XXI SIMPÓSIO NACIONAL DE BIOPROCESSOS
XII SIMPÓSIO DE HIDRÓLISE ENZIMÁTICA DE BIOMASSA

3 a 6 de setembro de 2017
Aracaju, Sergipe, Brasil

Extraction of hemicellulose as prebiotic xylo-oligosaccharide in the process of obtaining nanocellulose from sugarcane bagasse

Wilian F. Marcondes, Valdeir Arantes

Biochemical and Biorenewable Producs Laboratory,

Escola de Engenharia de Lorena - Universidade de São Paulo (EEL-USP)

E-mail: wilian.fm@usp.br; valdeir.arantes@usp.br

ABSTRACT

To apply the concept of biorefinery to the process of nanocellulose production from sugarcane bagasse, this work aims to extract *the hemicellulosic fraction of the bagasse as xylo-oligosaccharides (XOS) with prebiotic properties, a high-value product. With the aid of an experimental statistical design, process conditions for the selective solubilization of hemicellulose as XOS was studied by assessing the effect of temperature, time and acid concentration. The best condition to produce XOS with high yield and selectivity was 190 ° C for 5.5 minutes and no acid addition. No correlation was found between process conditions and XOS properties like acetylation, and important parameter for XOS as prebiotic. In conclusion, it was possible to tailor the hemicellulose extraction step in the sugarcane bagasse-to-nanocellulose process to selectively produce high levels of XOS.*

1. INTRODUCTION

Production of nanocelluloses from lignocellulosic materials (LCM) occurs by isolation of nanoparticles from a cellulosic pulp. This pulp is obtaining through a series of treatments to remove the hemicellulose and lignin fractions by chemical, enzymatic and/or biological method. In chemical processes, acid and alkaline treatments are applied to solubilize hemicellulose and lignin, respectively (Lee et al. 2014). Since xylan is the main hemicellulose sugarcane bagasse (SCB), the major compounds expected to be released in the liquid fraction following a treatment in acid medium are xylose, xylo-oligosaccharides (XOS) and some degradation products as furfural (Diedericks et al. 2013). XOS is characterized as nondigestible soluble fiber with prebiotic activities. It promotes health benefits to the consumers by regulating the microbiota, serving as substrate for specific groups of beneficial bacteria, such as *bifidobacterium*, in the colon (FAO 2015). While the most commercialized prebiotics are fructo-oligosaccharides (FOS) and galacto-oligosaccharides (GOS), XOS has been gaining prominence in the prebiotic market because it presents unique characteristics such as greater specificity for certain *bifidobacteria* (Mäkeläinen et al. 2010).

To apply a biorefinery concept to the sugarcane bagasse-to-nanocellulose, this work on the valorization of the hemicellulosic fraction aims to produce prebiotic XOS through the treatment step in an acid medium in the process of obtaining a cellulosic pulp from sugarcane bagasse.

2. Methodology

A full factorial experimental design with star rotation and three replicantion at center points was employed to study the effect of the variables time (15-45 minutes), temperature (150-190 ºC) and acid concentration (H_2SO_4 0-1% w/w) shown in Table 1, on the selective solubilization of hemicellulose of sugarcane bagasse in the XOS form. The reactions were carried out in Parr 2L reactor, with a reaction volume of 0.5 L and at solid content of 10% (w/w). The chemical characterization of bagasse and the solid and liquid fraction after the reaction was performed according to Sluiter (Sluiter et al. 2008). Statistical analysis was done with Statistica (version 13). The combined severity factor (CSF) for the different reaction conditions was calculated according to equation 1 (Schell & et.al. 2003).

Table 1: Experimental condition of hydrolysis pretreatment

Condition	**- α**	**-1**	**0**	**+ 1**	**+ α**
Temperature (ºC)	138	150	170	190	200
Time (min.)	5.5	15	30	45	55
[H_2SO_4] (% w/w)	0	0	0.5	1	1.32

