Preface

The Biological Systems Engineering Department, at 103 years young, is the oldest agricultural engineering department in the United States. The department has been a national leader in research, teaching, and extension. As this annual summary booklet shows, we are engaged in many exciting, innovative, forward-looking activities.

To that end, we are pleased to provide you with our 2007 Annual Summary, based on activities underway and completed in 2006. The Biological Systems Engineering Department is affiliated with the College of Agricultural and Life Sciences, the College of Engineering, the UW-Madison Agricultural Research Stations, and the University of Wisconsin Cooperative Extension Service. The mission of the department includes achieving excellence in teaching, research and extension. Our Biological Systems Engineering undergraduate program is fully accredited by ABET. The graduate program offers both Master of Science and Doctoral degrees. We have approximately 60 undergraduate and 30 graduate students. The department offers a wide range of courses with options in Machinery Systems Engineering, Food and Bioprocess Engineering, Natural Resources and Environmental Engineering, and Structural Systems Engineering.

The goal of our research program is to contribute new and valuable knowledge to the fields of food and bio-processing, bio-energy and energy systems, machinery systems, construction, natural resources and environment, and agricultural safety and health. Research projects also serve to train graduate students and to increase the quality of undergraduate education. Our research program is financially supported by state and federal appropriations and by gifts and grants from industry, government agencies, and individuals. This support is gratefully acknowledged. The gifts and grants continue to increase as a percent of budget.

Extension and outreach programs are an integral part of the department. Many of our Extension personnel are also involved in research and classroom teaching. Extension and outreach activities are directed toward providing continuing education opportunities for the citizens of Wisconsin and the nation. The mission is to extend research knowledge and to assist in assimilating it into the community.

Since this report is a summary without a lot of detail, I encourage you to contact the specific project leader (indicated by a "*" in front of the person's name) or me. Publications listed in this report are available upon request.

I welcome your comments on the Annual Summary and other departmental matters. Please visit our website, <bse.wisc.edu>, to keep informed of our activities. Also, do not hesitate to contact me: e-mail rjstraub@wisc.edu; telephone 608-262-3311; FAX 608-262-1228; or mail your comments to:

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Richard J. Straub
Professor and Chair

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Faculty

David R. Bohnhoff, Professor, Ph.D.
Teaching / Research: wood structures
Robin K. Connelly, Assistant Professor, Ph.D.
Teaching / Research: food and bioprocess engineering
Ferencz S. Denes, Associate Professor, Ph.D.
Teaching / Research: food safety
Sundaram Gunasekaran, Professor, Ph.D.
Teaching / Research: food and bioprocess engineering
Awad D. Hanna, Professor, Ph.D.
Teaching / Research: construction engineering and management
Brian J. Holmes, Professor, Ph.D.
Extension / Research / Teaching: farmstead engineering
David W. Kammel, Professor, Ph.D.
Extension / Research: farm structures
Director, Center for Dairy Profitability
K.G. Karthikeyan, Associate Professor, Ph.D.
Teaching / Research: natural resources and environment
Richard E. Muck, Professor, Ph.D.
USDA Agricultural Research Service: structures and environment
Xuejun Pan, Assistant Professor, Ph.D.
Teaching / Research: Bioenergy and bioproducts engineering
Started in September 2006
Douglas J. Reinemann, Professor, Ph.D.
Extension / Research / Teaching: milking equipment and facilities, rural energy, stray voltage
Roger M. Rowell, Professor, Ph.D.
USDA Forest Products Laboratory: wood chemistry, composites
Ronald T. Schuler, Professor, Ph.D.
Extension / Research / Teaching: power and machinery
Kevin J. Shinners, Professor, Ph.D.
Teaching / Research: power and machinery
Richard J. Straub, Professor, Ph.D.
Teaching / Research: power and machinery
Chair, UW Biological Systems Engineering Dept. and
Director, Agricultural Programs and Research Stations, Research Division, College of Agricultural and Life Sciences
Anita M. Thompson, Assistant Professor, Ph.D.
Teaching / Research: natural resources and environment
Patrick W. Walsh, Professor, J.D.
Extension / Research: energy and environmental policy, legal liability
Director, Solid and Hazardous Waste Education Center

Faculty with Joint or Adjunct Appointments

(Research activities and publications are not included.)

Mark R. Etzel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering
Robert J. Fick, Adjunct Assistant Professor, Ph.D.
Alliant Energy: rural energy
Richard W. Hartel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering
King-Jau (Sam) Kung, Professor, Ph.D. (UW Soil Science)
Teaching / Research: soil physics
Philip R. O'Leary, Chair and Professor, Ph.D. (UW Engineering Professional Development)
Teaching / Research: environmental quality
Mark A. Purschwitz, Adjunct Assoc. Professor, Ph.D.
Research Scientist, National Farm Medicine Center (Marshfield, WI): agricultural safety and health
Aicardo Roa-Espinosa, Adjunct Professor, Ph.D.
Dane County Land Conservation Dept.: urban conservation, agricultural engineering
Paul D. Thompson, Adjunct Professor, Ph.D.
Bou-Matic: milking equipment and milk cooling

Emeritus Faculty

Glen D. Barquest
Theodore J. Brevik
Gary D. Bubenzer
Frederick H. Buelow
James C. Converse
Calvin O. Cramer
Ferencz S. Denes
Marshall F. Finner
Richard G. Koegel
Leonard R. Massie
James O. Peterson

Academic Staff

Acronyms of programs/projects with which several of the academic staff are associated

AAW – AgrAbility of Wisconsin
CASH – UW Ctr. for Agricultural Safety and Health
HFHP – Healthy Farmers/Healthy Profits Project
NAP – National AgrAbility Project

For several others, names of associated faculty follow in parentheses.

Nathan Q. Altfeather, Research Intern, M.S. (R.T. Schuler, P.W. Walsh)
Mary F. Beck, Senior Outreach Specialist, M.S.; NAP
Perry E. Cabot, Ph.D., Research Associate (K.G. Karthikeyan)
Larry J. Chapman, Senior Scientist, Ph.D.; HFHP
Cally A. Ehle, Associate Outreach Specialist; AAW
William E. Enters, Research Specialist; Environmental Quality Lab (J.C. Converse, K.G. Karthikeyan)
Joseph D. Grande, Research Specialist, M.S. (K.G. Karthikeyan)
Kyunghyun Kim, Research Associate, Ph.D. (A.M. Thompson)
Sanghoon Ko, Research Associate, Ph.D. (S. Gunasekaran)
Fachuang Lu, Associate Scientist, Ph.D. (Xuejun Pan)
Marcia G. Miquelon, Senior Outreach Specialist, M.S.; HFHP
Jeffrey W. Nelson, Senior Research Specialist (dept. IT) and Lecturer (farm equipment and power), M.S.
Astrid C. Newenhouse, Associate Scientist, Ph.D.; HFHP
Mark E. Novak, Senior Outreach Specialist; NAP
John C. Panuska, Associate Faculty Associate (K.G. Karthikeyan)
Kathryn M. Pereira, Outreach Specialist, M.S.; NAP
Daniel C. Rodman, Lecturer (surveying; also Dept. of Civil and Environmental Engineering), M.S. (P.W. Walsh)
Scott A. Sanford, Senior Outreach Specialist; Wisconsin Focus on Energy (D.J. Reinemann)
Cheryl A. Skjolaas, Senior Outreach Specialist; CASH and NAP; Interim Director; CASH

Technical Personnel

Harold M. Bohne, Senior Instrument Maker
Bradley A. Brooks, Instrumentation Specialist

Office Personnel

JacqueLynn M. Cary-Pope, Financial Specialist
Hallie R. Kirschner, University Services Associate
Sherry T. Liantonio, University Services Associate
Candy L. Pharo, Department Administrator
Debra K. Sumwalt, University Services Program Associate

Graduate Students

Names of major advisor follow in parentheses

Filiz Altay (S. Gunasekaran)
Robert D. Bade (D.J. Reinemann)
Tausif R. Baig (D.J. Reinemann)
Shanti Bhushan (R.K. Connelly)
Garritt C. Boettcher (K.J. Shinners)
Colin F. Byrne (K.G. Karthikeyan)
Perry E. Cabot (K.G. Karthikeyan)
Amanda D. Crowe (A.M. Thompson)
Matthew F. Digman (K.J. Shinners)
Baiyan Dong (F.S. Denes)
Aaron R. Flouro (D.R. Bohnhoff)
Philip D. Gaebler (K.G. Karthikeyan)
Cheng Gu (K.G. Karthikeyan)
Kerem Gungor (K.G. Karthikeyan)
Daniel S. Hoffman (K.J. Shinners)
Wantida Homthawornchoo (S. Gunasekaran)
Natalie L. Huisman (K.G. Karthikeyan)
Matthew P. Johnston (D.J. Reinemann)
James B. Jordan (R.K. Connelly)
Andrew J. Kotloski (B.J. Holmes)
Seth B. McClure (K.G. Karthikeyan)
Gregory D. Mueller (A.M. Thompson)
Jesse T. Munk (K.J. Shinners)
Michael A. Nimmer (A.M. Thompson)
Jane L. O'Dell (R.M. Rowell)
Asli A. Ozkaynak (K.G. Karthikeyan)
John C. Panuska (K.G. Karthikeyan)
Adam C. Paul (A.M. Thompson)
Adam L. Petersen (A.M. Thompson)
Ronald A. Pichardo (A.M. Thompson)
Nathan D. Sandwick (D.J. Reinemann)
Ajay P. Singh (S. Gunasekaran)
Eakasit Sritham (S. Gunasekaran)
Erik L. Storvik (A.M. Thompson)
Adriano Sun (S. Gunasekaran)
Sai Kit (Terry) Tau (S. Gunasekaran)
Vladimir Totolin (F.S. Denes)
Shin Yee Wong (R.K. Connelly)
Jinjin Zhou (S. Gunasekaran)

TEACHING

One part of the department's mission is undergraduate and graduate education. The department is responsible for:

- Undergraduate Major – Biological Systems Engineering
- Graduate Program:
  - Master of Science – Biological Systems Engineering
  - Doctor of Philosophy – Biological Systems Engineering
- Technical/Service Courses
- Farm and Industry Short Courses
- College of Agricultural and Life Sciences Student Advising

Biological Systems Engineering

Currently there are about 60 undergraduate majors in Biological Systems Engineering. The major consists of a core of courses taken by all students and four emphasis areas of which students choose one: machinery systems; structural engineering systems; natural resources and environment; food and bioprocess engineering. The following courses are dedicated to the Biological Systems Engineering major.

