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Chemical characterization of the fast-growing industrial hemp (Cannabis sativa) woody core and bast fiber

Soo-Jeong Shin, Bon-Wook Koo, Jae-Won Lee and In-Gyu Choi

산업용 대마의 목부와 인피섬유의 화학 조성 분석

신수정, 구본욱, 이재원, 최인규

Key words : industrial hemp (*Cannabis sativa*), bast fiber, woody core, carbohydrate composition, Klason lignin, extractives

Abstract : 대마에 대한 분석 결과, 인피 섬유의 경우 리그닌 함량은 7.6%로 다른 목질계 바이오매스나 일년생 초본류와 비교하여 매우 낮은 리그닌 함량을 나타냈으며 탄수화물 함량은 65.4%로 목질계 바이오매스와 유사하고, 초본류보다는 오히려 높았다. 목부는 리그닌 및 탄수화물 함량이 활엽수와 유사한 경향을 나타내었는데 특히 높은 자일란의 함량이 확인되었다. 또한 회분 함량이 인피섬유와 목부에서 각각 5.0%와 2.3%로 낮은 값을 나타내어 당화 및 발효 공정에 적용될 때 회분에 의한 공정 장애(스케일링 등)의 가능성을 낮추어 줄 것으로 사료되었다. 최종적으로 이러한 화학적 분석을 통해 대체에너지 생산을 위한 자원으로서 대마의 가능성을 확인할 수 있었다.

1. Introduction

With shortage of fossil fuels and the global warming from the carbon dioxide accumulation, interests in renewal energy have been increased significantly. Due to depletion of forest land, new biomass resources are needed for bio-energy production. Industrial hemp is one of the fast-growing energy crops and can be the candidate for bio-energy crop.

Annual biomass production from hemp is 30 tons/ha, which is quite higher than other bioenergy crop candidate (aspen: 13 tons/ha (coleman et. al. 2006), willow: 16-18tons/ha (Börjesson and Berndes 2006), eucalyptus: 10-13 toms/ha (van den Broek et. al. 2001), kenaf: 20.9 tons/ha (Manzanares et. al. 1997)).

For chemical characterization, industrial hemp was separated as the bast fiber and the woody core, and analyzed the chemical composition of each fraction as ethanol-benzene soluble extractives, hot-water soluble extracts, and lignin. We also investigated the polysaccharide and oligosaccharide composition of bast fiber and woody core. In this study, we evaluated the industrial hemp as bioenergy crop candidates.

2. Materials and methods

2.1 Material

Industrial hemp was provided by the Dangjin Agricultural Technology Center, Chungnam province, Korea. Industrial hemp was planted late June, 2005 and harvested mid November, 2005 for hemp seed production. We collected the hemp biomass, which was remained in field as agricultural residue. The hemp biomass were separated to bast fiber and the woody core fraction by manually, and grounded each fraction to pass through 40 mesh screen by the Wiley mill.

2.2 Chemical characterization

The bast fiber and the woody core were extracted by

* Dept. of Forest Sciences, College of Agriculture and Life Sciences, Seoul National University
E-mail : cingyu@snu.ac.kr
Tel : (02)880-4785 Fax : (02)873-2318
1) Dept. of Forest Sciences, College of Agriculture and Life Sciences, Seoul National University
E-mail : soojeongesf@hotmail.com
Tel : (02)880-4795 Fax : (02)873-2318

ethanol-benzene and hot-water extraction sequentially.

Extractives-free biomass was analyzed for the lignin content and the carbohydrate composition. Hot-water solubles were freeze-dried for further analysis. All the analytical procedures were followed as described in Tappi Standard. The carbohydrate composition was analyzed by Dionex High-pH Anion Exchange Chromatography (HP-AEC) with Carbopac PA10 (4 X 250cm) column. Oligosaccharides or monosaccharides in hot water-soluble extracts were hydrolyzed to monosaccharides with 3% sulfuric acid at 120 ℃ for 1 h and further analyzed for the carbohydrate composition by HP-AEC.

3. Results and Discussion

There are two different kinds of the hemp cultivation depending on the target material. The one is for the bast fiber production for the textile, which is planted on April and harvested on mid June before ligninfication of the bast fiber for flexible fiber production. The other is for the hemp seed production, which is planted on July and harvested on October. In this study, we used the hemp biomass for the seed production and the woody core was fully lignified during the seed formation. In the hemp biomass, the bast fiber were 11.7% and the remaining 88.3% were the woody core. The bast fiber content was quite lower than other reports. van der Werf et. al.(1994) reported the bast fiber fraction as 30-35% based on September harvested. Sankari(2000) reported the hemp yield as 5.9 ton/ha for the woody core and 1.3 ton/ha for the bast fiber, which can be converted as 18.1% bast fiber in the hemp biomass.

In hemp, extractives contents were higher in the bast fiber than in the woody core for both ethanol-benzene extraction and hot-water extraction (Table 1). In the bast fiber, hot-water soluble extractives contents were unusually high as 19.5%. We further analyzed this fraction to water-soluble carbohydrate and lower molecular weight phenolic compounds.

