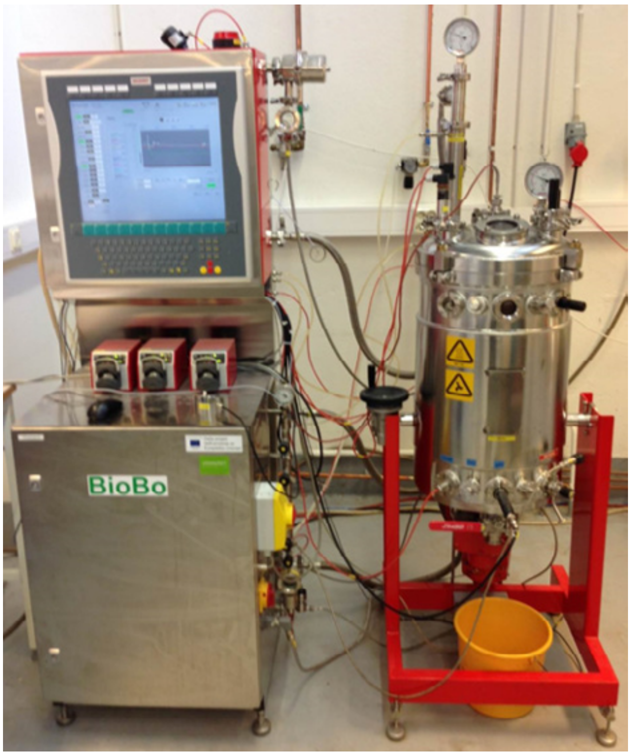
Forest Refine

Pretreatment and Fermentation of Stumps and Small Trees

The objective of the study was the pretreatment, hydrolysis and fermentation of new and/or rarely used assortments from the forest for biorefining purposes, for example for the production of ethanol. The raw materials tested were spruce stumps and small spruce trees collected during culling. Both assortments were analyzed within the Forest Refine project by Metla and SLU and are therefore well defined. The stumps were extracted a year after the clear cutting of the timber and then stored for 6 months above ground prior to its use to degrade parts of the toxic extractive compounds. For the small trees, the average diameter at breast height was 8.7 cm and with an average height of 8.6 m. The material was delimbed (but not debarked) at the forest site and transported to the Biofuel Technology Centre in Umeå immediately after harvesting. The trees were chipped within a month after harvest. In Sweden as well as in Finland, spruce is a common raw material for the forest and biorefinery industries.

Pretreatment in the Biorefinery Demo Plant in Örnsköldsvik, Sweden

Lignocellulose is the most abundant renewable biomass on earth. It is composed mainly of cellulose, hemicellulose and lignin. Both the cellulose and hemicellulose fractions are polymers of sugars and, consequently, a potential source of fermentable sugars. The usability of lignocellulosic material is reduced due to its recalcitrant structure. In a pretreatment step, most of the hemicelluloses are released and the recalcitrant structure of the lignocellulose is opened up to make it accessible for a subsequent hydrolysis step to produce fermentable sugar molecules. There are different methods used for the pretreatment of lignocellulosic material; physical, physicochemical, chemical and biological. In addition to an effective release of cellulose in the pretreatment step, it is important to minimize the formation of degradation products because of their inhibitory effects on subsequent hydrolysis and fermentation processes.



In this study, a physicochemical pretreatment method (steam explosion) was used, where a high temperature (for about 5-10 min) and a low pH (1.8-1.9) transformed the chopped wood into a slurry with high solids content. The slurry was filtered and both the filtrate and the solid retentate were analysed (Table 1).

Table 1. Analysis of the filtrated slurry after pretreatment.

Filtrate	Extractives	Arabinose	Galactose	Glucose	Xylose	Mannose	Furfural	HMF	Formic acid	Acetic acid	Levulinic acid
	g/kg	g/l	g/l	g/l	g/l	g/l	g/l	g/l	g/l	g/l	g/l
Small trees	5,4	2,8	7,8	30,5	9,2	19,5	2,4	4,5	1,9	6,1	2,1
Stumps	5,0	0,7	3,7	22,1	2,5	6,7	2,7	8,5	2,4	5,4	3,6
Solids	**Ash**	**Extractives**	**Lignin**	**Arabinose**	**Galactose**	**Xylose**	**Glucose**	**Mannose**			
	%	%	% TS	g/kg TS	g/kg TS	g/kg TS	g/kg TS	g/kg TS			
Small trees	0,2	13,3	50,2	0,9	2,4	5,1	432,0	7,8			
Stumps	1,1	18,7	58,7	< 0,2	0,5	1,3	363,0	1,7			

Hydrolysis and fermentation at SP Processum AB

The slurry produced in the Biorefinery Demo Plant was subsequently hydrolysed by enzymes and fermented into ethanol with Baker's yeast (Saccharomyces cerevisiae). Initial small-scale hydrolysis and fermentation experiments in shake flasks and the analysis of the slurry showed that the pre-treated material contained compounds toxic to the yeast. To improve growth, the raw material was diluted 1:3 with water, a high yeast inoculum (~5 g/L) was used, and the material was also detoxified with a reducing agent (sodium dithionite). Using these alleviations, the yeast was growing and produced ethanol. In the up-scaled experiment using our 50-L bioreactor, a simultaneous saccharification and fermentation (SSF) experiment was performed on both the small trees and the stumps slurry. The highest ethanol concentration measured during the small trees fraction experiment was 29.5 g/L. The stump slurry was more toxic than that of small trees and a second addition of yeast was needed for growth and consumption of sugar and production of ethanol (12 g/L).

Conclusion

It was possible to pre-treat both the stumps assortment and the small trees fraction in the Biorefinery Demo Plant, Örnsköldsvik, Sweden into liquid slurry. The slurry was relatively easy to hydrolyse for both assortments at decreased suspended solids content (SS = 10-12 %), and 12.5 % SS was also used in the pilot scale SSF experiments. Ethanol production reached almost 3 % for the small trees and 1.2 % for the stumps, which are very good numbers for an initial experiment with new raw material. Toxicity of the material decreases the potential for these assortments to be used in commercial biorefineries, at least without optimization, since a high yeast inoculum and decreased solids content was needed for growth of the cells. Nevertheless, optimisation of the pretreatment, detoxification and design of saccharification and fermentation gives both tree stumps and small trees the potential to be used as raw material for commercial production of bioethanol.

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