Summer 2004

WRRC

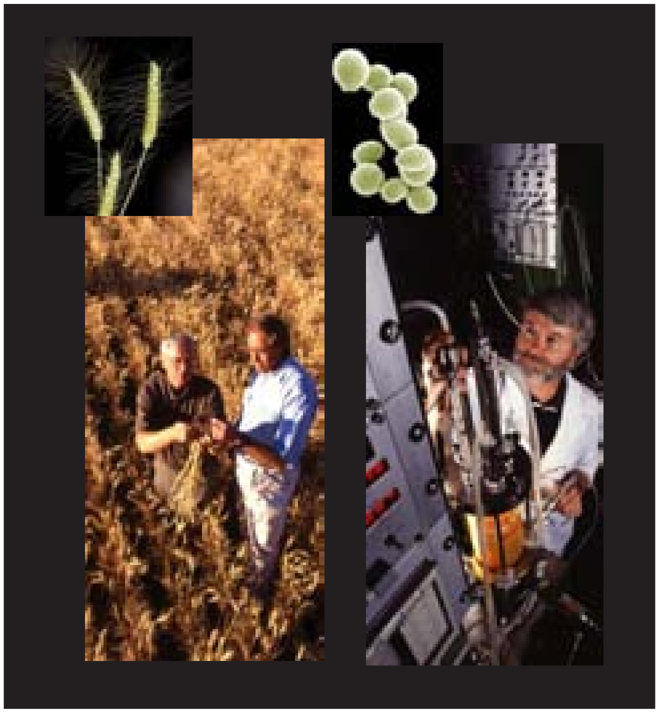
The Western Regional Research Center

Dr. James N. Seiber, Center Director

Creating and Capturing Total Value of Agricultural Resources for Biofuels and Biobased Products

Biorefining research at WRRC features an "out of the box" view of the biorefinery that reaches beyond the refinery walls to include the farm and forest. Hence our research (a) identifies and creates or induces the plant chemical and physical architecture that is the foundation of the biorefining enterprise and (b) defines the ways that alter the crop architecture to capture its inherent value.

In our non-traditional view the farm becomes one step in the chain of events leading to biofuels and biobased product. To the "new biorefiner", the farm takes on the role of a large flat plate reactor with a crop of corn or wheat as the culture, just as the fermenter is a microbiological crop in a bottle. To the "new biologist, the biorefining system becomes a complex network of biochemical and chemical pathways. Farm-based and city-based components of biorefining are intimately linked through foundations in genetics and molecular biology. These determine the chemical and physical architecture of the crop resource and the kinetics of the chemical and biological separations and conversions.



Biorefining, in the crop plant and in the field or the refinery, is crucial to the full development of biofuels and biobased industrial products. The successful implementations of biorefining enterprises reduce imports, stabilize economies, create markets for surplus agricultural production, improve the balance of payments, create rural employment, and reduce the impact of unstable petroleum supplies.

WRRC uses genomics, separation science, process integration, novel solvent properties, and polymer formulation in its research. There is a partial focus on nationally important small grains such as wheat and rice, and on physical and genetic methodologies with generic utility to all grains and grain straws The research reflects the efforts of 15 full time PhD scientists and approximately 40 technical staff.

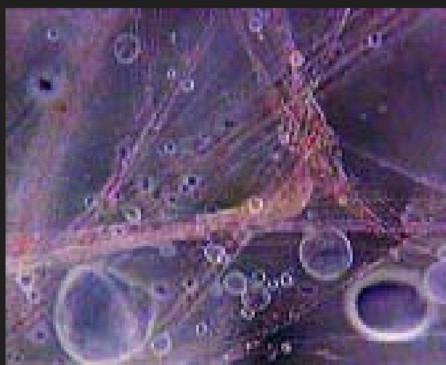
Inductive Biorefining... Finding and Inducing New Chemical and Physical Architectures:

Changing the Genetic Resource for Biofuels. WRRC scientists seek to develop the knowledge and genetic technologies to improve the use of renewable plants as a resource for chemical feedstocks and fuels. The focus is on the cereal crops (especially wheat and rice) and other high yielding grasses with potential to be biofuel resources such as switch grass (shown). Plant molecular biology, genomics, bioinformatics, and plant transformation are being marshalled to alter these crops. The research is defining (1) factors for expression of polysaccharides and proteins in plant leaf and stem tissue, (2) the potential for new plant architecture and cell wall structure for more efficient light gathering, storage capacity, and post-harvest refining; and (3) the potential for polysaccharide production to enhance ethanol production as well as existing and novel polymer structures. Drs. Christian Tobias, John Vogel, Olin Anderson.