Engineering Principles for Biological Systems, 3 cr
Surveying Fundamentals, 1 cr
Field Applications in Surveying, 1 cr
Structural Design for Agricultural Facilities, 3 cr
Operating and Management Principles of Agricultural Machines, 3 cr
Engineering Principles of Agricultural Machinery, 3 cr
Measurements and Instrumentation for Biological Systems, 3 cr
Food Engineering Operations, 4 cr
Food and Pharmaceutical Separations, 2-3 cr
Rheology of Foods and Biomaterials, 2 cr
Engineering Properties of Food and Biological Materials, 3 cr
Sediment and Bio-Nutrient Engineering and Management, 3 cr
Irrigation and Drainage Systems Design, 2 cr
Small Watershed Engineering, 3 cr
On-Site Waste Water Treatment and Dispersal, 2 cr
Topics in Natural Resources Engineering, 1-3 cr
Topics in Renewable Energy Systems, 1-4
Biological Systems Engineering Senior Design, 3 cr
Career Management for Engineers, 1 cr

The curriculum consists of 128 credits. Our undergraduate program was evaluated in 2006 by the Accrediting Board for Engineering and Technology (ABET),.and accredited again for another six years, the maximum allowable. Approximately 20 students earn B.S. degrees each year.

Technical/Service Courses

The department provides several service courses for other majors.

Principles of Food Engineering, 3 cr
Livestock Housing and Waste Management, 3 cr
Irrigation Systems – Design and Use, 1 cr
Drainage Systems, 1 cr
Surveying Fundamentals, 1 cr
Field Applications in Surveying, 1 cr
Operating and Management Principles of Off-Road Vehicles, 3 cr
Engineering Principles of Off-Road Vehicles, 3 cr

Farm and Industry Short Course Program

The department teaches the following courses for the Farm and Industry Short Course (FISC) program offered through the College of Agricultural and Life Sciences.

Agricultural Safety and Health, 1 cr
Agricultural Energy Management, 1 cr
Farm Power, 2 cr
Farm Machinery, 3 cr
Livestock Housing, 3 cr
Milking Systems and Design, 1 cr

Graduate Programs

Each year about 30 graduate students are pursuing a Master of Science or Doctor of Philosophy degree in Biological Systems Engineering. In addition, our faculty advise several graduate-level students in other departments and in the programs of Water Resources Management and Land Resources Management of the Institute for Environmental Studies. The M.S. degree requires a minimum of 18 credits of course work and 6 credits of thesis work. A Ph.D. requires a minimum of 48 credits of course work and 24 credits of thesis work for a minimum of 72 credits beyond a B.S. degree in Biological Systems Engineering. Students who have bachelor's degrees in non-engineering fields may pursue a Master's degree in Biological Systems Engineering but must complete appropriate prerequisites.

RESEARCH

Biological Engineering

Effects of Silage Inoculants on Dairy Cattle Use of Silage

*RE Muck, FE Contreras-Govea, I Filya, DR Mertens, PJ Weimer
Funding: USDA Agric. Res. Service
Collaborators: USDA Dairy Forage Res. Ctr.; UW Agronomy

Objectives:

Farmers often use bacterial inoculants to supplement the natural lactic acid bacteria on a crop at ensiling to help ensure good fermentation in the silo. About half the time, cattle performance (weight gain or milk production) is improved typically 3 to 5% by these additives. However, the reasons for such improvements are not understood. The objective of this research is to study silage digestion in rumen fluid taken from dairy cows to see if there are any differences in how rumen bacteria utilize silage, whether or not it has been inoculated.

Progress:

An *in vitro* method was used to study differences in potential ruminal fermentation among alfalfa and corn silages inoculated with different microbial inoculants. Five trials were completed: three with alfalfa silage and two with corn silage. The inoculants had varied effects on silage fermentation. The largest effects occurred when the natural populations of lactic acid bacteria on the crop at ensiling were lower than inoculant application rates. The effects of inoculation on the *in vitro* digestibility of the silages varied across the five trials. Inoculated silages sometimes produced reduced *in vitro* gas production and increased volatile fatty acid production. The most consistent effects of inoculated silages, however, showed in microbial biomass yield. Silages inoculated with certain inoculant strains consistently produced greater microbial biomass yield during *in vitro* ruminal fermentation than untreated control silages. These results suggest that certain inoculant strains may potentially have a probiotic effect on the cow.

Current efforts on the project are focusing on discovering potential explanations for these effects.

Effects of Additives on the Ensiling of Corn Stover

*RE Muck, KJ Shinners
Funding: USDA; Dept. of Energy
Collaborators: Iowa State U.; Pennsylvania State U.

Objectives:

One of the keys to using corn stover as a feedstock for biofuel production is storage of the stover until it is ready to process. Ensiling has the potential to not only preserve moist stover but also to pretreat the biomass. The objectives of this study are to investigate the ensilability of various corn stover sources ensiled at different moisture contents with and without various additive treatments.

Progress:

Four different varieties of corn stover were harvested and ensiled over a range of moisture contents from approximately 40 to 70% moisture with and without the use of lactic acid bacterial inoculants. Stovers ensiled as harvested (42 to 55% moisture) ensiled well with no additive. Similarly, stovers rehydrated to 60% moisture ensiled well and were stable over 90 days. Stovers rehydrated to 70% moisture ensiled well initially (21 days) but experienced secondary fermentations by 90 days. It appears that ensiling stover at 70% moisture may result in occasional clostridial activity that could reduce the recovery and quality of the stover for downstream uses. All three inoculants tested were successful in affecting ensiled stover quality in all trials, even when the inoculant application rates were less than 1% of the natural lactic acid bacterial population. The homofermentative inoculant shifted fermentation to lactic acid and reduced pH relative to the untreated control, particularly in stovers at less than 55% moisture. The two inoculants with *L. buchneri* shifted fermentation toward acetic acid and 1,2-propanediol. These two inoculants would help to guarantee the stability of stover in transit between farm and bioprocessing plant.

Current efforts are studying a wider range of treatments and corn stover varieties.

Cell Wall Structure Analyses for Improved Forage Digestibility and Improved Biomass Utilization

*X Pan
Funding: USDA Agric. Res. Service

Objectives:

1. Provide the plant cell wall and biomass research communities with improved methods for polysaccharide and lignin structural profiling, based on complete cell wall solubilization and NMR.
2. Develop and streamline procedures to allow 20-30 samples/day to be profiled and develop chemometric methods that allow this profile to predict digestibility and bioconversion efficiency.

Improvements to the current dissolution/NMR methods will be sought to:

1. Provide the necessary database, via model compounds and isolated components, to characterize component polysaccharides and lignins in whole-cell-wall mixtures.
2. Optimize milling conditions for the various biomass sample types and seek alternative solutions that require less rigorous milling.
3. Attempt to develop improved rapid dissolution methods that can be performed directly in the NMR tube; determine solvent systems that do not interfere with the correlation contours from polysaccharide and lignin components.
4. Develop NMR methods that allow the crucial 1D-proton and 2D-HSQC NMR spectra to be acquired in less than one hour (on the whole cell wall sample).
5. Develop methods for databasing and quantifying the NMR cell wall spectra.
6. With collaborators, attempt to develop chemometric methods that can be applied to 2D-NMR data.

Evaluation of a Modified System of Dairy Farm Regulatory Oversight

*PL Ruegg, DJ Reinemann, SA Rankin

Funding: UW Coop. Ext. Service

Collaborators: UW Biological Systems Eng.; UW Dairy Sci.; UW Food Sci.

The overall objective of this project is to evaluate the ability of an alternative method of direct regulatory oversight of high-performing Wisconsin dairy farms. Specific objectives are:

- Develop and evaluate objective criteria that can be used to identify producers who qualify as "high-performing producers" based on milk quality;
- Develop criteria for FDA-approved monitoring and reporting systems on milk quality performance;
- Evaluate the performance of producers enrolled in the pilot project relative to specific outcomes important to ensuring the safety and suitability of milk produced on the farms.

Use of Low- and Atmospheric-Pressure Plasma Processing, Originally Developed at the Center for Plasma-Aided Manufacturing and Biological Systems Engineering Laboratories, to Functionalize Surfaces in Controllable Fashion and to Synthesize Nanoparticles

*FS Denes, RB TImmons

Collaborators: UW Ctr. for Plasma-Aided Manuf., U. of Texas at Arlington

Applying plasma technology to molecularly tailor surfaces is an extremely active, promising area particularly with respect to the field of biomaterials. Recently designed and developed plasma reactor systems represent significant advances in this field. Among these inventions is a 360° rotating reactor for use in tailoring surfaces of fine particles, including nanoparticles, successful production and use of the first dense medium plasma, and equally innovative work in the field of atmospheric plasmas.

These findings, resulting from applying novel plasma tools and technologies, have broken new ground in areas such as developing non-fouling and antimicrobial surfaces, functionalizing nanoparticles for forefront studies in drug delivery, and synthesizing nanoparticles including some extremely important magnetic carbon-based composite nanostructures.

Plasma-Enhanced Surface Functionalization of Silicon Membranes and Development of Silicon Membrane-Based Sensors

*FS Denes, MG Lagally

Collaborators: UW Ctr. for Plasma-Aided Manuf.; UW Materials Sci. Program

Implantation of organic functionalities onto Si-membrane surfaces is being studied, and the influence of chemically- or thermally-induced strain in the membrane structure on the activity of surface functionalities will be evaluated. Morphology changes of the Si-membrane will be related to electronic and chemical behavior of the functionalized substrates.

The atmospheric pressure plasma-generated hybrid membranes, such as Si/Ge membranes, are also considered during this research.

Structures / Construction

Lateral Load Distribution in a Metal-Clad, Wood-Frame Building

*DR Bohnhoff, PA Boor, MH Gadani

Funding: USDA Hatch; USDA Natl. Res. Initiative; UW Biological Systems Eng.; UW Graduate Sch.; Lester Bldg. Systems

This project involved constructing and testing a full-scale, metal-clad, post-frame building with the goal of gaining a better understanding of the complex distribution of load in this popular agricultural building system. The building was erected, instrumentation was installed, and initial tests were conducted in 2001. Research in 2002 was dedicated entirely to testing and data analysis. Research in 2003 and 2004 consisted of data analysis and computer modeling.

