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Production and characterization of cellulose nanoparticles from nopal waste by means of high impact milling

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Abstract

Apart from its dietary use, *Opuntia ficus-indica* (OFI), also known as nopal, is widely used in diverse non-food areas given its multiple properties and health benefits. In Mexico City, each year de-thorning process of nopal generates around 40,000 tons of waste. This waste contains a huge amount of hemicellulose and cellulose that can be used as a new biodegradable nanocomposite. Therefore, the aim of this work was to purify nopal thorns to obtain cellulose nanoparticles by high impact milling or high-energy ball milling. Confocal laser scanning microscopy (CLSM) showed that thorns have two main polysaccharides arranged in parallel fibers: cellulose and lignin. Size of the obtained cellulose nanoparticles were ranged from 24 to 122 nm. Crystallinity, as well as the type of cellulose obtained, were analyzed by means of XRD to evaluate its potential use as nanocomposite.

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Keywords: nanoparticles, mechanical milling, nopal wastes, cellulose.

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1. Introduction

Food wastes have been considered an important issue due to the environmental problems that they generate. Nowadays, the search of environment-friendly sources, as well as the use of non-timber agro-industrial wastes, for obtaining lignocellulosic materials, can be considered as potential alternatives to obtain cellulose without affecting forests (Sharma and Varma 2014).

Cactus (*Opuntia ficus-indica*: OFI) is an endemic cactaceae from America that develops in arid and semiarid lands (Habibi et al., 2008). Plant structure is formed by modified flattened stems known as cladodes. Cladodes are covered with thorns and multicellular hairs called trichomes that form the cactaceae characteristic areole (Vignon, et al., 2004). OFI thorns can have different sizes, while cladodes usually present different green tones and sometimes reddish or purple tones (Guevara, et al., 2010).

Young OFI cladode (nopal) is consumed as a vegetable at different stages of maturation (30 to 110 days) and has proved to be an important food with bioactive properties in both human and animal diets. Given its multiple properties, and its use as a cosmetic or as a medicinal plant, nopal has been widely studied (Ammar, et al., 2015). On the other hand, while is true that OFI has a high fiber content, that can be considered as an ecological source of cellulose, presence of lignin and hemicellulose microfibrils arrangements can reduce accessibility to cellulose microfibrils, making difficult the purification of cellulose.

Therefore, delignification method is a critical step to successfully separate cellulose from other components. Nevertheless, variations on contents and types of lignin and hemicellulose affect separation performance, obtaining costs, and purity of the resulting cellulose (Sharma and Varma 2014). On the other hand, cellulose nanoparticles (CNP) have generated scientific interest given their availability, low cost, high biodegradability, high strength, among other characteristics.

However, dimensions of CNP depend on several factors that include the source from where the cellulose was obtained and the precise preparation conditions (Hubbe et al., 2008). Currently, organic nanoparticles are being synthesized due to its importance in diverse areas such as in food and pharmaceutical industries, in packaging technologies, as components of paints, etc. (Cruz-Estrada et al., 2005; Kallioranta, 2012).

Furthermore, cellulose nanofibers are being used as reinforcement material in electronic devices, medicines, and many other products, given their functionality, easy synthesis, properties, biodegradability, and biocompatibility. However, the use of spherical CNP has not widely been applied in the industry at present (Qing et al., 2012). Hence, the aim of this work was to obtain CNP from nopal thorns that could be used as reinforcement material in diverse industries.

Nomenclature

CNP	Cellulose nanoparticles
CR	Cellulose reference
OFI	*Opuntia ficus-indica cactus*
I_{AM}	Amorphous region
I_{200}	Crystalline region

2. Materials and procedures

2.1 Plant material

OFI thorns were removed from nopal wastes from a recollection center located in Milpa Alta, Mexico City. Removed thorns were dried at 35 °C and sieved (Siave Shaker RX-86 US) to eliminate any trace of cladodes.