a plant cell wall and established methods are needed for an isolation process. Biomass from plant is commonly selected for this process due to theirs abundance resources. Nanocellulose from jatropha plant will be thoroughly discussed in this paper where several isolation methods will be highlighted.

Keywords: Isolation, jatropha waste, nanocellulose, nanofibrillated, nanocrystalline

1.0 INTRODUCTION

The high demand on eco-friendly materials lead to many investigation and research on biomaterials. Cellulose is an example of polymer that has been widely research by scientist due to its hydrogen bond network which makes cellulose become a high axial stiffness [1]. The hydrogen bonding also contribute to a stable polymer because of the tendency to form crystalline aggregates. This natural occurring polymer can be found in plant based materials and microorganism.

Anselme Payen in 1838 was first discovered the unique structure of polymer [2]. Since then, many research involving chemical and physical properties of cellulose have been discovered through time. The term ‘nanocellulose’ is widely used as the result of an isolation process from plant and generally referred as cellulosic nanosize material.

Nanocellulose can be categorized by three types known in literature as nanofibrillated cellulose, nanocrystalline cellulose and bacterial nanocellulose according to materials and methods used. Nanofibrillated cellulose consists of long and flexible nanosize particles, whereby nanocrystalline cellulose consists of crystal form of nanoparticles. Most of the literatures used microfibrillated cellulose as synonym with nanofibrillated cellulose. However, Moon *et al.* (2011) described the different between both, where nanofibrillated cellulose is finer in particle diameters than microfibrillated cellulose [3].

Figure 1 shows the difference between nanofibrillated and nanocrystalline celluloses.

The advantages of using nanocellulose have been broadly discussed among the researcher. Samir *et al.* (2005) listed several advantages of nanocellulose, includes, biodegradable, renewable resources, high specific strength and modulus [4]. Hence, numbers of researches have been done in order to isolate nanocellulose from various plants. Nanocellulose obtained from plant is more economical than from microorganism, because the latter of nanocellulose can cause contamination on digestive system [5].

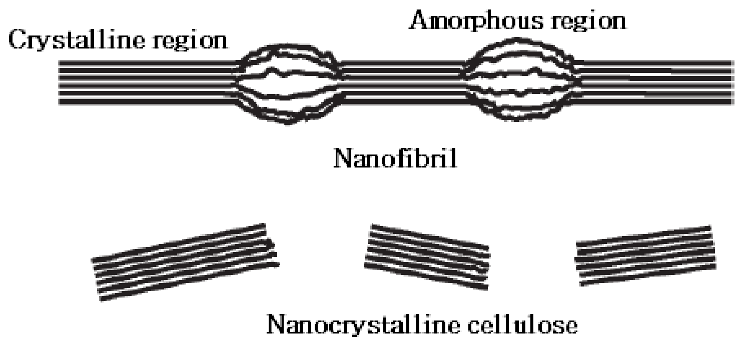


Figure 1 Difference between nanofibril and nanocrystalline cellulose.

Over a decade, isolation of nanocellulose from biomass has gained more attention and interest. Mass production of nanocellulose could be gain since biomass are abundant resources and have high cellulose components. Currently, there is no isolation processes of nanocellulose using jatropha waste have been reported. The characteristics of jatropha waste will be discussed on next subtopic. A trend and chemical compositions on isolation of nanocellulose from biomass by using various raw materials is shown in Table 1. This paper is an overview on isolation of nanocellulose from jatropha waste that can be used in many fields such as medical and electronic application.

Table 1 A trend and chemical compositions of nanocellulose from biomass.

Raw Materials	Year	Chemical Compositions			Reference
		Cellulose (%)	Hemicellulose (%)	Lignin (%)	
Banana pseudeostem	2008	64.04 ± 2.8	18.60 ± 1.6	4.90 ± 0.7	[6]
Mulberry Barks	2009	37.4 ± 2.3	25.3 ± 2.5	10.0 ± 0.8	[7]
Pineapple Leaf	2010	81.3 ± 2.5	12.3 ± 1.4	3.5 ± 0.6	[8]
Corncob	2013	31.2 ± 3.1	43.1 ± 4.0	16.5 ± 2.0	[9]
Oil Palm Empty Fruit Bunch	2014	45.0 ± 5.0	25.0 ± 5.0	25.0 ± 5.0	[10]

2.0 JATROPHA WASTE AS AN ABUNDANT SOURCE OF CELLULOSE

Jatropha (*Jatropha curcas L.*) or common name, physic nut, has been known as multipurpose plant. This plant belongs to Euphorbiaceae family and can be found in South America, Africa, India, and South Asia. Jatropha is a drought resistant and can cultivate in almost any type of soils, therefore, this plant is easily established.

Several researchers have been focused on jatropha as second generation fuel. As palm oil, jatropha can produce oil which is important for renewable energy sources. In addition, palm oil is an edible which will be used for food and cooking based material. However, jatropha is non edible as palm oil, thus very useful as non food feedstock for oil extraction.

As a woody plant, biomass from jatropha consists of lignocelluloses, a combination of cellulose, hemicelluloses and lignin. Previous research has been done to determine the cellulose percentage in different part of jatropha plant. Based on Table 2, jatropha waste has the highest percentage of cellulose compared to other biomass. Eventhough the percentage shown was 56% but by using chemical treatment, this percentage can be increased.