The test building was 40 × 200 ft with trusses on 10-ft centers. Trusses were pin-connected to posts, which, in turn, were pin-connected to concrete piers. Centered under each interior truss was a hydraulic frame loader (HFL) that attached by rods to each end of the truss. An HFL can be set to operate in one of four modes: (1) north load, (2) south load, (3) lock, or (4) float. Although there were no HFLs under the endwall trusses, they could be either locked in place or allowed to float during a test.

Using the versatility of the HFLs, 22 different loadings were applied to each of 10 different building configurations. Different building configurations were obtained by adding and removing the ridge, chord reinforcing hardware, roof-to-sidewall fasteners, roof panel stitch screws, sidewall steel, and eave trim. This experimental design was replicated twice for a total of 440 building tests in 2002. During each test, signals from 225 different transducers were recorded every 4.7 s. With a test time of at least 3 minutes, each loading usually generated at least 10,000 data points, obviously an unwieldy amount of data to analyze without significant data reduction.

Throughout early 2003, research effort was dedicated to data reduction by first calculating an average horizontal frame force for each 4.7-s scan. The second step was to linearly regress the output from each transducer on the average horizontal frame load values. After these regression analyses, the data file for each load case was reduced to 204 values.

During the latter part of 2003 and throughout 2004, research effort was dedicated to modeling full-scale building behavior. In the end, a model with three displacement degrees of freedom (DOF) per building frame was selected. These DOFs included a displacement parallel to the frame and two displacements perpendicular to the frame – one at each sidewall. The 3-DOF/frame model contains four different simple spring elements (a.k.a. truss elements): a frame element, a roof cladding element, a chord element, and a wall cladding element.

The primary task during the modeling phase of the study was to determine axial stiffness properties for each of the four elements or, more specifically, to find element stiffness values that were a function of building configuration, and thus could be used to accurately predict full-scale building behavior regardless of building configuration or distribution of applied loads. This turned out to be a formidable task, requiring thousands of computer simulations due to the interdependency of wall cladding, roof cladding, and chord force element properties. Nevertheless, a set of element properties was selected that do a very good job of predicting building displacements, as well as the in-plane bending moment and shear forces between building bays. The results of this modeling were presented at the 2004 ASAE/CSAE International Meeting in Ottawa, Ontario.

The 3-DOF/frame model is embodied in the computer program DAFI3 (Diaphragm and Frame Interaction 3dof/frame). Once a pre- and post-processor are added to the program, it will be made available to the general public.

The test building was disassembled in 2006. All materials except the cast-in-place concrete piers were salvaged and are stored for construction of a post-frame building at the UW West Madison Agricultural Research Station. Lifting tongs were fabricated in hopes of removing the cast-in-place piers. Although one pier was successfully pulled, the tongs were destroyed when the uplift force approached 30,000 lbf during the attempt to remove a second pier.

Reinforced, Deep End-Notched Wood Members

*DR Bohnhoff

Funding: UW Biological Systems Eng.; Lester Bldg. Systems; USDA Forest Products Lab

Deep end-notched wood members are wood members whose ends contain notches that exceed one-fourth of the member's depth – the maximum currently allowed by the National Design Specification for Wood Construction. In 2003, deep end-notched wood purlins were used to construct a post-frame building at the UW Rhinelander Agricultural Research Station. The notches were slightly less than 1.6 inches wide and were located slightly in from the ends of the members so they locked over the trusses they were set on. This use of notched purlins shows how effective they are in increasing construction safety, speed, and accuracy.

Construction safety begins with predrilling holes for fasteners (nails or screws) at the same time the members are notched. Predrilling is possible because notch location dictates fastener location. Safety is enhanced because fasteners can be partially installed before the members are shipped from the manufacturing facility. Safety also results because predriven fasteners help secure lines that are slipped over purlin ends for lifting purposes. Pulling purlins onto a roof with a tag line is considerably safer than having someone toss them up from the ground (a common practice). Reaching for a thrown purlin increases likelihood of a fall, and a thrown purlin is a dangerous flying object – especially when it doesn't reach its mark. On the roof, notched members are considerably easier to position. The notch also helps hold the purlin in place while the fasteners are driven home. This, and the fact that fasteners are already started, means a worker has one hand free to use for greater personal stability. Also, because of predriving, less energy is expended by workers maneuvering around on the roof framing. It follows that notched purlins and predrilling fastener holes improves construction accuracy. Notches lock in truss spacing. Predrilling fastener holes ensures that fasteners penetrate the center of rafter/truss top chord. Improved construction speed results because truss spacing is quickly and easily fixed, fastener installation is more rapid, and the use of lifting lines keeps construction smooth and continuous.

Notching enhances the transfer of both tensile and compressive chord forces between purlins in adjacent bays. Since purlins in adjacent bays are both locked to the truss between them, any axial force in one purlin will be transferred via notches and nail connections to the other. Transfer of measurable tensile chord forces is frequently a problem with purlins that rest in joist hangers. Such purlins must generally be tied together over the top of the truss with special metal strapping. Also note that, by decreasing the depth of a purlin at a notch, shorter fasteners can be used to attach the purlin to the truss, and purlin roll forces (forces that work to bend such a connection) are reduced.

During 2006, a series of reinforced and non-reinforced, deep-notched wood members were laboratory tested. Two different methods were used to reinforce the notches so as to reduce shear/tension-perpendicular-to-grain splitting at the inside corner of the notch. In one case, metal plate connectors were pressed into each side of the member alongside the notch. For another set of specimens, a screw was inserted up into the wood member alongside the notch. These tests showed that, with minimal reinforcing, strength lost by notching can be easily recovered.

Future work on notched purlins will involve finite element analysis and laboratory testing, with the goal of establishing a procedure to predict strength reduction associated with deep-end notching and strength increases associated with different notch reinforcement methods.

Post Installation Tools

*DR Bohnhoff

Funding: WI Frame Builders Assn.; UW Biological Systems Eng.

Embedded post foundations are largely responsible for the cost-effectiveness of the post-frame building system. However, like other foundation systems, installation of embedded post foundations has its unique challenges. To help overcome some of these difficulties, prototypes of three different tools – a post-hole installation shield, a posthole bottom leveler, and a footing transport and placement cart – were designed by Bohnhoff and tested in 2003. Research in 2004 concentrated on refining the posthole-bottom leveler. Research in 2005 resulted in a new version of the footing transport and placement cart and modifications to the posthole installation shield.

A posthole bottom leveler is a simple, inexpensive device that levels soil at the base of a hole prior to tamping and placement of a precast concrete footing (a.k.a. cookie). The use of

such a device becomes increasingly important as footing diameters increase. Without such a device, it is difficult to ensure that the base of a hole is not tilted or uneven. A tilted base results in a tilted footing and, consequently, a significantly reduced area of contact between the footing and post. Uneven terrain (i.e., high and low points) results in more variant footing stresses and increases the likelihood of future foundation settlement. It is recommended that such a tool be present on any job site where precast concrete footings are being placed.

Sloughing of posthole sides is associated with drilling in noncohesive soils (e.g., sands and gravels with low clay content) that are low density, poorly compacted, very wet due to a recent rain, or because they are poorly drained or saturated because they are near or below the water table. Vibrations that occur when hitting rocks and/or tree roots generally increase the likelihood of posthole collapse. As a posthole side sloughs, the top diameter of the posthole enlarges, which makes it more difficult to throw material away from the posthole by spinning the auger after it has been brought to the surface. It also becomes more difficult for workers to prepare the base of the posthole for a footing, to place the footing, and to properly position, brace and backfill the post, even when planking is used to bridge the large opening. A post-hole installation shield prevents posthole sides from collapsing during hole drilling and any time prior to footing and post installation. It is recommended that all major post-frame companies stock at least one posthole installation shield to use on job sites where conditions make it difficult to maintain proper posthole geometry.

Round, precast footings (a.k.a. cookies), especially those with diameters less than 17 inches, are frequently dropped into postholes. Unfortunately, the likelihood of a "dropped" footing landing properly in a hole is extremely remote, regardless of its size. If one edge of a footing hits first, the result is a localized soil bearing failure – a failure involving the movement and "loosening up" of a good portion of the surrounding soil. To avoid damage to the footing base, some contractors use special tongs to lower smaller footings. Others wrap steel banding around the footing and remove the banding after the footing is in place. Neither method works very well with larger/heavier footings. Footings too large for one person to lift are typically handled with a rough terrain forklift, skid steer loader, front-end loader tractor, or similar piece of equipment. This equipment is used not just to move footings around a job site, but often is also used to lower larger footings into postholes. In addition to the equipment operator, another worker is typically needed to attach/detach footings to/from the equipment and to guide footings so they do not hit posthole sidewalls as they are lowered. In other words, it takes two workers and a large piece of equipment to properly install large precast footings. Using a footing transport and placement cart, a single person can transport and place precast concrete footings as large as 350 lbm and 34 inches in diameter without the use of self-propelled equipment. Any company that stocks and/or routinely uses footings weighing more than 100 lbm should not be without a footing transport and placement cart.

There are no patents protecting the three post installation tools described above. They are provided for public use and to stimulate development of similar tools. In return, we simply ask that any individual or company that uses the designs, or in any way profits from them, help support through donation the post-frame building research effort at the UW-Madison. University research is a non-profit venture that can only be sustained via continual support from those whom it benefits.

Concrete Pier-to-Wood Post Connector Design

*DR Bohnhoff

Funding: UW Biological Systems Eng.; Perma-Column, Inc.

A greater number of post-frame buildings are being constructed using precast or cast-in-place concrete piers. This increased interest in concrete piers can be attributed to the following seven, largely interrelated reasons.

