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Damgaard, Henriette Svejstrup; Hansen, Maria Thestrup; Christensen, Knud Villy

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Production of Bioethanol
Henriette Sveistrup Damgaard, Maria Thestrup Hansen and Knud V. Christensen (University of Southern Denmark, Faculty of Engineering, Odense, Denmark)

Abstract
An attempt to develop a profitable method for production of bioethanol is made. The ethanol is produced from an anaerobe fermentation of saccharides by the microorganism Saccharomyces cerevisiae. As raw material for the saccharides rape grass and deep bedding of wheat straw from farming are used. The raw material contains large amounts of lignocellulose that has to be degraded to monosaccharides using high temperature hydrolysis and enzymatic hydrolysis before the actual fermentation [1]. Various fermentation methods can be used in the production but it seems that Simultaneous Saccharification and Fermentation, SSF is the most rewarding method and it is therefore used in this project. [2]

Introduction
Conversion of low cost surplus crops into high quality chemical fuels for transport has been an ongoing research area for many years. One such fuel is bio-ethanol used as a gasoline additive. The demand on bioethanol production has increased recently owing to EU resolutions about reducing the carbon dioxide emission. Further more there is a desire to become independent of the major oil producing countries. At present none of the processes known are cost efficient enough to compete with petrochemical fuels on market terms. In an attempt to develop a profitable method for production of bioethanol this production is to form an integral part of a biogas plant for conversion of energy crops, household waste, manure and other farm waste.

In this specific case the raw materials are rape straw and deep bedding which are hydrolyzed to the saccharides. The saccharides are then fermented under anaerobic conditions by the yeast Saccharomyces cerevisiae in ethanol.

Methods
The raw materials contain large amounts of lignocellulose that has to be degraded to monosaccharides before it can be utilized by the microorganism [1]. Glucose is the potentially most abundant monosaccharide in rape straw and deep bedding and the monosaccharide easiest digested by the yeast. Therefore the present work concentrates on the degradation of lignocellulose into this particular saccharide. Lignocellulose consists of three types of polymers: lignin, cellulose and hemicellulose where cellulose is a glucose polymer. The three polymers are linked together in a tight network. This network has to be broken before cellulose can be depolymerized into glucose.

The network degradation is investigated at different temperatures and pressures [1]. The process is carried out in a closed stainless steel container specially designed for this purpose. In a typical experiment the container is filled with 1 liter milled raw material and placed in an oven. The container is heated until the center temperature reaches the required value.

The depolymerization is catalyzed by the enzymes NZ186® and Celluclast® kindly provided by Novozymes [3]. The enzyme loading is about 7 FPU [4]. The enzymatic hydrolysis and ethanol fermentation can be performed as either: SSF or Separate Hydrolysis and Fermentation (SHF). Both methods have advantages and disadvantages but it seems that SSF is by far the most rewarding method of the two. Therefore this particular method and a combination of the two methods [2] are tested in order to investigate which one is most effective.

In SSF the enzymes and the yeast are added simultaneously, in the combined SSF-SHF the yeast is added when the amount of glucose released has reached a maximum. The yields of the various experiments as well as the experimental conditions are laid out in table 1. The process steps are illustrated in figure 1.

Table 1: Various fermentation conditions and yields obtained.

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Type of fermentation</th>
<th>Degradation temperature [°C]</th>
<th>Yield [% of theoretical ethanol yield]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape grass</td>
<td>SSF</td>
<td>180</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>63</td>
</tr>
<tr>
<td>Deep bedding</td>
<td>SSF</td>
<td>220</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>SSF-SHF</td>
<td>200</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>SSF-SHF</td>
<td>220</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>29*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>35*</td>
</tr>
</tbody>
</table>

*Theoretical yield is not precise and these yields should not be compared to the rape grass yields.

Figure 1: Flow sheet of the processes in the production of bioethanol

Discussion
According to literature experimental yields of 74 % - 100 % is possible when wheat straw is used as raw material [5]. As the composition of rape straw and wheat straw are fairly close these results are comparable. As can be seen in table 1 the highest yields are obtained in the combined SSF-SHF. From the ethanol and glucose production/conversion illustrated in figure 2 it is obvious that the production rate of ethanol is much higher in SSF. The maximum concentration in SSF is reached only 6 hours after initiation of the fermentation compared to 30 hours in the combined SSF-SHF. Considering the energy consumption it is not profitable to use combined SSF-SHF for production of bioethanol. Further more it is obvious that a degradation temperature at 200 °C and above gives the highest yields. It is not possible to compare the yields obtained for rape straw and deep bedding as it is difficult to determine the exact content and thereby the theoretical yield of deep bedding.

References:

Henvendelse kan rettes til:
- Maria Thestrup Hansen: maria_th_hansen@hotmail.com
- Henriette Sveistrup Damgaard: hsd@ofir.dk

Specialetuderende, Institut for kemi-, biologi- og miljøteknologi, Teknisk Fakultet, SDU.