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ORIGINAL PAPER

# Maximizing the yield of water-soluble cellouronic acid sodium salt with high carboxyl content by 4-acetamide-TEMPO mediated oxidation of parenchyma cellulose from bagasse pith

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**Abstract** Parenchyma cellulose, isolated from bagasse pith BP, was utilized as an alternative resource for preparation of soluble cellouronic acid sodium salt (SCA) by selective oxidation with the catalytic amounts of 4-acetamide-TEMPO and NaClO, in which $NaClO_2$ was used as a primary oxidant in an aqueous condition. The yield and carboxyl content of SCA were measured as a function of $NaClO_2$ content, 4-acetamide-TEMPO loading, oxidation temperature, initial pH, and reaction time, and optimized by an orthogonal test with the objective of achieving a maximum yield with high carboxyl content. An optimal SCA yield of 71.0 % with 32.92 % carboxyl content was found under the conditions of $NaClO_2$ dosage of 16 mmol/g, 4-acetamide-TEMPO loading of 0.20 mmol/g, and oxidation temperature of 50 °C in acetate buffer at pH 5.5 for 72 h. The structure and morphology of both parenchyma cellulose and its oxidized product were further characterized by means of Fourier transform infrared spectroscopy (FTIR), X-ray photoelectronic spectroscopy (XPS), X-ray diffraction (XRD), and scanning electron microscopy (SEM). These techniques confirmed that parenchyma cellulose from bagasse pith was successively modified by an effective TEMPO-derivative-catalyzed oxidation process. The finding of this study might provide guidance in maximizing the yield of SCA from parenchyma cells utilizing the 4-acetamide-TEMPO/NaClO/$NaClO_2$ system. Considering the simple preparation process and favorable SCA property, this BP parenchyma cellulose showed unique characteristics with a great promise for high-valued modification and application in the areas of advanced and functional materials.

**Keywords** Bagasse pith · Parenchyma cellulose · 4-Acetamide-TEMPO · Cellouronic acid sodium salt · Yield

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## Introduction

With the growing awareness on increasing exhaustion of non-renewable resources, e.g., petroleum and coal, natural polymers have been widely studied for the use of biosynthesized, biocompatible, and biodegradable materials. In this regard, cellulose, one of the most important biopolymers, has acquired enormous significance as a rich biopolymer and feedstock due to its polyhydric alcohol structure suitable for chemical derivatization [1]. Commonly, cellulose utilized for modifications is extracted only from fibrous materials, such as wood [2–4], bamboo [5], kenaf or sisal fibers [6, 7], date palm leaves [8], cotton [9, 10], rice and wheat straws [11–13], but not yet from non-fibrous sources. Due to difficulty in availability of parenchyma cells, the bagasse pith (BP), an agricultural residue of depithing bagasse, is usually used as the complementary boiler fuel in cane mill as well as the bagasse pulp mill. Actually, the high productivity of BP of annually 60 million tons should be exploited as an alternative natural resource. With more than 75 % of holocellulose contained in BP [14], its application is considered more valuable than the simple burning. Compared with fibrous cellulose of timber and other annual plants, parenchyma cellulose has translucently lamellar morphology [14] and looser supermolecular structure [15], presumably directing its inherent reactive properties for further chemical modification.