1. Durability. End users have more confidence in the long-term durability of a concrete foundation than they do in a preservative-treated wood foundation.
2. Reduced availability and/or higher cost of CCA-treated lumber. As of December 31, 2003, no wood treater or manufacturer could treat wood with CCA for most residential uses. While posts for agricultural and commercial buildings could still be CCA-treated, the partial ban on CCA significantly reduces the amount of CCA-treated wood, making it more difficult and expensive to obtain.
3. Corrosiveness of CCA alternatives. Alternative CCA treatments include ACQ (alkaline copper quat) and ACC (acid copper chromate). These alternative treatments have a higher copper concentration, resulting in increased galvanic corrosion when metals less noble than copper (e.g., magnesium, zinc, iron, steel, aluminum) are driven into or brought into direct surface contact with the treated wood. Excessive corrosion of metal fasteners is a primary concern to engineers concerned about structural integrity and hence safety of building occupants.
4. Reduced use of preservative-treated lumber. Where possible, engineers try to eliminate preservative-treated lumber because: (a) it costs more than non-treated lumber, (b) it generally requires use of more expensive, less-corrosive fasteners, and (c) the preservatives are pesticides which can make eventual disposal of preservative-treated wood problematic.
5. Lumber length. Lumber becomes increasingly expensive (on a board foot basis) in longer lengths. Additionally, dimension lumber is not readily available in lengths longer than 20 feet. When concrete piers are used, the overall length of wood posts are generally shortened by four to seven feet. This means that engineers are using shorter, less expansive lumber to obtain the same building heights and can also build structures with 20-ft eave heights using unspliced sidewall posts.
6. Ease of building disassembly. Agricultural and commercial buildings have a relatively short functional design life. Therefore, it is beneficial to be able to easily disassemble building components for use in a more functional structure. This is much easier to accomplish when wood posts are attached to concrete piers.
7. Recycling. If history teaches us anything, it is that reuse of lumber treated with a particular preservative is largely dictated by

restrictions on how that lumber may be reused later. Some researchers suggested that the development of good organic-based preservative wood treatments may result in restricted use of all heavy-metal based preservatives, thus making products treated with CCA, ACQ and ACC of little value several years from now. If this is the case, anything that can be done to replace preservative-treated wood with untreated wood may increase the future value of a building.

Despite the increased use of concrete piers in post-frame building construction and the number of post-frame buildings that have been erected on concrete frost walls and grade beam foundations, very little attention has been paid to concrete-to-wood post connections. Common steel brackets used by the post-frame industry to attach wood posts to cast-in-place concrete are treated as pin connections in design because of the lack of bending strength and stiffness of: (a) the steel bracket-to-concrete connection, (b) the steel bracket-to-wood post connection, and/or (c) the steel bracket itself. With concrete-to-post connections that lack bending strength and stiffness, the building designer must rely entirely upon diaphragm action and/or on rigid column-to-truss connections to handle horizontal forces applied to the structure.

In 2005, UW-Madison undergraduates Kyle Bunnow and Aaron Flouro designed a concrete-to-wood post connection with the goal of developing a connection with significant bending strength and stiffness. The design was tested in 2006. Kyle and Aaron entered their design in the ASABE AGCO Student Design Competition and were awarded second place. Also in 2006, conceptual plans for a concrete pier to wood I-post connection were developed. Perma-Column, Inc. has agreed to fabricate precast piers with the connection for full-scale laboratory testing.

Incorporation of Animal Manures as Reinforcing Fillers in HDPE and HDPP

*RM Rowell, EL O'Neill, A Krzysik, D Bossman, DF Gallaway
Funding: Private US company

Animal agriculture is under increasing pressure to produce more and more meat, milk and eggs, giving rise to an increasing amount of manures. In the past, manures have been viewed as a waste by-product used mainly as a fertilizer with a value of 2 to 4 cents per dry pound. We need to change our view of manures from waste to asset. Destroying manures by burning or lagooning may solve the environmental problem, but it adds nothing to animal income.

One alternative is to use manures in industrial products. Wood and agricultural flours and fibers have been used as fillers in thermoplastics. This research program uses swine and cow manures as reinforcing fillers in HDPE and HDPP. This is a win-win situation as it increases the value of the animal manures and decreases the cost and improves mechanical properties of the thermoplastic composites.

Swine manure solids are collected using a flocculation process, removing more than 95% of the manure solids. The solids are dried, mixed with cotton-mill by-products, and composted for 30 days. The composted resource is then compounded with either HDPE or HDPP at different concentrations with and without a compatibilizer. A 40% blend of swine manure with HDPE and 2% MAPE gives a composite with MOE in bending of 1.31 GPa and MOR of 34.7 MPa as compared to unfilled HDPE MOE of 0.75 GPa and MOR of 15.1 MPa.

A mixture of dried cow manure with straw bedding (40% with 2% MAPE) direct from the UW Experimental Farms, compounded with HDPE gives MOE in bending of 2.18 GPa and MOR 21.9 MPa as compared to 40% pine flour with 2% MAPE MOE 2.98 and MOR 33.4 MPa.

High Performance Wood Composite Materials through Activation Bonding

*FS Denes, SO Manolache, V Totolin
Funding: McIntire and Stennis Grant

Wood-based composite materials, including particle boards and fiberboards, are produced from disintegrated waste-wood materials. Generating high-quality composite materials strongly depends on the adhesion between the wood substrate surfaces and the adhesive materials involved.

The main objective of this research is to use plasma-aided technology to modify both wood and lignin-particle surfaces and to generate specific surface functionalities that will enhance adhesion characteristics.

Powdery lignin substrates were exposed separately to oxygen, argon and ammonia plasma environments in a rotating glass plasma reactor and reacted under *in situ* conditions. Thickness swelling of extracted and non-extracted aspen fiberboards decreased in the oxygen-plasma treated samples, while the thickness swelling on ammonia-plasma exposed boards was barely affected.

As expected, the wet strength of all fiberboards was lower than dry strength. Oxygen-plasma treatment of the extracted and non-extracted fiber resulted in the highest dry strength of the fiberboards, whereas oxygen-plasma treatment of the non-extracted fiber resulted in the highest wet strength. Ammonia-plasma treatment of the extracted aspen boards also resulted in a significant increase of the strength values.

Results from these investigations indicate that the cold plasma technique is an efficient approach for surface modification of lignin and wood substrates.

Development of New Treating Equipment Based on Roller Pressing

M Inoue,*RM Rowell
Funding: Wood Res. Inst., Kyoto, Japan

Green lumber can be pressed between two rollers to remove water. The wood will recover to its original thickness after pressing. The roller press can also be used to treat wood with chemicals by immersing the press in the treating solution. The chemical is sorbed by the wood in the thickness recovery process.

Development of Advanced Wood Fiber-Based Composites Based on Fiber Modification

*RM Rowell

Funding: USDA Forest Service

The performance of wood fiber-based composites can be greatly improved by chemically modifying the fiber from which the composite is made. Dimensional stability and water repellency can be greatly improved by bulking the cell wall with bonded chemicals and by using hydrophobic reactants. Decay resistance can be greatly improved using the same chemistries, since keeping water from the micro-organisms is one way to stop or decrease fungal attack.

One technology that has been studied is the reaction of wood with acetic anhydride. The dimensional stability of acetylated wood is greatly increased as is decay resistance. This is a non-toxic approach to wood preservation that is presently under commercial development.

Safety and Health

Community Partners for Healthy Farming Nursery Field Crop Growers Intervention Project

*LJ Chapman, AC Newenhouse, MG Miquelon

Funding: US Ctrs. for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health

Collaborators: UW Biological Systems Eng.; various grower organizations in WI; UW Coop. Ext .Service

This project will accomplish three specific aims.

1. Develop or identify existing control technologies for work performed by Midwestern nursery operations engaged in bedding and garden plants and nursery crop production. We will reduce hazards (and thereby injuries) by developing or identifying controls that reduce exposure to physical work hazards for musculoskeletal and traumatic injuries. The types of controls we will consider include work practices, tools, labor aids, and administrative controls. We will seek out reports from nursery managers, commercial suppliers, university Extension personnel, and others about emerging production practices that could improve both safety and profits. We will also collaborate with university instructors and their students in design and other engineering courses to accomplish this aim.
2. Conduct field research to evaluate the control technologies from #1 above which show the most promise to determine their impact on production and to verify that musculoskeletal risk factors are actually reduced when the practices are adopted. We will undertake small-scale field studies to quantitatively evaluate the hazard-reducing and profit-enhancing aspects of two to four of the best production practices each year. Comparisons will be made in the field or in laboratory situations between accomplishing work by conventional methods and with the improved control technology. Fewer than six subjects in each condition for less than half a day of work are anticipated. Small-scale field studies will also be undertaken on operations that have adopted practices to verify that musculoskeletal risk factors are really reduced.
3. Conduct and evaluate a large, region-wide intervention to promote the best control technologies from #2 above to the 7,888 nursery operations in seven north central states (WI, MN, MI, IA, IL, IN, OH) that produce bedding and garden plants and nursery crops. Disseminate information about the improved work practices through sources that growers already rely on for information about new production methods (e.g., other growers, trade publications, public events, university Extension agents, other private and public sector resource people, the Internet, etc.) Evaluate the interventions with annual mail questionnaires to separate, population-based, rolling probability samples of the study group (n = 650 nursery growers/yr) and the control group (n = 320 New Zealand nursery growers/yr).

Development and Synthesis of Magnetic, Fluorescent, Carbon-Based Nanoparticles that Display an Array of Antigens and Adjuvants in Order to Create a New Class of Vaccines Against Infectious Diseases

*FS Denes, M Sandor, ZS Fabry

Collaborators: UW Ctr. for Plasma-Aided Manuf.; UW Pathology and Laboratory Medicine; UW Sch. of Medicine and Public Health

Objective:

Medical application of plasma-enhanced nanotechnology, including development of nanoparticle-based immune modulatory therapy to treat autoimmune diseases, such as multiple sclerosis and rheumatoid arthritis.

It has been demonstrated that magnetic nanoparticles are specifically taken up by dendritic cells, cells that are critical for initiating immune responses. Experiments are also underway for remote accessing magnetic nanoparticles *in vivo* to generate hypertheramal effects and to selectively "kill" particle-associated cells. Successful results in these investigations will open up a novel way to cure autoimmune diseases that represent an ever-increasing problem to public health.

An MFRC collaborative proposal has recently been submitted that targets health priorities from the state health plan, "Healthiest Wisconsin, 2010," focused specifically on priorities for the development of novel treatment for diseases. An *Invention Disclosure Report* was also submitted to the Wisconsin Alumni Research Foundation for patenting our discoveries.

Use of Plasma-Synthesized Carbon-Based and Specifically Functionalized Nanoparticle Systems in HIV Research and Development of Potential Therapies

*FS Denes, DI Watkins

Collaborators: UW Ctr. for Plasma-Aided Manuf.; UW Sch. of Medicine and Public Health; UW Primate Inst.