Toxin-Free Castor as a New Oilseed Resource: WRRC research is leading to a new domestic crop for castor oil, a key industrial oil that is now imported because the traditional castor plant is hazardous to grow. The castor seed produces a unique oil with up to 90% ricinoleate (12-hydroxy-oleate). The oil is used to produce lubricants, coatings and plastics. Albany researchers have invented the means to transform the castor plant, *Ricinus communis*, the source of castor oil, to eliminate the toxin ricin and allergens from castor. This research could lead to the re-introduction of castor in a non hazardous form as an energy and chemical crop for bio-based products. Dr. Thomas McKeon.

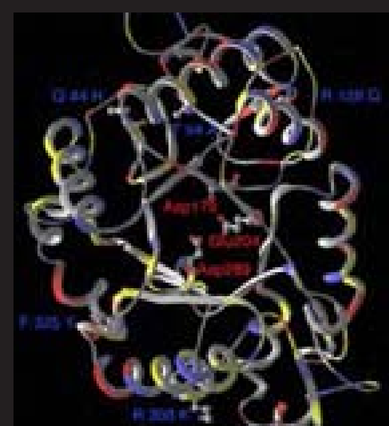
Domestic *Guayule* as a New Source of Industrial and Hypoallergenic Rubber: Natural rubber is vital to United States commerce, defense, transportation and medicine. The entire domestic supply is imported and is subject to shortages and high cost due to declining production, increasing global demand, international politics, and crop disease. Life-threatening "latex allergy" to *H. brasiliensis* rubber products makes development of an alternative, safe source imperative. WRRC is developing alternative rubber-producing domestic crops . The research has led to an exclusive patent license for commercial production of the perennial *guayule*, as a source of high-value, hypoallergenic latex. Expanded research will lead to higher-yielding guayule lines as well as to production of non-gyuayule annual rubber-producing crops. Dr. Colleen McMahan.

Reductive Biorefining...Capturing Native Values



Wheat Grain Separation by Cold ethanol displacement to starch and protein platforms. The separation of wheat precedes all refining options for wheat grain. WRRC has developed the cold-ethanol separation method that improves on both the separation and the subsequent drying technology (shown at left are starch grains being displaced from developed gluten fibrils). The cold ethanol method is capable of producing a gluten that meets or exceeds the properties of freeze-dried gluten, a conventional standard of gluten vitality, by enabling low temperature drying. This lab-scale technology is now being adapted for scaleup. New efforts include evaluation of gluten subfractionation to new protein platforms. Dr. George Robertson.

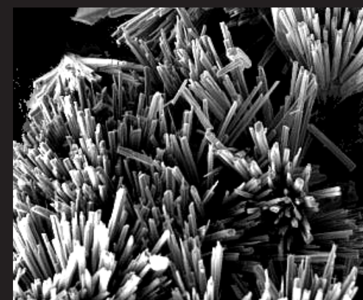
Reductive Biorefining: Separation / Disassembly: Starch-to-sugar platform by enzyme evolution/ cold hydrolysis: Processes for the conversion of crops or crop components into fuel or chemical products are inefficient and have high energy use. WRRC is utilizing molecular evolution to create enzymes to help overcome these limitations. In one example a process called cold hydrolysis could reduce energy and capital needs for grain-to-ethanol conversions. Enzymes with enhanced properties for this purpose have already been produced at WRRC and plans are underway to begin evaluation at larger scale. Shown in the color example is one highly-active mutant amylase enzyme created in the lab. Drs. Dominic Wong, George Robertson, Charles Lee.