This percentage is higher as compared to oil palm empty fruit bunch in Table 1. The compositions of cellulose indicate the potential that nanocellulose can be isolated from jatropha waste. Recent studies reported that, the jatropha waste can be utilized from oil extraction using jatropha seeds. There are many types of waste that generate from biodiesel production, including husk, shell and seed cake.

Table 2 The composition of difference part of jatropha plant

Type of fibre	Cellullose (%)	Lignin (%)	Hemicellulose (%)	Reference
Jatropha Waste	56.31	23.91	17.47	[11]
Hull	42.8 ± 0.6	9.6 ± 0.6	14.7 ± 0.5	[12]
Wood Component of Shell	22.29	47.60	23.84	[13]
Stem	42.99	24.11	19.11	[14]
Shell	33.75	11.90	9.70	[15]
Fruit Coat	13.11	28.91	7.69	[16]

3.0 NANOCELLULOSE RECOVERY FROM PLANT WASTE

There are two types of nanocellulose that can be formed from plant, which are nanofibrillated cellulose or nanocrystalline cellulose. The recovery yield depends on the method used. Several methods have been discussed by researcher to obtain nanocellulose. Several novelty methods have been found in order to achieve and isolates nanocellulose from plant. However, each method has its own advantages and disadvantage compared to others. The method used depends on the level of difficulty to isolate the cellulose from the plant. High concentration of chemical reagent will be required if the lignin content in the plant is higher than usual [17].

Generally, there are two stages of producing nanocellulose from plant source materials, pretreatment and chemical or mechanical methods [18]. Nanofibrillated cellulose is generally isolated by using mechanical method, meanwhile, nanocrystalline cellulose are generated from chemical method. The most common method use to produce nanofibrillated cellulose is by using high-pressure homogenizer. This method was applied by Herrick *et al.* (1983) and Turbak *et al.* (1983), where they first discovered the nanofibrillated cellulose [19, 20]. This method involved homogenizing cellulose into slurry that is usually suspended in water, by using high pressure applied to the nozzle of the homogenizer. Cryocrushing is an alternative mechanical method to produce nanocellulose. This method used liquid nitrogen to freeze the sample and high impact is applied to crush the sample through mortar and pestle. Alemdar and Sain (2008), applied this technique prior of using laboratory defibrillator [21]. They found that by applying this technique, the size of nanofibrillated cellulose can be reduced.

As for nanocrystalline cellulose, a pretreatment is important to isolate cellulose from lignin, hemicelluloses and other impurities component. After a pretreatment process, acid hydrolysis is used to remove amorphous region in order to obtain high crystallite particle or nanocrystalline cellulose. Acid hydrolysis involve high concentration of acid such as hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) as a medium. During this process, only crystalline region will remain because of their resistance against acid [22]. Steam explosion is a technique that can also be used to isolate cellulose from plant fibres. This technique uses hot steam and pressure, followed by a fast decompression to derive cellulose nanofibrils from plants. Cherian *et al.* (2008), had use steam explosion in alkaline medium, and subsequently acidic medium to derive nanocellulose from banana fibers [6]. This method is an efficacious method to isolate cellulose nanofibrils from biomass due to less hazardous of chemical used and low environmental impact [6].

Several steps to isolate nanocrystalline cellulose from biomass were described by Brinchi *et al.* (2013), starting from pretreatment, followed by acid hydrolysis, dialysis and sonication [18]. Sonication plays an important role to stabilize the dispersion of nanocrystals. Combination of those methods resulted on more promising cellulose in term of length and diameters. Previous researches on using biomass to produce nanocellulose are shown in Table 1.

Table 3 Previous research on using biomass for nanocellulose

Authors	Methods	Type of nanocellulose	Length (nm)	Width (nm)
Cherian *et al.* (2010) [8]	Steam explosion in alkaline medium and bleaching, followed by acidic medium	Nanocrystalline Cellulose	200 – 300	5 – 60
Wang & Sain (2007) [23]	Alkali treatment, acid hydrolysis and bleaching, refining and beating, followed by high pressure defibrillation	Nanofibrillated Cellulose	Several µm	50 – 100
Pelissari *et al.* (2014) [24]	Alkali and bleaching treatment, acid hydrolysis with high-pressure homogenization	Nanofibrillated Cellulose	375.2 – 454.9	10.9 – 22.6
Silvério *et al.* (2013) [9]	Alkali and bleaching treatment, blending, acid hydrolysis and sonication	Nanocrystalline Cellulose	166.6 – 255	3.07 – 5.23
Rosa *et al.* (2010) [25]	Alkali and bleaching treatment, acid hydrolysis	Nanocrystalline Cellulose	58 – 515	4 – 8.3
Li *et al.* (2009) [7]	Alkali and bleaching treatment, acid hydrolysis and sonication	Nanocrystalline Cellulose	400 – 500	20 – 40

4.0 CONCLUSION

An overview shows the potential of using jatropha waste as raw materials for isolation of nanocellulose based on cellulose percentage that is above than 50% which will require less concentration of chemical reagent. The type of nanocellulose produce depends on the method used, whereby a combination method of chemical and mechanical will result with shorter nanocellulose in term of length and diameter.

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