Our laboratory uses the macaque animal model to search for and develop effective, novel AIDS vaccine strategies. These investigations use nanoparticles synthesized in the laboratories of the Center for Plasma-Aided Manufacturing (C-PAM) and Biological Systems Engineering using atmospheric pressure,

non-equilibrium technique, small non-toxic carbon-based molecules, which are not only magnetic but can also bind to proteins or small peptides of interest.

To date, there has not been a successful AIDS vaccine in monkey studies or human trials. Considering that almost 40 million people are now HIV-positive, developing a successful vaccine is crucial. One can elicit one or more of the following immune components in a vaccine: antibodies, cytotoxic T cells (CD8+), or helper T cells (CD4+). Antibody-eliciting vaccines have shown little or no promise in combating HIV. CD4+ T cell-eliciting vaccines have not been tested, yet seem to be crucial in fighting both human and simian immunodeficiency viruses.

Recent *in vivo* immunogenicity experiments in our lab have shown that conjugating small SIV peptides to Professor Denes' nanoparticles elicits SIV-specific CD4+ T cells. These induced immune responses in macaques are not only strong, but long-lasting. With these data we are currently writing an NIH R21/R33 grant to determine the importance of eliciting CD4+ T cells prior to infection using these nanoparticles. It is suggested that eliciting these cells will improve the animals' AIDS prognosis. Our collaborators are very excited by the recent nanoparticle vaccine success, and they are confident that C-PAM and BSE researchers will continue their integral part in these joint investigations.

These novel studies could not be done without the work of Ferencz Denes. The multidisciplinary research has been critical in our recent vaccine development, and we hope this collaboration will continue as we set up our future vaccine studies.

Electric Power and Energy Systems

Energy•A•Syst Comprehensive Web-Based Farmstead Energy Self-Assessment Tool Kit

*DJ Reinemann, PW Walsh, SA Sanford, J Kepka, R Hackner, J Hermans

Funding: NCRS Conservation Innovation Grant
Collaborators: UW Biological Systems Eng.; GDS Associates

This project will develop a comprehensive farm energy self-assessment tool and provide an on-line resource center, Energy•A•Syst, so agricultural producers can conduct customized energy analyses. The development of self-assessment tools will allow producers to conduct energy analyses of their current farming practices and production facilities with emphasis on electrical energy, natural gas, propane, and fossil fuel consumption. The self-assessment tools will estimate energy, cost savings, technology transfer feasibility, and environmental conservation and pollution benefits. The Energy•A•Syst site will also provide tools for more detailed on-farm energy audits that local utility representatives or energy service professionals might use. The web site will provide resource materials to producers with reference information to assist in planning, installing, and operating energy efficient technologies.

Another component of the Energy•A•Syst effort will be tools to assess opportunities for renewable energy production (primarily wind, solar, biogas, and biomass combustion). The combined analyses of energy use reduction and non-renewable energy estimation will allow for measuring environmental services and accounting for greenhouse gases.

Food Processing Energy Management

*D Reindl, DJ Reinemann, R Hackner, T Tucker

Funding: WI Focus on Energy
Collaborators: UW Mechanical Eng.; UW Biological Systems Eng.; GDS Associates; Envise

The objectives of this project are to identify and promote energy efficient technologies in food processing plants in Wisconsin with emphasis on dairy plants. Specific activities include:

- Seek and develop methods to promote best practice efficiency opportunities and emerging technologies;
- Develop a strategic plan for the cluster to impact energy efficiency;
- Develop a best practices guide and educational programs on energy efficiency opportunities;
- Coordinate implementation of energy efficient technologies with key industry associations, trade allies that sell efficient equipment to the industry, economic development agencies, and energy utilities.

Agricultural Energy Management Assessment System

*DJ Reinemann, SA Sanford, J Kepka

Funding: WI Focus on Energy
Collaborators: UW Biological Systems Eng.; UW Soil Sci.

This project will develop and test agricultural energy management assessment support materials. Energy management tools will be developed with various levels of technical detail targeted at specific user groups. A simple self-assessment tool will be developed for producers and will be available as a web-based tool. This interactive agricultural energy management assessment system will be incorporated into the Farm•A•Syst and Wisconsin Environmental Management Assessment programs as well as the Wisconsin Focus on Energy local energy service provider resources website, <www.focusonenergy.com>. More detailed energy audit tools will be developed for energy service providers. The program will be piloted in several counties in which energy auditors and county Extension agents will be trained to use these tools. Programs will be offered at Wisconsin Farm Technology Days and at regional seminars.

Food Engineering and Processing

Investigation of UV Treatment of Milk and Milk Products

*DJ Reinemann, JR Bishop, KB Houck

Funding: Pure UV

Collaborators: UW Dairy Sci.; UW Ctr. for Dairy Res.

A novel UV light treatment system is being evaluated for sanitizing milk and milk products. Objectives of this study are to establish the effect of UV treatment on the total psychrotrophic, thermoduric, and spore-forming bacteria load of raw farm milk and the collateral effects of UV treatment on the sensory character of treated milk. The effect of UV treatment on the bacterial load of refrigerated raw farm milk, whey and brine will also be investigated.

Use of Plasma Technology to Decontaminate Surfaces and Air in Food Processing Environments

*FS Denes, SO Manolache, ACL Wong

Funding: Dept. of Homeland Security, Natl. Ctr. for Food Protection and Defense

Two original plasma tools (array electrode reactor and flat plasma reactor systems) were tested for disinfecting surfaces that contact food during the processing environment. Preliminary data from plasma-enhanced disinfection of flat surfaces (project developed for the Department of Homeland Security) indicate that under appropriate experimental conditions, the number of 5 log bacteria-count can be reduced 99.99% in treatment times as short as 3-4 minutes.

Development of Atmospheric Pressure Non-Equilibrium Plasma Technologies for Efficient Disinfection of Milking Machine Teat Cup Liners

*FS Denes, SO Manolache, JM Helgren, DJ Reinemann

Funding: UW Ctr. for Plasma-Aided Manuf.; UW Biological Systems Eng.

An original atmospheric pressure non-equilibrium plasma (AP-NEP) reactor was designed and developed in the laboratories of the Center for Plasma-Aided Manufacturing (C-PAM) and the Biological Systems Engineering Department to disinfect milking machine teat cup liners. (An *Invention Disclosure Report* has been submitted to the Wisconsin Alumni Research Foundation; negotiations are underway with LELY for possible licensing.) Preliminary test results indicate that this novel plasma-enhanced technology allows very efficient disinfection of teat cup liners (non-detectable bacteria levels, plasma-exposure times as low as 30 s to 2 min., high voltage power in the range of 10-50 W/liner, easy handling) without using large amounts of liquid-phase conventional disinfecting agents. The implementation of plasma-enhanced milking systems is expected to considerably reduce mastitis infections.

Plasma-Enhanced Synthesis of Anti-Fouling Thin Layers and Surfaces that Kill Bacteria on Contact AND Atmospheric-Pressure Plasma-Enhanced Disinfection of Various Material Surfaces

*FS Denes, ACL Wong

Collaborators: UW Ctr. for Plasma-aided Manuf.; UW Food Res. Inst.

This research collaboration focuses on using cold plasma technologies to create anti-fouling properties on a variety of materials. A second focus is to develop cold plasma technologies to inactivate microbial pathogens attached to surfaces or in liquids. The resulting research data have applications in many areas, including food processing, medical devices, and textiles.

More than $1.2 million funding comes from federal and private agencies, including USDA, U.S. Department of Homeland Security (USDHS), Office of Naval Research, the American Meat Institute, and several food companies. The collaboration of the Center for Plasma-aided Manufacturing (C-PAM) and the Food Research Institute (FRI) so far has resulted in two patents, five publications, two manuscripts submitted, two in preparation, and multiple presentations at national and international meetings. We have co-advised five graduate students.

Currently this collaboration includes four separate projects funded by USDA, USDHS, and a private company that will continue until November 2007. Depending on future funding, other projects may be initiated that will continue to require both our expertise and the use of C-PAM, Biological Systems Engineering, and FRI facilities.

Plasma-Enhanced Deposition of Antifouling Macromolecular Layers on Material Surfaces Usually Involved in Food Processing Technologies

*FS Denes, SO Manolache, ACL Wong, H Jiang, B Dong

Funding: USDA Natl. Integrated Food Safety Initiative Award; Hatch

Collaborator: UW Food Res. Inst.

If bacteria attach to surfaces, biofilms may form and create economic and health problems in many settings, including those of food and medical industries. Developing new technologies to prevent or at least attenuate biofilm formation is highly desirable.

In this study, plasma-enhanced deposition of polyethylene glycol (PEG)-type structures are examined as possible antifouling materials, and the resulting antifouling mechanisms are investigated. PEG chains are highly flexible and can cause an intense entropic repulsion of protein molecules due to reduced degrees of confirmation freedom of protein macromolecular chains. PEG is also highly water-soluble and, as a result of hydrogen bonds created between the oxygen atoms of PEG and water molecules, a water molecule-based shield is created around PEG macromolecular chains that may contribute to their antifouling behavior.

Three different approaches were considered for depositing PEG-type layers onto stainless steel and silicon rubber surfaces.

1. Deposit thin layer PEG-type networks from various plasma-generated, charged and neutral, volatile, precursor molecular fragments.
2. Graft PEG molecular chains onto $SiCl_2H_2$-, H_2-, and $SiCl_4$-plasma-functionalized surfaces.
3. Generate antifouling layers by cross-linking predeposited PEG structures under oxygen and argon plasma radio frequency plasma environments.

It was shown that plasma-deposited PEG-type structures exhibit significantly-reduced bacterial attachment and biofilm formation in the presence of a mixed culture of *S. typhimurium*, *S. epidermidis*, and *P. fluorescense*. Biofilms developed on these coated surfaces were less stable and easier to remove than those on uncoated surfaces. Future research will involve optimizing plasma-deposition processes to generate highly effective antifouling layers. Antifouling characteristics will be related to the chemical nature and morphologies of PEG-type structures.

Recently it was demonstrated that PECVD-deposition of diamond-hard carbon thin layers can accommodate biologically active layers. The characteristics of these surface layers are under investigation to evaluate their potential application in the preparation of robust bioactive surfaces.