Reductive Biorefining: Separation / Disassembly: Hemicellulose-to-C5 and cellulose platform by enzyme evolution: The conversion to fermentable substrates of hemicellulose-rich crop components such as grain fiber, mill feeds, straws, etc. depends on chemically and energy- intensive acid hydrolysis to produce cellulase susceptible substrate. WRRC research is defining new enymatic resources that can enzymatically disassemble these substrates at temperatures that reduce energy usage. Key to this effort is the identification of new parent enzymes and the optimization of these by molecular evolution. Drs. Charles Lee, Dominic Wong, Kurt Wagschal, George Robertson.

New Separation Initiatives.....

Separation and Recovery of Nano Fibers: Reductive refining to fractionate and modify fibers from agricultural straws, and determine their physical, chemical, and mechanical properties will lead to novel composites and nanocomposites, plastic materials reinforced with ag-derived nanoparticles, silicates, clays, or cellulose whiskers (rice straw and silicate whiskers shown). Fiber refining methods such as organo-solv fractionation, hot water/mechanical pulping and micro-fibrillation will be used to isolate straws components. These high-value added materials will help to alleviate straw disposal problems in the western states. Drs. Gregory Glenn, Maria Inglesby, William Orts,

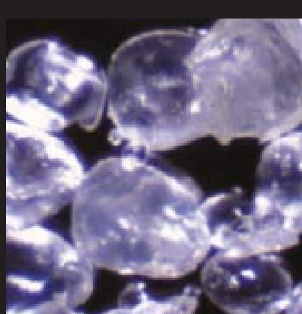


Separation and Recovery of Ethanol: Reductive refining is also applied at a molecular level using barrier or membrane-based methods and novel barrier compositions for ethanol from water separation. This is important to the recovery of ethanol from fermentation broths to increase fermentation efficiency but also reduces the energy used in the separation; thereby reducing the need for inefficient and energy-demanding distillation. Drs. Richard Offeman, George Robertson, William Orts.

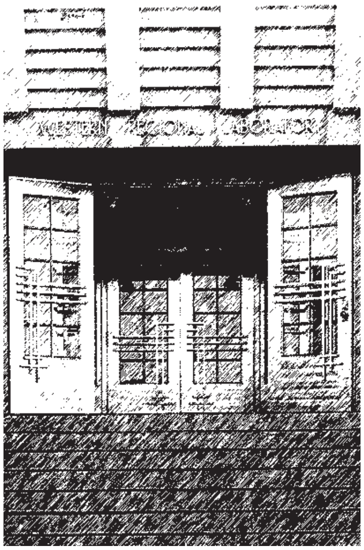
Inductive Biorefining at the Refinery... New Post-Harvest Values

Conversion from Starch Platform: Bio-Based Disposable Polymers: Various enzymatic and chemical methods are being applied to modify properties of starches and isolated fibers to improve their functionality, processability and compatibility within films, composites and nanocomposites. These characterized starches, fibers and other additives are being processed into packaging and building materials using extruders, baking molds, expanded bead cup molders, compression molders and injection molders. Performance and biodegradability of specific biomaterials derived within the project will be examined, focusing on their biodegradability.

One example is the clamshell fast food container using potato starch, cellulose fiber, and limestone that is currently being test-marketed at large fast food restaurant chains. Research using wheat starch to reduce brittleness, processing losses, and cost is underway. Wheat starch containers are opaque, low-density foams with excellent thermal insulating properties, high tensile strength and improved flexibility.



Another example, lightweight concrete, is made by first swelling a starch aggregate in water. Starch-based lightweight concrete is then made by mixing the starch gel with cement. The mixture is poured and allowed to harden. During the curing and subsequent drying process, water migrates out of the gels causing them to shrink and form voids within the concrete product. These void spaces make the concrete lightweight. Lightweight concrete has many uses in floors, walls, roofing tile and other products that need to be durable, lightweight and provide sound and thermal insulation. Dr. Gregory Glenn, William Orts, Syed Imam, Bor-sen Chou.

