



## Extraction, characterization, and catalytic potential of amorphous silica from corn cobs by sol-gel method



Palanivel Velmurugan<sup>a</sup>, Jaehong Shim<sup>b</sup>, Kui-Jae Lee<sup>a</sup>, Min Cho<sup>a</sup>, Sung-Sik Lim<sup>c</sup>, Sang-Ki Seo<sup>c</sup>, Kwang-Min Cho<sup>d</sup>, Keuk-Soo Bang<sup>e,\*</sup>, Byung-Taek Oh<sup>a,\*\*</sup>

<sup>a</sup> Division of Biotechnology, Advanced Institute of Environment and Bioscience, College of Environmental and Bioresource Sciences, Chonbuk National University, Iksan, Jeonbuk, 570-752, South Korea

<sup>b</sup> School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE, 68583-0817, USA

<sup>c</sup> Korea Rural Community Corp., Geurin-ro 20, Naju-si, Jeollanam-do, 520-350, South Korea

<sup>d</sup> National Institute of Crop Science, RDA, Iksan, 570-080, South Korea

<sup>e</sup> Department of Oriental Medicine Resources, Advanced Institute of Environment and Bioscience, College of Environmental and Bioresource Sciences, Chonbuk National University, Iksan, Jeonbuk, 570-752, South Korea

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### ABSTRACT

A simple method based on alkaline extraction followed by acid precipitation can be used to form silica aquagel from corn cob ash (CCA). SEM-EDS analysis confirmed the high silicon and oxygen content of the extracted silica. XRD diffraction indicated that the obtained product was amorphous silica, while FTIR data demonstrated the presence of siloxane and silanol groups. TEM images revealed the silica to be amorphous, and have an agglomeration form with an average diameter of ~50 nm. CCA-extracted silica (0.1 g/20 ml) was observed to have good catalytic potential with 100% removal of  $12 \times 10^{-4}$  M methylene blue.

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### Introduction

Silica occupies an increasingly prominent place in scientific research, primarily because of its easy preparation and wide applications in various industries, such as catalysis, pigments, pharmacy, electronics, ceramics, polymer materials, thin film substrates, thermal insulators, and humidity sensors [1–5]. Silica has been prepared using different techniques with different materials, including vapor-phase reaction [6], sol-gel [7] and thermal decomposition techniques [8]. By smelting quartz sand with sodium carbonate at 1300 °C, the precursor for silica and sodium silicate can be produced [9]. However, these production types are not cost effective and limit the wide application of silica produced in these manners. Alternatively, natural silica can be obtained from corn cob ash (CCA), and other types of agricultural waste whose major constituents are organic materials and hydrated silicon [9]. Rafiee and Shahebrahimi, [10], reported that

silicon atoms in agricultural waste rice husks are naturally and uniformly dispersed by molecular units, have a very fine particle size and very high purity and surface area; these can be used to produce silica powder under controlled conditions.

Corn cobs are a form of agricultural waste obtained from maize/corn, the most important cereal crop in various parts of the world. CCA contains >60% silica by mass with small amounts of metallic elements [5,11], and could be an economically viable raw material for the production of silicates, silica and silica nanoparticles. CCA is obtained as fine powder after combustion, and hence does not require further grinding; it is the most economical source of silica.

There have been several reports on the extraction of silica from rice husks using various techniques [4,12–15]. However, although corn cobs have been studied in various fields such as for the production/preparation of enzymes, proteins [16], fuel [17], absorbent [18], and cement [11], there has been little focus on CCA for the production of silica and its applications. To address this, we focused on the extraction of silica from agricultural waste CCA in an environmentally-friendly manner which could reduce the disposal of large quantities of materials that would otherwise pollute land, water, and air. In this way, pollution can be reduced and these wastes have additional value and use as secondary

\* Corresponding author. Tel.: +82 638500838; fax: +82 638500834.

\*\* Corresponding author. Tel.: +82 638500742; fax: +82638500741.

E-mail addresses: [ksbang@jbnu.ac.kr](mailto:ksbang@jbnu.ac.kr) (K.-S. Bang), [bttoh@jbnu.ac.kr](mailto:bttoh@jbnu.ac.kr) (B.-T. Oh).

resource materials. In CCA, 50–60% of the inorganic constituents are silica, and utilization of CCA as a source of silica requires the removal of impurities [19]. In addition, we characterized the extracted silica using various techniques and investigated the comparative catalytic efficiency of extracted and commercial silica using cationic dye methylene blue with various parameters. Methylene blue is a thiazine dye used in many industrial applications such as aquaculture, anti-malarial drugs, chemotherapeutics, and medicine [16]. Earlier, methylene blue has been removed by silica nano-sheets derived from vermiculite via acid leaching [20].