Design, Development and Testing of Novel Atmospheric Pressure Plasma Installations with Scaling-Up Possibilities for Pilot and Industrial Technologies

*FS Denes, SO Manolache

Funding: UW Ctr. for Plasma-Aided Manuf.; UW Biological Systems Eng.; Amer. Meat Inst.
Collaborator: UW Mechanical Eng.

Three original (patents and patent disclosures) atmospheric pressure (AP) plasma reactors were designed and developed at the Center for Plasma-Aided Manufacturing (C-PAM) and the Biological Systems Engineering Department. The reactors are the dense medium plasma (DMP) reactor, the array electrode reactor (AER), the barrier discharge reactor for small dimension cavities (BD-SDC), and the flat-plasma ceramic reactor.

The DMP reactor is based on a digitally controlled, rotating, interchangeable pin array electrode system which generates a volume character of the plasma processes due to the presence of an intense cavitation developed in the reaction media. It can be operated using DC or AC power, and it allows extremely efficient modification of various liquid media (e.g., solutions, suspensions, etc.) in the presence of inert or reactive gases.

The AER installation eliminates the drawbacks of conventional AP gas-phase techniques by using a multi-cylinder/wire electrode array system which allows plasma exposure of various substrates under static or continuous flow system conditions. This electrode configuration assures a uniform flow of plasma gases or gas mixtures through a multitude of cylindrical individual discharges. With the AER, both metal and dielectric materials can be surface-treated uniformly, while the presence of a low dimension gap between the electrode system (usually associated with conventional AP reactors) is not required.

With the BD-SDC tools, electrical discharges can be generated in low dimension dielectric cavities, channels or capillaries by adapting a special electrode/cavity configuration. Embedding the electrodes into dielectric materials and maintaining a certain position of the cavity- or capillary- or channel-volumes relative to these electrodes, AP discharges can be initiated and sustained in capillaries with inner dimensions smaller than 1 mm under batch or continuous system modes.

Rheological Characterization of Gelatin-Xanthan Gum Mixture with Co-Solutes at High Concentration

*S Gunasekaran, F Altay

Funding: Gift Funds

High sugar/gelatin confections tend to become sticky during handling and storage. There is also a need to modify characteristics of gelatin-based products to increase their melting point so as to avoid fast surface remelting and reduce elasticity. Synergistic effects of different additives can solve these problems since no single ingredient can mimic all the properties and functionalities of gelatin. This study investigated the effect of adding xanthan gum to a gelatin-high sugar system.

Mixtures of ingredients, generally in liquid state, undergo vitrification during manufacturing. Therefore, understanding their rheological changes during handling is necessary to control the composition-structure-property relationship which strongly affects consumer preferences. Adapting a polymer science approach to food polymers may be very useful for doing so. Our objective was to investigate the effect of adding xanthan gum on rheological properties of gelatin with co-solutes at high concentration using the Williams, Landel and Ferry (WLF) equation and free-volume theory. Some of the results were:

- For a gelatin-xanthan system, unlike for synthetic polymer systems, there are no universal values for WLF constants *C1o* and *C2o*.
- Adding xanthan decreased the free volume of gel system at 75% total solid content.
- Water has a plasticizing effect on the gel system as observed from the increase in free volume of gels with moisture content.
- Samples with xanthan gum are more resistant (and stable??) to temperature than samples containing only gelatin at 75% total solids because higher αf indicates that molecules collapse faster with temperature.

Effect of Xanthan Gum on Physicochemical Properties of Whey Protein Isolate Stabilized Oil-in-Water Emulsions

*S Gunasekaran, C Sun, MP Richards

The effect of adding xanthan gum (XG) on physicochemical properties of 2 wt% whey protein isolate (WPI) stabilized oil-in-water emulsions containing 20% v/v menhaden oil was investigated by measuring droplet size, viscosity, microstructure, oxidative stability, and creaming profile. In fresh emulsions, adding XG at different concentrations did not show any significant effect on the surface-area-average droplet size (d32). However,

emulsion microstructure and creaming profile indicated that the degree of flocculation is a function of XG concentration. When XG = 0%, there was no flocculation; when XG = 0.02~0.15 wt%, flocculation was limited; when XG = 0.2 wt%, flocculation was extensive, leading to the formation of an emulsion gel; and when XG = 0.5 wt%, there was little or no flocculation. Lipid oxidation of the emulsions was inhibited by the addition of 0.15 wt% or 0.2 wt% XG. In the presence of 0.5 wt% XG, the emulsion exhibited a high yield stress which appreciably inhibited creaming. Nevertheless, adding 0.5 wt% XG was believed to have interacted with unadsorbed WPI in the aqueous phase which inhibited the antioxidant property of WPI. Thus adding 0.5 wt% XG had a net prooxidant effect in the 2 wt% WPI stabilized emulsions containing 20% v/v menhaden oil.

Effects of Protein Concentration and Oil Phase Volume Fraction on the Stability and Rheology of Oil-in-Water Emulsions Stabilized by Whey Protein Isolate

*S Gunasekaran, C Sun, MP Richards

The influences of protein concentration (0.2-2 wt%) and oil phase volume fraction (5-40% v/v) on the emulsion stability and rheological properties were statistically investigated in whey protein isolate (WPI) stabilized oil-in-water (O/W) emulsions containing 0.2 wt% xanthan gum (XG). Data were reported from droplet size, surface charge, creaming index, oxidative stability, and emulsion rheology. The results indicate that increasing WPI concentration significantly ($P < 0.05$),affected droplet size surface charge and oxidative stability, but had little effect on creaming stability and emulsion rheology. Increasing oil phase volume fraction slightly increased droplet size and surface charge and led to a decrease in the rate of lipid oxidation. Oil phase volume fraction played a dominant role in creaming stability and emulsion viscosity. Dynamic rheological measurements indicated the O/W emulsions may undergo a behavior transition from an entropic polymer gel to an enthalpic particle gel when oil phase volume fraction increased from 20% v/v to 40% v/v.

Error Correction of Confocal Microscopy Images for *in Situ* Food Microstructure Evaluation

*S Gunasekaran, S Ko
Funding: Hatch Funds.

In situ evaluation of dynamic changes in food microstructure using confocal laser scanning microscopy suffers from errors associated with acquiring images and subsequent 3-D image reconstruction. Image processing tools we developed successfully corrected 2-D image layers for various errors, including aberrations due to refractive index mismatch, light attenuation with sample depth, uneven intensity across image layers, and image misalignment. These techniques were validated using a simulated image with different illumination conditions. As example applications, dynamic changes in microstructure of process cheese during heating and gelation of β-lactoglobulin (whey protein) were studied *in situ*. The error-corrected image layers were used to reconstruct a 3-D composite image of fat globules in cheese. These techniques will allow objective evaluation of *in situ* changes in 3-D microstructural features in different foods and can produce a 3-D composite image suitable for an objective evaluation of 3-D characteristics of image features of interest.

Biodegradability of Sub-100 nm β-lactoglobulin (BLG) Nanoparticles

*S Gunasekaran, S Ko
Funding: Gift Funds

BLG nanoparticles were prepared in the sub-100 nm range with a narrow size distribution by a dissolvation method. Preheating the BLG solution to 60°C and subsequent pH adjustment to 9.0 helped reduce particle size. The average particle size obtained with and without preheating were 131±8 nm and 59±5 nm, respectively. Preheating also improved the uniformity of particles as measured by the half bandwidth of 80% distribution. Under similar conditions, BLG nanoparticles were smaller and more uniform than those produced using bovine serum albumin (BSA) due to lower hydrophobic interactions of BLG than that of BSA. The BGL nanoparticles were also more stable than BSA nanoparticles in acidic and neutral environments with and without an added proteolytic enzyme. This could be attributed to the denser matrix structure and to a smaller amount of the basic amino acid composition of BLG compared to BSA.

Broadband Viscoelastic Spectroscopy of Foods

*S Gunasekaran, RS Lakes, AP Singh, E Sritham
Funding: USDA Natl. Res. Initiative

The method of reduced variables or time-temperature superposition (TTS) is widely used to characterize materials, especially polymers, over an extended frequency range that is not attainable in most commercially available instruments. In the TTS method, a number of frequency (or time) sweep tests are carried out at different temperatures, and a master curve is computed using shift factors to infer results over an extended time or frequency range. However, this technique works only for materials that are thermorheologically simple and over a limited range of about three decades of time or frequency. Materials for which the curves do not overlap by making a horizontal shift on the frequency axis are thermorheologically complex. Even for seemingly thermorheologically simple materials such as polystyrene, when experiments were carried out for six decades, data could not be superimposed using TTS.

Food systems are inherently complex with multiple constituents rendering them thermorheologically complex. Thus, it is necessary to acquire data directly over a wide frequency range in a single test to truly characterize such complex materials. Even a single-relaxation-time process described by an exponential in

the time domain or a Debye peak in the frequency domain occupies about one decade 5. A material with multiple relaxation times, therefore, would require conducting measurements over a wider time or frequency range. Currently, food rheology is in the realm of narrow frequency range, often from 0.1 to 10 Hz, mainly due to the lack of available test instrumentation and analytical methodologies.

Problems associated with TTS can be circumvented using broadband viscoelastic spectroscopy (BVS) capable of directly measuring viscoelastic properties over an extended frequency range. BVS has been used for a variety of materials ranging from soft rubber polymers to metal alloys. Data over nearly eleven decades of frequency have been gathered successfully in a single test to characterize these materials 6-8. Such a broadband viscoelastic spectroscopy of foods has never been done. With the availability of a broadband micromechanics rheometer at UW-Madison, we propose to pioneer a comprehensive rheological characterization of different food systems over a broad frequency range. We expect our investigation will find previously unknown rheological behavior and help further our understanding of the kinetics of molecular mobility and interactions in complex foods. One such application is the study of stress-induced flow of water in high-moisture foods (e.g., cheese) which can affect viscoelastic phenomena such as relaxation, creep, and dynamic response. Measurements over an extended frequency range can help us understand the movement of water within a food matrix.

Importance and Measurement of Yield Stress in Foods

*S Gunasekaran, A Sun

Yield stress is a well-recognized physical and rheological property of liquids and solids. It is classically defined as the minimum shear stress that must be applied to a material to initiate flow. Knowledge and understanding of yield stress is essential for successful industrial operations such as processing, handling, storage, and transportation. Yield stress can also serve as a measure of quality control and product evaluation.

