Bioconversion of rye straw at elevated temperatures

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Introduction

The bioconversion of biomass to high value products such as fine chemicals and biofuels has recently attracted the interest of scientists from academia and industry. The choice of the most suitable substrate and the process will be crucial for the success of the future biobased industry. Here, we propose a novel process that converts rye straw into bioethanol without the use of chemicals. Liquid hot water treatment at a pressure of 60 bar is used to make the cellulosic material accessible for hydrolytic enzymes that convert poly- and oligosaccharides to various monosaccharides.

Overview

RYE STRAW

↓

LIQUID HOT WATER TREATMENT

LIGNIN

↓

ENZYMATIC HYDROLYSIS OF PRETREATED RYE STRAW (SOLUTE AND RESIDUE)

↓

MONOSACCHARIDES GLUCOSE/XYLOSE

↓

BIOETHANOL

The substrate

In this process, rye straw is converted into the monosaccharides glucose and xylose with the objective of bioethanol production. Moreover rye straw is utilized as sole carbon source for growing thermophilic and mesophilic fungi inducing the production of cellulolytic enzymes (Fig. 1).

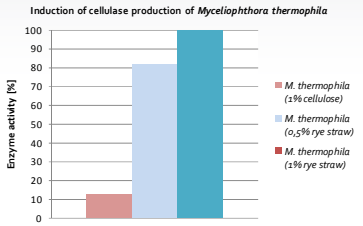


Fig. 1: Cellulase activities in the supernatant of *M. thermophila* are highly induced when growing on rye straw as sole carbon source.

Heat treatment of rye straw

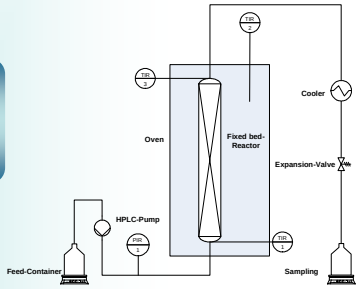


Fig. 2: Schematic illustration of the assembly used for liquid hot water treatment.

Liquid hot water with temperatures up to 220°C liquefies hemicellulose (Fig.2 and Fig. 3) and makes cellulosic material accessible for enzymatic treatment. Treatment above 220°C was not performed to avoid the formation of HMF and furfuraldehyde, which are inhibitory.

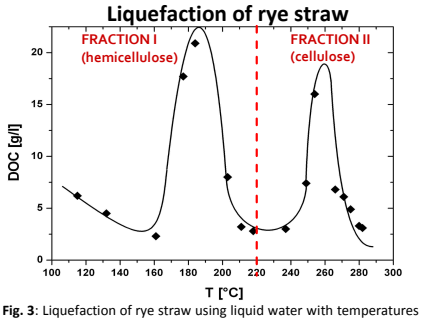
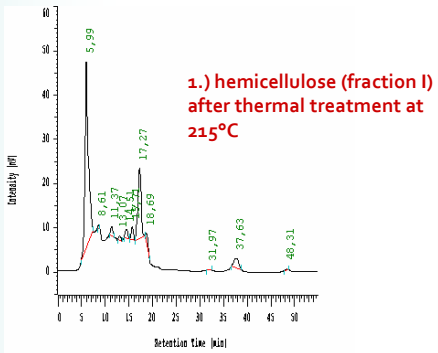


Fig. 3: Liquefaction of rye straw using liquid water with temperatures up to 280°C. Hemicellulose is liquefied at temperatures around 180°C, Cellulose is liquefied at temperatures around 260°C.

Enzymatic treatment of thermal pretreated rye straw

a) Enzymatic hydrolysis of solubilized hemicellulose (fraction I)



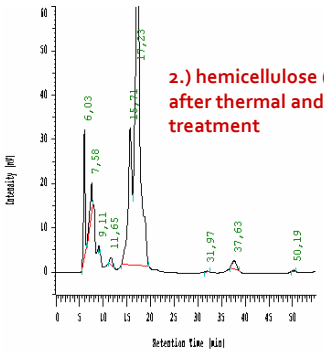


Fig. 4: HPLC analysis of heat treated (I) and enzymatically treated (II) hemicellulose from rye straw.

As shown in Fig 4, the liquefied hemicellulose was converted to

- Xylose (17,23)

→ recovery around 60%

- and Xylobiose (15,71)

(retention time in brackets)

b) Enzymatic hydrolysis of insoluble cellulose (fraction II)

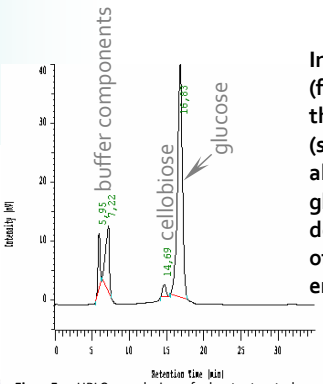


Fig. 5: HPLC analysis of heat treated and enzymatically treated cellulose from rye straw.

Insoluble cellulosic material (fraction II) was treated with thermoactive cellulases from fungi (strains: F1 and F2). Cellulose was almost completely converted to glucose (99%). The recovery depends on thermal pre-treatment of rye straw and the amount of used enzyme complex (Fig. 5 and Fig. 6).

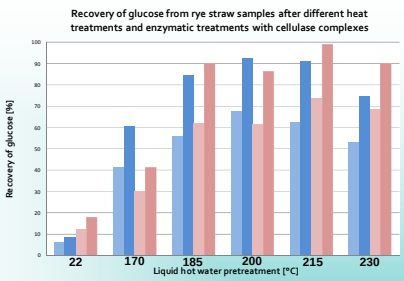


Fig. 6: Recovery of glucose from heat pretreated rye straw samples using cellulase enzyme complexes from different fungi (F1 and F2) at pH 4 and 50°C for 4 and 24 hours.

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