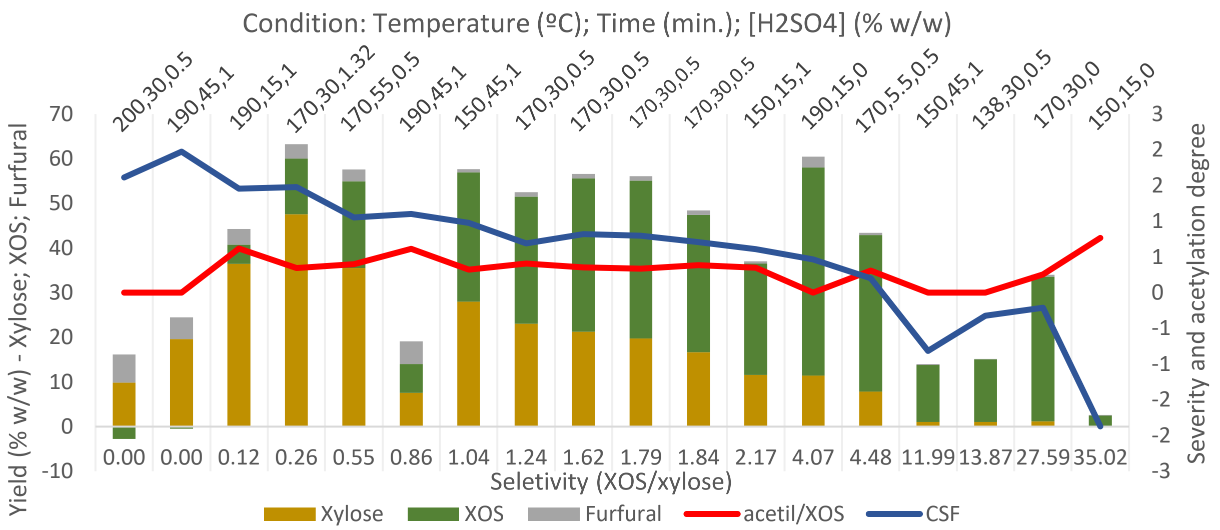
Equation 1: Combined severity factor (CSF)

$$CSF = Log_{10}\left(t.e^{\left[\frac{T-100}{14,75}\right]}\right) - pH$$

3. Results and discussion

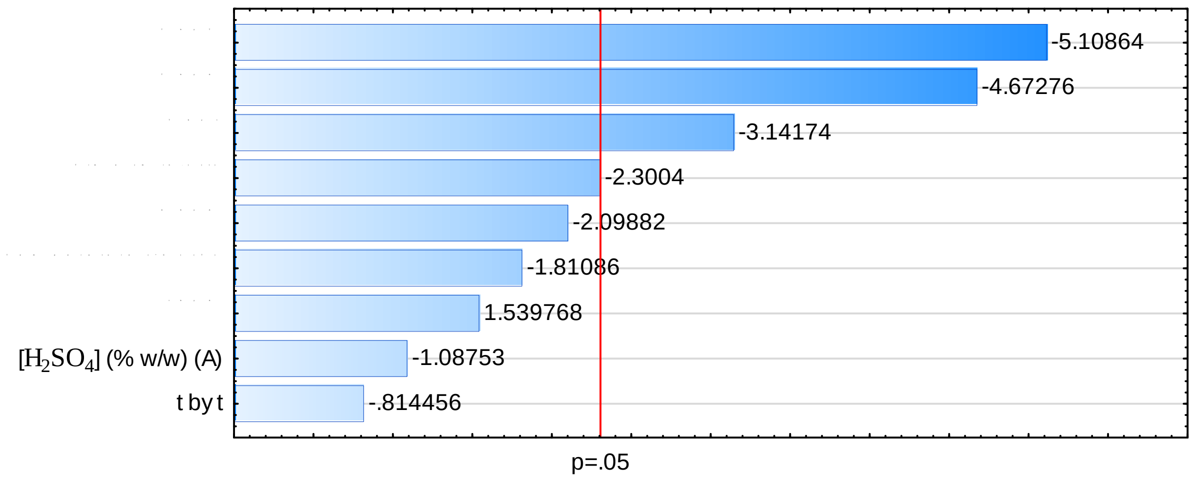
The severity of the process and its selectivity towards XOS formation in relation to xylose (XOS/xylose) are related. Less severe process conditions provide a greater recovery of XOS and less release of xylose and formation of degradation products, as furfural, (Figure 1). These results reinforce the theory that the hydrolysis of hemicellulose pass through the stage of liberation of its as presented in other works (Garrote et al. 1999; Vallejos et al. 2015).

Figure 1: Yield from xylan hydrolysis's products after acid pretreatment, with severity factor and selectivity XOS/Xylose.



The degree of acetylation (DA) is an important characteristic for prebiotic use and different substituent groups and degree of substitution affect the prebiotic propriety of oligosaccharides (Vallejos et al. 2015). These experiments show that there is a modal value for DA of 0,35 and that high severity result in less DA. The degree of polymerization (DP) is so important than DA and will be determinate to relate with prebiotic activity.

Figure 2: Pareto Chart of Standardized Effects; R-sqr=.9025



At statistical analysis, temperature shows be a main factor combined that influence the XOS recover (Figure 2). The best condition for XOS recovery was 190 ºC, 5.5 minutes and no acid addition. Further experiments will be carried out to optimize for prebiotic activity. The results from these experiments, currently under statistical analysis will help to determinate which is the best condition to obtain a XOS recovery with high prebiotic property, as a high value product from bagasse hemicellulose.

4.Conclusion

It was possible to simulate the variation of the process conditions to maximize the solubilization of the hemicellulose in its oligomeric form. By varying the process conditions, it was also possible to obtain XOS with different structural characteristics, like degree of acetylation and possible polymerization, which is related to the XOS's prebiotic activity.

5. REFERENCES

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