Technology

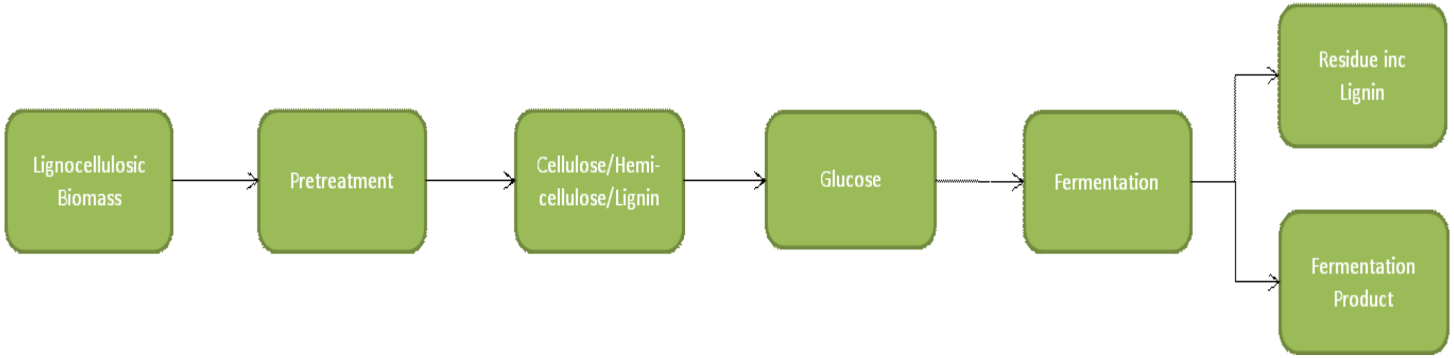
Renewable Chemicals Factsheet

Biomass Pre-treatment

This Factsheet gives an overview of Biomass Pre-treatment

Introduction

Pre-treatment refers to a number of technologies which physically alter plant biomass to either change the amount of hemicelluloses, cellulose and lignin or which alter the physical characteristics of the biomass to increase the efficiency of biomass breakdown[1].



Biomass pre-treatment technologies should[2,3]:

1. Be economic.
2. Maximise the amount and quality of fermentable sugars.
3. Minimise the potential formation of inhibitors which could affect downstream processing.
4. Maximise the potential for co-product production.
5. Be suitable for a range of biomass types.
6. Be suitable for commercial scale operation.

There is no 'one-size-fits-all' technology. Pre-treatment technologies are usually bespoke to each production plant. Each technology has particular advantages and disadvantages, and the technology deployed at any given plant will depend upon the feedstock, the scale and the quality of the material required by a specific downstream process and market.

Technology Summary

There are a large number of technologies in this area. These may be thermal, chemical, biochemical or a combination:

1. Acid based pre-treatments use either mineral acids, water (which acts as an acid at high temperature) or acetic acid produced *in situ*[4]. Acids promote the breakdown of lignin and hemicelluloses to increase access to cellulose[4]. These include concentrated acid, dilute acid (including flow through acid), uncatalysed and acid catalysed steam explosion, and liquid hot water technologies (pH controlled water and flow through liquid hot water).
2. Alkaline pre-treatments typically use calcium hydroxide, ammonia and sodium hydroxide to promote the breakdown the bonds which link hemicelluloses to lignin[4]. These include Ammonia Fibre Explosion (AFEX), Ammonia Recycle Percolation (ARP), lime and wet oxidation technologies.
3. Biological pre-treatments utilise enzymes from bacteria, fungi and other microorganisms to break down the lignin fraction of the biomass. These include enzymes derived from white rot fungi, marine woodborers and the termite hindgut. Such enzymes would be introduced through bacteria in industrial applications.

Other pre-treatments include extractive pre-treatments like the organsolv process, ozonolysis and carbon dioxide.

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Image courtesy of Dupont

Process Attributes

The nature of the treated product is highly dependent upon the pre-treatment technology used.

Some pre-treatments rearrange biomass, i.e. AFEX, whereas other pre-treatments result in the production of a sugar stream and a solid fraction, i.e. acid hydrolysis, alkaline hydrolysis and liquid hot water treatments. The amount of residual components left within the biomass is dependent upon the efficiency of the process[1].

Pre-treatments can affect downstream carbohydrate hydrolysis and fermentation. High thermal severity pre-treatments, such as steam, dilute acid and liquid hot water, can produce furfurals and other degradation products[4]. AFEX has been reported to result in hemicellulose oligomers, which are not easily fermented[5].

Chemical pre-treatments are conducted under high temperature and pressure, so involve significant capital investment[4]. Biological based pre-treatment methods are being developed which may allow significant reductions in energy use because they are carried out under milder conditions[4].

Project	Location	Scale (ktpa)*	Pre-treatment
Verenium	Jennings, Louisiana	4	Mild acid hydrolysis/steam
Abengoa	Hugoton, Kansas	34	Steam explosion
Petrobras	Rio de Janerio, Brazil	52	Acid hydrolysis
SEKAB	Örnsköldsvik, Sweden	Pilot	Dilute acid
Iogen	Saskatchewan, Canada	70	Steam explosion
Dupont/ Danisco	Vornore, Tennessee	Pilot	Mild alkaline (ammonia)

* ktpa = thousand tonnes per year

Feedstock Suitability

Lignocellulosic materials can be classified as hard woods, soft woods, herbaceous and agricultural residues. The effectiveness of a pretreatment depends on the feedstock being processed. For example, steam explosion is suitable for pretreating wood biomass whereas AFEX performs well with herbaceous and agricultural residues, but is less suited to hardwoods and is unsuitable for soft woods[5].

Current Status

Some technologies, such as mild acid hydrolysis, steam explosion, dilute acid and mild alkaline processes, are close to commercialisation and have been mentioned in specific plants as shown in the table[6].

Liquid hot water, AFEX, ARP and biological breakdown technologies are less advanced and there is no evidence that they have evolved beyond the lab scale of deployment[1].

References and Further Reading

[1] NNFCC (2009) Marketing Study for Biomass Treatment Technology, Appendix 2 Technology Review. Report for North East Process Industry Cluster. www.northeastbiofuels.com/_assets/file/marketingstudynnfccappendix2.pdf

[2] Jorgenson, H., Bach Kristenson, J. & Felbt, C (2007) Enzymatic Conversion of Lignocellulose into Fermentable Sugars: Challenges and Opportunities. BioFPR, 1 (2): pp 119-134.

[3] Kumar, P. *et al.* (2009) Methods for Pretreatment of Lignocellulosic Biomass for Efficient Hydrolysis and Biofuel Production. Industrial and Engineering Chemistry Research; 48 (8): pp 3713-3729.

[4] Waldron, K. (ed) (2010) Bioalcohol Production. Biochemical Conversion of Lignocellulosic Biomass. Woodhead Publishing Ltd. Cambridge, UK.

[5] Mosier, N. *et al.* (2005) Features of Promising Technologies for Biomass Pre-treatment. Bioresource Technology; 96 (6): pp 673-686.

[6] Bioenergy2020+ and FJ-BLT http://demoplants.bioenergy2020.eu/projects/mapindex