

BBE 4001

Chemistry of Biomass and Biomass conversion to fuels and products

Catalog Description

Students are introduced to the environmental implications of biomass utilization for Biofuels and Bioproducts within the context of chemical principles underlying the structure, properties, processing and performance of plant materials; chemical composition of plant materials and typical reactions as well as specific chemical reactions during conversion of biomass to industrial products are discussed. The topics covered include: Carbohydrates, Cellulose, Hemicelluloses, Lignin, distribution of chemical components in plant material, Extractives and Oils, Starch, Proteins including Enzymes, Alkaloids. Also covered are chemical reactions during conversion of biomass to industrial products and environmental implications, for example: conversion of cellulose and hemicellulose to ethanol, furfural, PLA (Polylactic acid); conversion of oil to biodiesel; gasification of biomass followed by Fisher Tropsch conversion to fuels. Environmental and ethical implications of biomass utilization for energy and industrial products are discussed (e.g. water and energy use in bio-ethanol plants, food vs. fuel, waste through unwanted

Prerequisites: Chem 2301, or instructors consent

Text: Course package, recent Scientific Journal articles, web resources (will be made available on-line through class web site). No textbook required

Other helpful material:

Sjoestroem, Eero "Wood Chemistry, Fundamentals and Applications", 2nd edition

Hon, D.; Nobuo Shiraishi "Wood and Cellulosic Chemistry" 2nd Edition, Marcel Decker, NY 2001
Fengel, D.; Wegner, G. "Wood, Chemistry, Ultrastructure, Reactions" Walter DeGruyter, NY 1984,
Byron, David, "Biomaterials, Novel Materials from Biological Sources" M Stockton, NY 1991
Hon, D. "Chemical Modification of Lignocellulosic Materials" Marcel Decker, NY, 1996
Gross, R. Scholtz, C.; "Biopolymers from polysaccharides and agroproteins", American Chemical Society, Washington DC, 2001
Haigler, C.H; Weimer, P.J. "Biosynthesis and biodegradation of Cellulose" Marcel Dekker, 1991
Waldron, K. "Bioalcohol production" Woodhead Publishing, NY, 2010

Instructor: **Ulrike Tschirner**, e-mail ulrike@umn.edu , 204 Kaufert Lab

Course Credits: 4

Schedule: 3 lectures per week (Mo, We, Fr)

Office hours: Monday 8-11 or by appointment

Teaching Assistants: William Dean deanx183@umn.edu

Week 1:

Carbohydrate Chemistry (a short review)

Definition; Classification; Stereochemistry; Family of Aldoses; Ring Structures of Monosaccharides; Some typical Reactions and Derivatives of Carbohydrates.

Reading and activities "Bio-ethanol in Brazil - use of sugar cane" several assigned web sites, links are available on class web site. *Focus on:* a.) when did it start b.) environmental issues c.) food versus fuel considerations d.) predictions for the future.

Always be prepared to discuss the reading material in class by Friday.

Week 2General Carbohydrate Reactions continued

Hemiacetal formation; Acetal formation; Carbohydrate Esters and Ethers. Where are carbohydrates currently used; relate carbohydrates to use in biofuels and bioplastics. Oligosaccharides, examples of oligosaccharides in food.

Cellulose

Cellulose Supramolecular Structure, Cellulose in cell wall, Microfibrills, Crystalline areas. How does structure affect degradation.

Reading and activities:

“Cellulose Crystals, Review of structure and formation”. J. Lund 2009, (paper on moodle)

Focus on: types of cellulose and conversion options

Week 3Cellulose and cellulose reactions continued

Cellulose Molecular Weight and Weight distribution; Biosynthesis of Cellulose
Cellulose degradation reactions (peeling, enzymatic, acid, alkaline);

Reading and activities:

New York times article “Rush to use crops as fuel raises food prices and hunger fear”

http://www.nytimes.com/2011/04/07/science/earth/07cassava.html?_r=4&src=twr, (article also posted on Moodle) *Focus on: What does the author feel would be some of the major implications if we rely heavily on crop as source for fuels. Is he right? What do you think*

Week 4Hemicellulose

Hemicellulose in Softwood, Hardwood and in other plant material; Analysis of hemicelluloses; Other Polysaccharides in Plants; Hemicellulose Biosynthesis; Hemicellulose use in biofuel generation (C5 sugar issue). Other products from hemicelluloses such as adhesives, binders etc. Fermentation inhibitors originating from hemicelluloses (acetyl groups).

