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Fractionation of cellulose fibers by lytic polysaccharide monooxygenase (LPMO) enzymes for cellulose nanofibril production

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PURPOSE OF THE ABSTRACT

Cellulose is one of the main sources of renewable carbon available to face tomorrow?s environmental concerns. During the two last decades, research efforts have focused on a new class of cellulose-derived products: the nanocelluloses. Nanocelluloses are produced from cellulosic fibres and comprise cellulose nanocrystals and semi-crystalline cellulose nanofibrils, termed nano-fibrillated cellulose (NFC). Both have a great potential in a variety of industrial applications, such as papers and boards, coatings, barriers, food, cosmetics, pharmaceuticals, health and electronics leading to intense research and patenting activity. Preparation of NFC consists in a mechanical delamination of cellulosic fibres that requires high energy, limiting industrial production of NFC. In order to face this challenge, innovative pre-treatments of the fibres are still required to meet cost-effective, environmentally friendly and sustainable production of NFC.

Lytic polysaccharides monooxygenase (LPMO) enzymes are recently discovered fungal enzymes possessing a type II copper active center coordinated by a histidine brace. Their interest arises from their observed boosting effect on the enzymatic polysaccharide degradation. LPMOs are classified into the auxiliary activity (AA) family from the CAZy database; and they have demonstrated to disrupt cellulose by an oxidative cleavage, which could be an entry point for further degradation or hydrolysis.(1 ,2)

In this work, kraft pulp fibers were treated with LPMO followed by a soft mechanical treatment applied to the fibers. LPMO-treated fibers showed intense defibrillation whereas control samples remained intact.(3,4) Optical microscopy showed cellulose defibrillation occurs even at low enzyme/substrate ratios (1:500). Cellulose structure modifications were investigated by several techniques including molar mass determination by SEC, AFM and TEM. Fibers and high degree of defibrillation was observed down to nanoscale while the chains cleavages remain limited. Solid state 13CNMR results demonstrate that LPMO creates nicking points that trigger the disintegration of the cellulose fibrillar structure with the rupture of chains and the release of elementary nanofibrils. Investigation of LPMO action using solid-state NMR provides direct evidence of modification of accessible and inaccessible surfaces surrounding the crystalline core of the fibrils. The chains breakage likely induces modifications of the cellulose network and weakens fibers cohesion promoting their disruption. Therefore, LPMOs can be viewed as promising candidates for enzymatic modification or degradation of cellulose fibers including the preparation of nanocelluloses.

FIGURES

FIGURE 1

FIGURE 2

KEYWORDS
Nanocellulose | LPMO

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