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Evaluation of cellulose content in hemp shives after salt catalyzed hydrolysis

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Abstract

In recent years, substantial steps into the transition toward a bio-based economy have been taken. Therefore, biomass, due to its physical and chemical properties, has become one of the key sources to produce bio-based value products. From the current point of view, cellulose is the most common organic biopolymer and is considered as a source of the raw material for environmentally friendly and biocompatible products. The aim of this study was to analyze the effect of hydrolysis time (30–70 min) and temperature (160–180 ºC) at different amounts of aluminum sulfate octadecahydrate as catalyst (0 %, 5 %and 7 % of the oven-dried material) on the content of cellulose in the hemp shives leftover after furfural production. The results have shown that it is possible to save up to 83 % of initial cellulose in the hemp shives leftover if the produced yield of furfural is similar to the industrial scale production yield, which is 55 % from the theoretically possible one. The highest loss of cellulose in hemp shives was observed after hydrolysis at 180 ºC, 7 % catalyst of the oven-dried mass and 70 min, whereas a smaller loss of cellulose was observed under autohydrolysis conditions. Thus, the study identifies important structural features of the lignocellulosic leftover and relevant hydrolysis parameters related to the commercialization of lignocellulosic biorefineries.

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Keywords: lignocellulose; salt catalyst; hydrolysis; cellulose; furfural; hemp; shives

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1. Introduction

The development of industrial methods for production of bio-based products has been gaining attention in recent years [1]. For the production of such products, industrial hemp can be considered as one of the efficient and sustainable renewable resources in the world that has proven itself for several hundred years [2, 3]. Industrial hemp can be grown as a fiber, seed, or dual-purpose crop. Traditionally, it is grown for its long and strong fibers. From the fibers production process, large amount of short woody fibers (up to 75 % of the oven dry stem [4]), called shives or hurds, are formed. These shives are considered as solid waste. Therefore, shives are mainly used as a high-performance bedding material for animals [5]. A new way how shives are used in its native form is in combination with lime for the production of construction materials [6, 7]. Due to the high content of carbohydrates, mostly glucose and xylose (Table 1), hemp shives can be considered as a potential source of bio-based chemicals, such as furfural [8, 9], lactic acid [10], ethanol [11], etc.

Table 1. Chemical composition of hemp shives.

Component	Quantity	References
Extractives	4.1–5.1	[9, 12–14]
Xylose	16.5– 31.2	[9, 12–14]
Arabinose	0.43–2.3	[9, 13, 14]
Mannose	1.4– 8.2	[9, 12–14]
Glucose	32.3– 56.7	[9, 12–14]
Galactose	0.67– 2.9	[9, 13, 14]
Rhamnose	0.25– 2.1	[12, 13]
Lignin	20.7–24.5	[9, 12–14]
Ash	1.2– 4.4	[9, 12]

However, due to the compact and rigid structure of hemp shives as all lignocellulosic materials, the selective release of convertible sugars for platform chemicals has become a bottleneck for industrialization of lignocellulosic biorefinery. Based on the results of our previously published study where furfural was obtained from hemp shives [9], it can be concluded that the lignocellulosic leftover from hydrolysis can be considered as a potential source for other bio-based platform chemicals due to the high content of C6 sugars. It means that this novel hydrolysis technique is a promising stage in the lignocellulosic biorefinery concept. However, there is still a lack of information how hydrolysis time affects the C6 sugars content in the lignocellulosic leftover. In this respect, the present study aimed to analyze the effect of hydrolysis time at different temperatures and amounts of the catalyst on the cellulose content in the hemp shives lignocellulosic leftover. The evaluation of the effect of the same hydrolysis parameters on the yield of furfural was also performed.

2. Materials and methods

2.1. Physical pretreatment

Industrial hemp shives (Bialobrzeskie variety, Poland, code 893), with a cellulose content of 47 % [9], were used as a raw material. To separate the contained fibers and sand, the raw material was fractionated by an MUOTOTERA OY classifier using 5 screens according to the SCAN-CM 40:01 standard.

2.2. Hydrolysis

A 3–12 mm fraction with a moisture content of 12 ± 2 % was hydrolyzed in a bench-scale reactor system described previously [9]. In this study, hemp shives were hydrolyzed 30, 40, 50, 60 and 70 min at three different temperatures (160 ºC, 170 ºC and 180 ºC) and three different amounts of aluminum sulfate octadecahydrate-water solution as a catalyst (0 %, 5 %, and 7 % on the oven dry solid basis). These hydrolysis parameters were chosen with the aim to