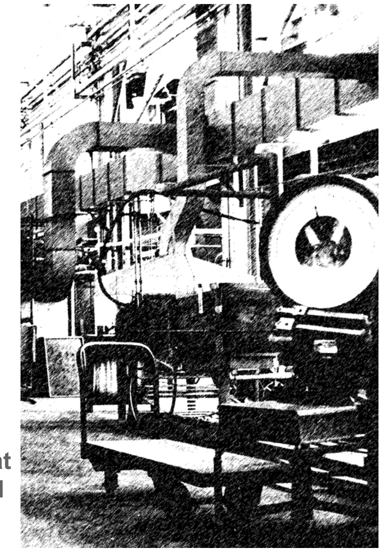


Selected Publications

1999 to 2003 (July)

Scientists
in current
biofuels, biobased products,
and biorefining projects

For on-line updates,
see
the WRRC Scientists Publication Database at
http://www.pw.usda.gov/publication.html



Research units represented:

Bioproduct Chemistry and Engineering, Crop Improvement Utilization Genomics and Gene Discovery

Inductive Biorefining: Creating new genetic resources

Anderson O.D., Blechl AE. Transgenic Wheat - Challenges and Opportunities. In : O'Brien L, Henry RJ editors. Transgenic Cereals. St. Paul, MN.: American Association of Cereal Chemists, 2000: 1-27.

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Inductive Biorefining: New Crop Resources: Rubber

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Cornish K. Similarities and differences in rubber biochemistry among plant species. Phytochemistry 2001; 5:1123-34.

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Krishnakumar R, Cornish K, Jacob J. Rubber biosynthesis in tapping panel dryness affected Hevea trees. Journal of Rubber Research 2001; 131-9.

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Cornish K., Brichta JL, Chapman MH *et al*. Biological and physical characteristics of Parthenium argentatum (guayule) latex in comparison with latex from Hevea brasiliensis and Ficus elastica. Proceedings of the 5th International Latex Conference. 2002: 1-15.

Inductive Biorefining: New Crop Resources: Castor

Lin JT, Lew KM, Chen JM, Iwasaki Y, McKeon TA. Metabolism of 1-acyl-2-oleoyl-sn-glycero-3-phosphoethanolamine in castor oil biosynthesis. Lipids 2000; 35:481-6.

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Whitaker JR, Wong DWS. Catalase. Whitaker J.R., Voragan AGJ, Wong DWS, editors. Handbook of Food Enzymology. New York, NY: Marcel Dekker, Inc., 2002: 389-402.

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Reductive Biorefining: Biorefining: Separation to starch and gluten

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Inductive Biorefining: Biorefining: New Values

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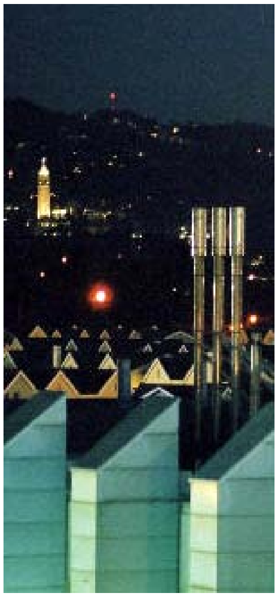
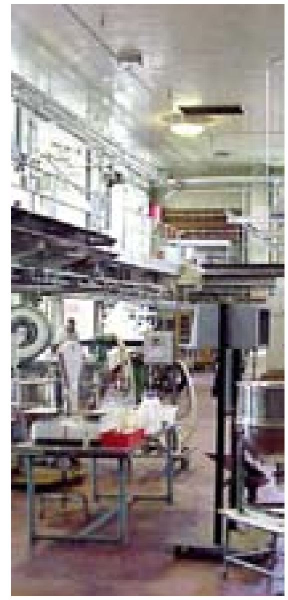


A primary mission of the Western Regional Research Center is to enhance utilization of agricultural products, through development of pre-harvest and post-harvest technologies.

Located on the Pacific Rim in Albany, California, WRRC is the largest ARS lab west of the Mississippi. It is the first of the USDA/ARS Centers to modernize its base laboratories. These laboratories are the core resource supporting innovative, long-range, federally-appropriate research leading to stakeholder-useful solutions. The first phases of the the renewed Research and Development pilot facilities have recently opened.

The Center includes a 40,000 ft^2 Research and Development Facility for pilot-scale research up to commercial scale. This facility is currently being renovated to enhance its utility to both staff and cooperators.



The Agricultural Research Service has research underway that addresses nearly every technical problem in the biorefining arena. These research activities are coordinated through National Program 307, Biofuels and Energy Alternatives and NP306, Quality and Utilization of Agricultural Products. Biofuels and bio-based product research includes efforts at all ARS regional research centers

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http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=306

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