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A novel combined pretreatment of ball milling and microwave irradiation for enhancing enzymatic hydrolysis of microcrystalline cellulose

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HIGHLIGHTS

▶ Bioconversion potential on MCC was evaluated with a new pretreatment method.
▶ An equation correlating glucose yield with CrI, SSA and DP was deduced.
▶ The rate of enzymatic hydrolysis was much more sensitive to CrI than SSA and DP.
▶ Combination of BM and short time MWI is a feasible approach to treat biomass.

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ABSTRACT

Microcrystalline cellulose (MCC) was performed as a mode substrate to investigate its potential ability of bioconversion in a novel combined pretreatment of ball milling (BM) and/or microwave irradiation (MWI). The variation of structure characteristics of MCC before/after pretreatment were investigated, including crystallinity index (CrI), size of crystal (S_C), specific surface area (SSA) and degree of polymerization (DP). Their correlation with the rate of enzymatic hydrolysis was differentiated by an optimized equation which indicated the rate of hydrolysis was much more sensitive to CrI than SSA and DP. To achieve the same or higher glucose yield of BM for 3 h and 6 h, BM for 1 h with MWI for 20 min could save 54.8% and 77.40% energy consumption, respectively. Moreover, chemicals were not required in this process. It is concluded that the combination of BM and short time MWI is an environment-friendly, economical and effective approach to treat biomass.

1. Introduction

Excessive consumption of fossil fuels has resulted in emission of high levels of pollutants such as greenhouse gases during the last few decades. Biomass such as rice straw, sugarcane bagasse and corn straw are attractive feedstock for the production of alternative fuels and chemicals, which are used to being refined from petroleum (Sarkar et al., 2012). But due to the complex structure of biomass, the unit operations of the biorefinery are expensive, low-effective and cause environment pollution, which limit the development of biomass energy. Pretreatment unit is one of the most expensive units (Laser et al., 2002), which arouse the concerns of researchers. At the same time, many pretreatment technologies have already been developed, such as steam explosion, ammonia fiber explosion (AFEX), liquid hot water treatment, biological treatment, ball milling, microwave irradiation (MWI), ionic liquid treatment, etc. However, these technologies suffer

Abbreviations: B, full width half maximum (FWHM) of the reflection measured in 2θ corresponding to Bragg angle; BM, BM1, BM3, BM6, ball milling, ball milling for 1 h, 3 h and 6 h, respectively; BMMWI, ball milling followed by microwave irradiation; BM1MWI, ball milling for 1 h followed by microwave irradiation; C_G, concentration of glucose, g/L; CrI, crystallinity index; DP, degree of polymerization; G_{MC}, glucosyl monomer concentration, μg/mL; G_Y, glucose yield of the theoretical, %; G_{6Y}, glucose yield of the theoretical after 6 h, %; I_{002}, maximum intensity above base line at $2\theta = 22°$; I_{Amorph}, minimum intensity above base line corresponding to amorphous content at $2\theta = 18°$; k, Scherrer constant (0.84); MWI, microwave irradiation; M_{PS}, mass of solid fraction after pretreatment, g; M_R, mass of raw feedstock, g; M_P, mass of pretreated MCC, g; R_{EC}, reducing-end concentration, μg/mL; R_S, solid recovery after pretreatment, %; S_C, average size of crystal; V_E, volume of the enzymatic reaction mixture, L; λ, X-ray wavelength, 1.54 Å; ϑ, diffraction angle, °.

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