Reading and activities:

“Wood cell walls: biosynthesis, developmental dynamics and their implications for wood properties”, Ewa J Mellerowicz and Bjorn Sundberg, in Current Opinion in Plant Biology, 2008 available on Moodle site. *Focus on cell structure, what does this mean if we want to degrade the cell.*

Week 5Hemicellulose continued

Reactions of Hemicellulose; Differences to cellulose, Isolation of Hemicellulose

Lignin

Structure and Types of Lignin; Lignin Biosynthesis; differences of lignin structure in different plant materials; How do different lignin structures affect conversion; Energy from lignin in current biorefineries

Reading and activities:

“The biomass biorefinery concept” (selected web sites, links are available on moodle site).

Focus on a.) how is the biorefinery defined, b.) what material is refined c.) what are the products coming out c.) how does this compare to a petroleum refinery d.) how does environmental impact compare to petroleum refinery.

Week 6Lignin continued.

Functional groups in lignin, Lignin-Carbohydrate Bonds, Reactions of Lignin in conversion processes, Acid media , Alkaline media, Lignin isolation

Distribution of chemical components in plant material

Implication of combination cellulose/lignin/hemicelluloses for to biofuels and bioproducts

Reading and activities:

“Top value added chemicals from biomass-Lignin” Holladay, Pacific Northwest Laboratories, 2007, available on moodle site, **please read chapter 4 only** ; *Focus on what material currently made from petrochemicals can be replaced by lignin*

Week 7Extractives and oils

Wood Extractives; Green chemicals from extractives, Plant oils, Lipids, Fats; Algae and oil/Free fatty acids in algae. Bio-diesel from vegetable oil and algae oil. Biodiesel demonstration.

Reading and activities:

“Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use “ EPA report 2007 (available on moodle site). *Focus on a.) what renewable fuel option offers the largest potential for green house gas reduction b.) why do you think that is? c.) where is biodiesel as compared to corn based ethanol?*

Week 8Extractives continued

Discussion on environmental impact of biodiesel use, green house gas emission, food vs. fuel., Other extractives, terpene demonstration

Inorganic material in plants

Type of inorganic material in plants; Impact of inorganics on conversion processes; Ash going to landfill or used as fertilizer

Reading and activities:

“Wood ash at McNeil power plant used as fertilizer” web resource, link available on class web site. *Focus on a.) why is wood ash considered a fertilizer b.) could there be any environmental issues? c.) what is being replaced.*

Week 9Starch

Starch characteristics and reactions; Comparison Cellulose/Starch, what are the implications for conversion; Corn dry/wet milling process; Bioethanol, production and environmental considerations (water, air). Use of starch in food applications: thickener, dextrose, high fructose corn sugar, sweeteners from sugar? Health considerations?

Reading and activities:

Find information on “Sugar from Corn”. Focus on: what is the message and who do you trust and why (quote all your sources)

Week 10Proteins in renewable resources

Presence in plant material, structures, reactions; Enzymes; Applications; e.g. enzymatic hydrolysis of biomass. Bioremediation, Comparison of environmental impact between enzyme and concentrated acid hydrolysis. Fermentation inhibitors

Reading and activities:

“Enzymes in the Environment, “Brett, 2003 Rhodes University . *Focus on a.) potential uses of enzymes in the environment and b.) limitations of enzymes.*

Week 11Alkaloids

Presence and structures; Functionalities

Chemical reactions of Lignocellulosic material

Pulping and bleaching chemistry (for example, alkaline, acid conditions, radical reactions, sulfide, Anthraquinon in process.) Environmental considerations in pulp mills (where is the skunk??), pulp mills as potential biorefineries.