Materials that exhibit yield stress are typically multiphase systems. Examples include cements, soils, paints, printing inks, pastes, greases, and a variety of food products (salad dressings, sauces, spreads). It is common to characterize yield stress with mathematical models such as the Hershel-Bulkley equation. Depending on the flow properties (i.e., consistency index *K*, flow index *n*), a material can be classified as Bingham viscous-plastic (e.g., tooth paste), shear-thickening (e.g., corn starch solution), or shear-thinning (e.g., purées) fluids with yield stress. Other models have also been used to describe fluid behavior exhibiting a yield value. For example, the Casson equation was adopted to model the flow behavior of melted chocolate and blood.

The objective of this study was to evaluate an alternative method to measure yield stress of thick, concentrated, spreadable foods using a modified squeezing-flow apparatus, the UW Meltmeter, developed by our research group to measure melt and flow behavior of cheeses.

Micro- and Nano-Encapsulation of Ginseng to Improve Bioavailability and Functional Properties

*S Gunasekaran, S Ko, J Zhou, W-S Kang

Funding: Gift funds

We are investigating micro- and nano-encapsulation of ginseng to improve its bioavailability and functional properties. Ginseng is one of the oldest, most widely recognized traditional herbal treatments for a myriad of potential health benefits. Both Asian ginseng (Panax ginseng) and American ginseng (Panax quinquefolium) are very important medicinal plants. Ginseng is typically available commercially as a dried root. The basis of the drying process is to extend the shelf-life of ginseng by reducing moisture content and water activity. Fresh ginseng root normally contains approximately 75% moisture which can render bioactive compounds such as ginsenosides.

Primary bioactive components of ginseng are generally recognized to be a group of triterpene saponins, also called ginsenosides. They are the main active constituents in ginseng and include neutral ginsenosides and malonyl ginsenosides. Their many biological and pharmacological activities include antitumor, chemopreventive, antiphlogistic, immunomodulating, and antidiabetic activities and activities on the cardiovascular, central nervous, and endocrinal systems. For example, ginsenoside Rh2 currently is sought for its bioactive activities that can reduce proliferation of a variety of cultured cancer cells and can influence apoptosis. Rg3 has been shown to possess antitumor properties and to affect drug-resistant cultured cancer cells.

Use of Whey Proteins for Encapsulation and Controlled Delivery Applications

*S Gunasekaran, S Ko

Funding: Hatch funds

Whey proteins can be used as hydrogels and nanoparticle systems for encapsulation and controlled release of bioactive compounds. Whey protein concentrate (WPC) hydrogels exhibit pH-sensitive swelling behavior with minimum swelling ratio near the isoelectric point (*pI*) of whey proteins (~5.1). The release kinetic of the hydrogels parallels that of their swelling ability. Controlled drug release behavior of WPC hydrogels was studied using caffeine as a model drug. Consistent with the swelling behavior, the release of the encapsulated model drug from the hydrogels was slower when the pH was below *pI* than it was at pH above *pI*. Swelling and release behavior of WPC hydrogels can be changed easily with different layers of alginate coating. Nanoparticles of about 60 nm average particle size were prepared from β-lactoglobulin (BLG) using a desolvation method by preheating BLG solution to 60°C. Preheating also improved particle size uniformity. The stability of the particles was investigated by degradation experiments at neutral and acidic conditions. BLG nanoparticles are more stable at neutral conditions than at acid conditions, with and without proteolytic enzymes.

Mixing and Simulation Research

*RK Connelly

Funding: UW Foundation; NC1023; UW Graduate Sch.

The Mixograph is a planetary pin mixer that has been used for decades to evaluate the hydration of flour. In the past, the response curve was studied as a source of more information about the strength and development rate of the dough. These studies have recently shifted to evaluating the dynamics of the mixer itself, rather than the response curve. Computational fluid dynamics (CFD) can be used to gain greater understanding about a mixer by evaluating both local and global measures of dispersive and distributive mixing, such as mixing index and efficiency. CFD results are known to be subject to several types of error, such as discretization error, if not properly guarded against. In this study, a basic Newtonian corn syrup is used so that the approach and methodology of meshing the Mixograph may be evaluated without complex results from more difficult fluids. The 3D mesh of the Mixograph is built as an extension of a 2D mesh. The 2D mesh is first optimized with respect to pin movement simulation, mesh discretization, and time step size. Several methods of qualitative and quantitative analysis are used to resolve differences between the different proposed meshes. Once optimized for minimizing error and required calculation resources, the 2D mesh is expanded into 3D for observing local and bulk mixing properties. It is shown that the Mixograph does not experience as much vertical mixing and cross-sectional mixing over the same time span. Additionally, it is observed that different pin positions are more efficient than others. These meshes and results will be used to develop future studies around more complex fluids, and these results will be presented at the 2007 Institute of Food Technologists Annual Meeting.

A new short-term project was begun to look at the simulation of mixing in a simple in-line mixer, which is being validated collaboratively using NMR by Kathryn McCarthy at UC-Davis. This project is under the umbrella of the multi-state project NC1023, "Improvement of thermal and alternative processes for foods." Mixing is a universal unit operation addressed within this project that impacts a wide range of food processing issues but is poorly understood. The multi-state project is an opportunity to bring together these two different sets of expertise to better define and validate these results to increase understanding of mixing and build trust in the simulation results.

Another recently begun project in this category is to extend the fundamental study of the mixing of viscous, viscoelastic materials to simple but relevant vane rheometer geometry. The approach is to combine use of classical rheological techniques to characterize and model the viscoelastic responses of the materials studied, computational fluid dynamics using commercially available finite element method techniques for viscoelastic constitutive models to simulate the flow and mixing, and experimental torque measurement and flow visualization to validate and improve the simulations. The results are expected to show the effect of a wider range of realistic viscoelastic responses on mixing in a relevant geometry. Currently, geometry input is complete, and initial simulations using a fixed top surface boundary with generalized Newtonian models have been run. Work is ongoing to use a deformable top surface and planned to extend the simulations to simple viscoelastic fluid models based on real materials. We also expect to do experimental validation by using a high speed digital video camera to capture trace paths and surface shapes, as well by measuring the torque generated. This work will better define mixing behavior of complex fluids with validated simulation results, thus increasing understanding of mixing and building trust in CFD simulation results.

Investigation of the Effect of Mixing Intensity on Dough Development and Rheological Property Measurement

*RK Connelly

Funding: USDA Hatch

Doughs made from wheat flour were mixed at varying speeds using the 50g Farinograph, a twin sigma blade mixer, and the 10g Reomixer, a planetary pin mixer similar to the Mixograph. Work and strain input to reach peak torque at different speeds were used to compare the mixing intensity of the two mixers. Initial testing with Mennel Milling hard and spring flour in the Farinograph indicated the presence of a minimum critical mixing speed of 43 rpm for dough to fully develop and a maximum critical mixing speed of 103 rpm where dough development became independent of mixing speed. At that speed, dough development became dependent on work input rather than strain input. Subsequent tests conducted on both yeasted and non-yeasted dough mixed in the Reomixer and the Farinograph using Bay State Bouncer again identified the minimum critical speed in the Farinograph as 43 rpm. Critical points were validated by mixing and baking tests. Future work with different drive belts and gears for a wider speed range and an additional torque sensor is planned to obtain these values in the Reomixer. Extensibility tests showed a general increase in extensibility with increased speeding both mixers. Rheology tests did not identify any trends based on speed, although there were significant differences between the mixers. These results were presented as posters at the 2006 Institute of Food Technologists Annual Meeting in Orlando, FL, June 24-28, and at the American Association of Cereal Chemists International, World Grains Summit: Foods and Beverages in San Francisco, CA, September 17-20, 2006.

Computational Fluid Dynamics Simulation Integrated into Crystallization Process Modeling Research and Food Engineering Instruction

*RK Connelly, RW Hartel

Funding: UW Graduate Sch.; USDA Natl. Res. Initiative

The overall goal of our newly funded USDA NRI integrated research and education project is to foster use of computational fluid dynamics (CFD) simulation technology as an advanced engineering tool for solving problems in food process engineering in order to enhance food quality attributes. The educational component will involve training food engineers by engaging them in the creation of teaching tools using CFD simulation that illustrate

hard to visualize good engineering concepts, thus improving basic undergraduate food engineering instruction for food science students. As graduate food engineering students develop advanced CFD simulation skills in their research, they can then help undergraduates in food engineering learn how to properly set up and analyze simulations of food processes. Those results will become teaching tools to illustrate engineering concepts for undergraduate food science students in introductory food engineering courses.

On the research side, CFD simulation of momentum, heat, and mass transfer will be coupled with the particle population balance equation and lactose crystallization kinetic models in research aimed at the industrially relevant problem of controlling the crystal size distribution during lactose crystallization. The resulting predictions of processing parameter effects will be used to optimize crystallization processes. When combined with validation experiments, the simulations will also be used to test the ability of the kinetic models to provide realistic results, thus increasing understanding of the kinetics of crystallization or suggesting new research decisions. As knowledge of the capabilities of CFD simulation as a food engineering problem solving and process optimization tool becomes more widespread, the potential of this powerful technology will be recognized and used in the food industry.

Machinery and Harvesting

Manure Application Equipment Compaction Study

*JL Posner, G Sanford, RT Schuler
Funding: UW Agronomy; UW Biological Systems Eng.
Collaborators: UW Agronomy; UW Biological Systems Eng.

Compaction caused by manure application equipment was evaluated in privately-owned production fields and at the UW Agricultural Research Station in Arlington, WI. The equipment wheel traffic created compacted soil based on increased cone penetration resistance and reduced corn yield in the trafficked area. Yield for the total fields was not significantly reduced due to wheel traffic.

Krusenbaum Dairy Farm Study

*JL Posner, RT Schuler
Funding: UW Agronomy; UW Biological Systems Eng.
Collaborators: UW Agronomy; UW Biological Systems Eng.

Since 1990 scientists have followed changes and decision-making during the transition on the Krusenbaum Dairy Farm near East Troy, WI, from a confinement dairy to a rotational grazing dairy and to organic milk production. The time associated with machinery operation has been substantially reduced due to increased grazing. Machinery cost has not been significantly reduced. Initially, tractors and tillage, seeding, and harvesting machinery were purchased as used. Later, forage equipment was purchased as new, thus creating higher fixed costs.