In the bast fiber, Klason lignin content was quite low as 7.6% than other lignocellulosic biomass. Klason lignin content in the perennial wood biomass was 25-30% in the softwood and 16-25% in the hardwood. Klason lignin content in the woody core was similar to the trembling aspen as 16.8%.

Table. 1. Chemical composition of the bast fiber and the woody core in hemp (%)

	EtOH solubles	Hot water solubles	Lignin	Carbohydrate	Ash
Bast fiber (Hemp)	2.5	19.5	7.6	65.4	5.0
Woody Core(Hemp)	2.0	8.9	16.8	70.0	2.3
Oak (Hardwood)*1	2.7	4.8	20.8	71.3	0.4
Poplar (Hardwood)*1	1.1	3.4	21.7	73.3	0.5
Pine (Softwood)*2	4.1	3.2	29.0	63.3	0.4

*1: Lee et. al. (1990), *2: Lee et. al. (1989)

The chemical composition data of the hemp and other herbaceous are summarized in Table 2.

Table.2. Percent dry weight composition of herbaceous species (%)

	Glu.	Xyl.	Gal.	Ara.	Man.	Lig.	Ex.	Ash
B.F. (Hemp)	49.4	7.3	3.3	2.6	2.9	7.6	21.9	5.0
W.C. (Hemp)	43.5	24.6	1.5	0.4	T	16.8	10.9	2.3
Corn stover*	36.4	18.0	1.0	3.0	0.6	16.6	7.3	9.7
Bagasse*	40.2	21.1	0.5	1.9	0.3	25.2	4.4	4.0
Wheat straw*	38.2	21.2	0.7	2.5	0.3	23.4	13.0	10.3
Rice straw*	34.2	24.5				11.9	17.9	16.1
Switch-grass*	31.0	20.4	0.9	2.8	0.3	17.6	17.0	5.8

*Glu: Glucan; Xyl: Xylan; Gal: Galactan; Ara: Arabinan; Man: Mannan; Lig: Lignin Ex: Extractives; B.F.:Bast fiber W.C.: Woody core

*From Wiselogel et al. 1996

Carbohydrate composition in the bast fiber and the woody core was analyzed by HPAEC with acid hydrolyzates. Main carbohydrate monomeric components were the glucose and the xylose but the xylose content was 3 times higher in the woody core than the bast fiber (Table 3). The arabinose, galactose and mannose contents were 2.6 ~ 3.3% in the bast fiber but quite low or not detected in the woody core. In agricultural residues, the mannose was not detected or very low content (Chandrakant and Bisaria 1998).

Table 3. Monomeric composition of polysaccharides in the hemp bast fiber and the woody core (%)

	Total	Ara.	Gal.	Glu.	Xyl.	Man.
Bast fiber (Hemp)	65.4	2.6	3.3	49.4	7.3	2.9
Woody Core (Hemp)	70.0	0.4	1.5	43.5	24.6	T
Oak (Hardwood)*1	73.8	0.7	T	51.9	18.6	2.8
Poplar (Hardwood)*1	71.7	1.9	0.9	46.3	21.4	1.2
Pine (Hardwood)*2	63.7	3.0	T	40.5	9.8	10.4

*Glu: Glucose; Xyl: Xylose; Gal: Galactose; Ara: Arabinose; Man: Mannose; T: trace

*1: Lee et. al. (1990),*2: Lee et. al. (1989)

We also investigated monosaccharides composition in the oligosaccharides or monosaccharides dissolved in hot water-soluble fraction. Carbohydrate content in hot water-soluble extracts was 25.0% in the bast fiber and 23.3% in the woody core. The glucose was main monosaccharide, and the arabinose and the galactose were detected less than 1%. The xylose and the mannose were not detected in both samples(Table. 4). Based on these results, we estimated the hot water-soluble extracts as arabinogalactan for the arabinose and the galactose, and starch for the glucose.

Table 4. Monomeric composition of hot water-soluble oligosaccharides or monosaccharides in the hemp bast fiber and the woody core (%)

	Total	Ara.	Gal.	Glu.	Xyl.	Man.	Non-C.
Bast fiber (Hemp)	19.5	0.5	0.7	3.4	0.0	0.0	14.9
Woody Core (Hemp)	8.9	0.1	0.3	1.7	0.0	0.0	6.8

*Non-C: non-carbohydrate

Based on overall carbohydrate analysis, main component was the glucose as 52.8% in the bast fiber and 45.2% in the woody core. Overall carbohydrate contents were 70.0% for the bast fiber and 72.1% for the woody core, which means about seventy percent of the biomass can be converted to bio-ethanol production.

4. Conclusion

Based on the chemical analysis of industrial hemp, hemp bast fiber had significantly lower lignin content than other woody biomass or annual herbaceous plants, consequently had higher carbohydrate content in hemp bast fiber. In hemp woody core, lignin and carbohydrate content was similar to the other woody biomass or herbaceous plants. Xylan content in hemp woody core was quite higher than other herbaceous plants of softwood biomass, and similar level with hardwood biomass.

Based on this work, industrial hemp has similar carbohydrate content with other woods or herbaceous biomass and lower lignin content than those other biomass. This chemical composition and fast growing property allows using hemp as bioenergy crop for bioethanol production. In addition, lower ash content in industrial hemp than other herbaceous plants also make less problems as scaling in process operation.

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