Reading and activities:

Hemicellulose pre-extraction before subsequent Kraft pulping, Tschirner 2010, article available on class web site. *Focus on hemicelluloses yield, pulp yield and paper properties. Is it worth it?*

Week 12Biomass as feed stock for biofuels and Bioproducts

Biorefining; cellulose to glucose, issues with side products, Formation of cellulose derivatives (for example cellulose solutions and regenerated cellulose (for example, cellulose esters, ethers, xanthate/rayon).

Reading and activities:

“Cellulosic ethanol fuels environmental concerns” 2006 web resource. *Focus on a.) in your opinion which of the arguments can be backed up by science? B.) which arguments are questionable and why?*

Week 13

Bio-plastics and chemicals made from renewable resources

Conversion of glucose from cellulose to Polylactic acid (a compostable plastic) and PHAs, biodegradable plastic; Production of chemicals from cellulosic glucose (for example, hydroxymethylfurfural, organic acids; Chemicals from pentoses

Reading and activities:

“Xylitol” web resources available on class web site. *Focus on a.) production, b.) usage c.) health advantages/disadvantages*

Week 14

Conversion of lignin, present uses and potential future applications, other products from plant extractives (for example, sizing agents, insecticides, tanning agents; Products from proteins (for example soy protein polymers, binders for coating, Casein).

Reading and activities:

Please start reviewing for final

Week 15Thermoconversion processes

pyrolysis, gasification and combustion, Fischer Tropsch conversion of gasification products to transportation fuels

Biogas generation from organic material.

Biogas from manure and Municipal Solid Waste, Biogas harvested from landfills. What is going on inside the landfill: Methane (Biogas) impact on GHG.

One class session will be use to review for final*Reading and activities:*

“Methane from landfills” web resources, links available on class web site.

Please continue reviewing for final

Grading Scale

Your grade for this course will be determined as follows:
You will be able to drop one quiz, but this course will not be curved.

Undergraduate students

6 Homework assignments 20%

6 Quizzes 45%

Participation 5% (come to class !)

Final 30%

Homework needs to be turned in at the beginning of class. Late submissions will have 15% subtracted each day (weekend counts too).

Class Moodle site:

There is a Moodle site available for this course. **All handouts, web links, articles. Powerpoints from lectures, homeworks, quizzes, homework/quiz solutions and grades** as well as some other general information will be posted on this site. Please log in ASAP and inform the instructor if you have problems accessing the site.

You will not need to buy a book, but there will be about 200 pages of handouts and several journal articles posted on the course web site. You will be responsible to access this material through the Moodle site. *Students may not distribute, via the Internet or other means, instructor-provided lecture notes or other instructor-provided materials, except to other members of the same class or with the expressed consent of the instructor.*

Percentage Achieved	Course Grade
93–100	A
90–92	A-
87–89	B+
83–86	B
80–82	B-
77–79	C+
73–76	C
70–72	C-
67–69	D+
60–66	D
0–59	F

Chemistry of Biomass Important Dates

Event	Due
Homework #1	Wednesday 21st of September
Homework #2	Wednesday 5th of October
Homework #3	Wednesday 19th of October
Homework #4	Wednesday 2nd of November
Homework #5	Wednesday 16th of November
Homework #6	Wednesday 30th of November
Quiz #1	Wednesday 28th of September
Quiz #2	Wednesday 12th of October
Quiz #3	Wednesday 26th of October
Quiz #4	Wednesday 9th of November
Quiz #5	Wednesday 23rd of November
Quiz #6	Wednesday 7th of December
Final	8-10 Tuesday December 20 302 Kaufert Lab (there will be a 2nd option for students in the on-line section)
Graduate project	Topic due October 5th
Graduate students only !	Paper Due 30st of November