## Materials and methods

### Corn cob ash preparation

Corn cobs were obtained from a local agricultural field (Iksan, Jeonbuk, South Korea) during the process of removing kernels and were washed thoroughly with distilled water to remove adhering dust. These corn cobs were dried under sun light until crispy and combustion was carried out at 650 °C for 3 h at a heating rate of

10 °C/min in a muffle furnace (AJEON Heating Industrial Co., LTD, Gyeonggi-do, South Korea), and left overnight to cool in the furnace [21].

### Extraction of silica

Silica was extracted according to the method described earlier by Okoronkwo et al. [21] and Kalapathy et al. [22], with minor modifications; 250 ml of 1 N NaOH (Daejung Chemicals, South Korea) was added to 50 g of CCA and boiled in covered 500-ml Erlenmeyer flask for 1 h with constant stirring to dissolve the silica and produce a sodium silicate solution. Then the solutions were filtered through Whatman No. 41 ashless filter paper, and the residues washed with boiled in reverse osmosis (RO) in Milli-Q Ultrapure water system (conductivity = 18  $\mu\Omega$ /m, TOC < 3 ppb, Barnstead, Waltham, MA, USA). The filtrate was allowed to cool to room temperature and the solution pH was reduced to 7.0 with 3 N HCl (Daejung Chemicals, South Korea) and constant stirring; it was then and incubated to support gel formation. After sol-gel transition, it was allowed to age up to 18 h. Subsequently, the aged soft gel was subject to gentle breaking, dispersed in Milli-Q

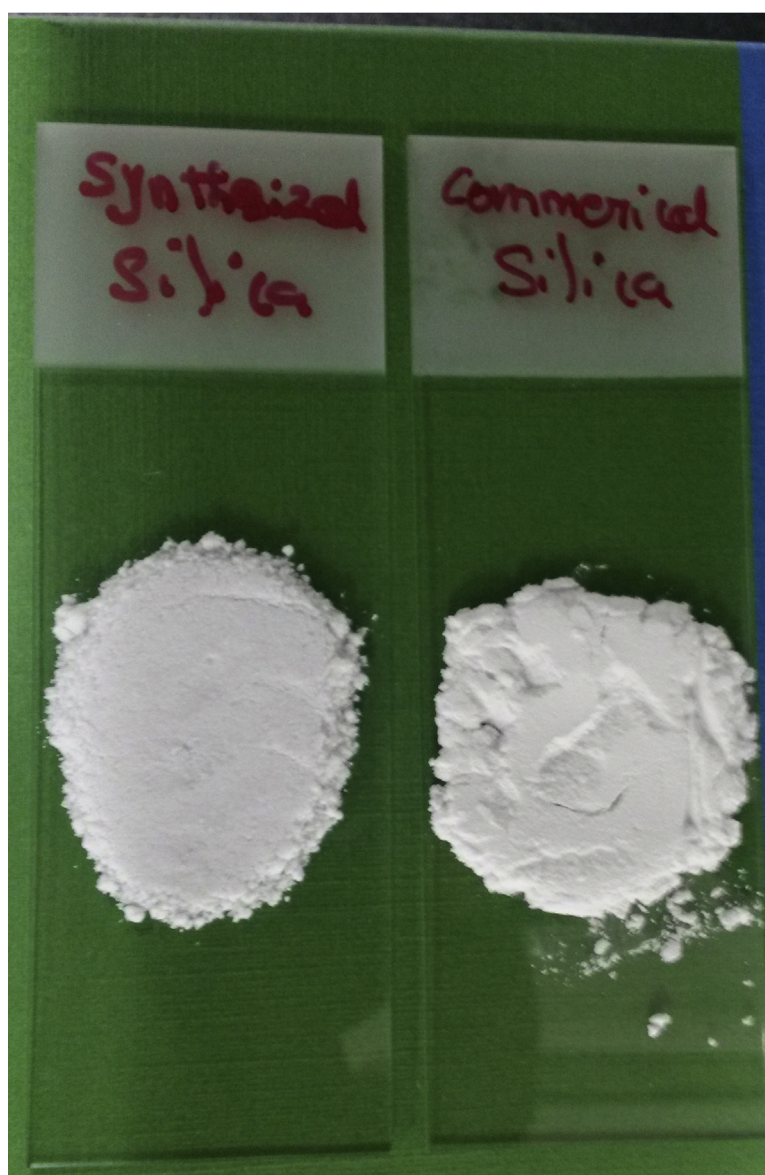


Fig. 1. Extracted silica and commercial silica.

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