Fractional Harvest of Biomass Alfalfa

*KJ Shinners
Funding: Hatch
Collaborators: UW Biological Systems Eng.

Harvest-fractionation of alfalfa involved stripping leaves from stem at harvest time using a tined rotor modified from a snap bean stripping rotor. The amount of leaf tissue stripped from the stem depends upon the penetration depth of the stripping rotor and the tine-to-tip speed ratio. In 2006, a biomass-type alfalfa from the University of Minnesota and USDA Agricultural Research Service was established on five acres at the UW Arlington Agricultural Research Station. This alfalfa type was bred to be harvested only once or twice per year and will be taller and have less tendency to lodge at later maturity stages. These traits allow less frequent harvesting than conventional forage-type alfalfa, reducing harvest costs. The stems can be readily field-dried after leaf stripping, but processing and storing the high-moisture leaf fraction is problematic. One storage option is to blend an amendment with the leaves to bring overall moisture down to ensiling moisture, but this option adds cost and complexity. Another harvesting option involves expressing the plant juice from the leaf fraction to bring the press cake to ensiling moisture. Normally, juice expression of the whole plant involves macerating the crop to increase its specific surface area and improve juice yield. However, alfalfa leaves are quite succulent and juice can be expressed without maceration first. For all plant fractions, maceration tended to improve process yield only slightly, primarily because the tearing and shredding action of the screw press tended to mask the physical effects of maceration. The solids content of the leaf juice fraction was always greater than that of the stems or whole plant. The solids content of the juice in the leaf fraction dropped with maturity. This was because the forage-type alfalfa lodged as it became mature, and it was difficult to strip leaves from the lodged plant without greater penetration of the stripping rotor into the crop canopy. This caused the stripped fraction to have more stem, thus diluting the leaf fraction.

Engineering Aspects of Harvesting and Storing Corn Stover as a Biomass Feedstock

*KJ Shinners, PJ Weimer, JG Coors, RE Muck
Funding: DOE; USDA Agric. Res. Service; John Deere Co.
Collaborators: UW Biological Systems Eng.; USDA Dairy Forage Res. Ctr.; UW Agronomy

This research deals with the engineering aspects of biomass feedstock production from corn crop residues. Biomass feedstock can be used to produce ethanol fuel by enzymatic hydrolysis of cellulose, to produce energy gasification or direct combustion at power plants, or to produce paper pulp. The objectives of this project are to:

- Modify the grain combine harvester to allow single-pass harvesting of grain and stover fractions in separate crop streams;
- Assess the fractional yield and moisture of stover when harvesting with this machine;

- Assess the storage characteristics of wet stover harvested with this machine;
- Begin a preliminary study of the potential of pre-treating the stover in the silo to add value to the feedstock prior to ethanol production.

Three combine harvester configurations were considered: (1) conventional snapper head with the material other-than-grain (MOG) size reduced and rear collected, (2) forage harvester whole-plant corn head (total plant through combine) with MOG size reduced and rear collected, and (3) a unique head which captures the stalk, leaf and some husk fractions before they enter the combine; size reduces and side-discharges the MOG> The combine harvester was equipped with instruments to measure machine fuel use and to measure power to the header and rear size reduction and material handling components. Average stover yield was 0.18, 5.0 and 6.1 MG DM/ha with the ear snapper, stalk gathering and whole-plant heads, respectively. Fuel use per unit area increased by 60 and 100% for the latter two heads compared to the conventional ear snapper head. Power consumed at the rear size reduction components when harvesting with the whole-plant head did not limit material throughput, but rather re-circulation of material through the flail chopper and frequent plugging limited material flow. Greatest improvement in bulk density was obtained by compressing loads in the transport vehicle, rather than by greater size reduction. Wet storage in silo bags continues to be successful, with low levels of fermentation products and DM losses. Ambient, on-farm pre-treatment of corn stover using dilute acids, ozone, and lime are underway in lab-scale silos.

Harvest, Processing and Storage of Perennial Forages as Biomass Feedstocks

*KJ Shinners, PJ Weimer, RE Muck

Funding: USDA Agric. Res. Service

Collaborators: UW Biological Systems Eng.; USDA Dairy Forage Res. Ctr.

The objective of this work is to quantify the performance of various systems used to harvest and store perennial grasses intended for use as biomass feedstocks. Two grasses are being considered: reed canarygrass and switchgrass. Reed canarygrass dried slightly faster than switchgrass because the former crop had lower yield. When dried in a swath, both crops dried to baling moisture by the afternoon of the second day. There was no advantage to using either impeller or roll conditioners to improve field drying rate. Bales were formed in July, August and October, 2005 using the following wrapping treatments: sisal twine, plastic twine, film wrap, and net wrap. These bales were stored outdoors to determine storage characteristics. A control treatment stored indoors was used for comparison. A final treatment involved baling right after cutting and wrapping the bales in a tube of plastic film for preservation by anaerobic fermentation. The bales were removed from storage in June, 2006. Dry bales stored outdoors for 9 and 11 months averaged 3.4, 7.7, 8.3 and 14.9% DM loss for bales wrapped with plastic film, net wrap, plastic twine, and sisal twine, respectively. Bales stored indoors averaged 3.0% DM loss. Bales stored outdoors had variable moisture and spatially dependent quality. Considerable degradation occurred in the outer 50 mm of all bale wrap systems and also with any material in contact with soil. Preservation ensiling in a tube of plastic film produced average DM losses of 1.1%. Bio-refineries will require a product with uniform quality, moisture, and physical and chemical properties. The most uniform biomass feedstock was generated by storing indoors or ensiling in a tube of plastic film. Baling and then ensiling without field wilting was successful, indicating that a single-pass system could be developed to reduce harvesting and storage costs. In 2006, a new slate of storage techniques was evaluated. Outdoor storage using net wrap, film wrap, and tarps was compared to storing indoors. All outdoor treatments were stored on a well-drained, raised surface to reduce spoilage in the base of the bale. A separate study considered the effects of initial moisture on physical and chemical properties of bales wrapped in a film tube and preserved by ensiling. A final study will look at direct harvest with a forage harvester. Three treatments will be considered: whole-crop, high-cut (mainly leaves), and low-cut (mainly stems). The first two treatments will be preserved by ensiling and the last will be dried and baled. Material placed in storage in 2006 will be removed in 2007.

Natural Resources and Environment

Densifying Agricultural Plastic Films into Packages Making Them More Convenient to Recycle

*BJ Holmes, KJ Shinners

Funding: UW Solid Waste Res. Ctr.; UW Biological Systems Eng.

Objectives:

1. Improve Wisconsin's environment by developing a system for safely and conveniently delivering used agricultural plastic films to recycling centers or landfills.
2. Develop and test the effectiveness of a system for removing contaminants (water, soil, forage) from used agricultural plastic film.
3. Develop and test a system for densifying plastic film for convenient and economical transport to recycling centers.
4. Communicate results of the debris removal and densification system to representatives of the plastics recycling industry to determine if they can find a market for low density polyethylene.

Use of agricultural plastic films has increased dramatically in recent years as low-cost forage storages and greenhouses for plants and animals have become more widely used. Plastic is seen throughout the countryside as: bunker silo and silage pile covers; silo bags; bale wraps or bags; bale tubes; and hoop structures with transparent covers. These films have a relatively short useful life from several months to several years before they become a waste product. Current disposal of waste plastic film is handled by on-farm dumping or burning, municipal landfill, and recycling. Recycling and municipal landfilling are usually acceptable environmental disposal methods, while on-farm dumping and burning raise environmental concerns and are illegal.

On-farm dumping and burning are convenient and low-cost. However, regulatory agencies throughout the country have raised concerns about the dioxin released during open burning of waste materials in general. Increased use and burning of agricultural plastic films pose health concerns for farmers, their families, their neighbors, and the customers who consume farm products. The Air Quality Division of the Wisconsin Department of Natural Resources (DNR), has conducted listening sessions to determine how open burning can be reduced. Recommendation 6 of the *Open Burning and Backyard Dumping Stakeholder* report to the DNR Board in December of 2003 states:

> *Agricultural Wastes. We recommend an effort at the state level to develop workable efficient systems for the collection and recycling or disposal of agricultural plastic films and bags such as silage bags. These widely used agricultural plastic products can be very bulky, making them difficult and inconvenient to properly dispose. Farmers need convenient low cost alternatives in addition to information about regulations*.

Recycling is limited because the films become soiled, and they are bulky and difficult to handle and relatively expensive to transport to landfills or recycling centers. Until recently, recyclers required extremely clean plastic, a requirement most used agricultural plastic could not meet. Also there is no convenient method for removing feed particles and soil to make them more acceptable to recyclers. Recently-developed products made from recycled plastic have lower requirements for cleanliness, which has opened new markets for recycled agricultural plastic.

A machine to clean and densify plastic films has been developed and tested. The machine's cleaning portion uses rotating rubber rolls to pull the film through the machine. The rolls are powered by the hydraulics of a farm tractor through hydraulic pumps. As the plastic is drawn through the machine, rotating brushes scour dirt and debris from all surfaces. The plastic accumulates in a cage behind the cleaning portion of the machine. A hydraulic cylinder forces a plate against the accumulated plastic to compact it into a bale. Once sufficient film has accumulated, the compacted bale is tied and ejected from the cage so it can be picked up and put into storage prior to transport to a recycling center.

The machine was able to remove on average 70% of contaminants in all situations. Under certain conditions, it was able to remove up to 85% of contaminants. Wet soil was the most difficult to remove. The machine was able to compact plastic film to a density of about 38 lbs/ft^3.

Characterizing Thermal Pollution in Urban Landscapes

*AM Thompson, K Kim, JM Norman

Funding: USDA Hatch

Collaborators: UW Biological Systems Eng.; UW Soil Sci.

Impervious surfaces in urban areas are a source of thermal pollution in cold climates and threaten the health of cold-water ecosystems. Impervious surfaces absorb energy from the sun. During a rainfall/runoff event, runoff absorbs some of that heat and is warmed. The higher runoff temperatures can raise the temperature of receiving waters. Stream temperature is a major limiting factor for cold-water fisheries, and increases in water temperature can result in biological impairment to aquatic habitat.

A field study has been conducted at the UW West Madison Agricultural Research Station (WMARS): 1) to study increases in pavement temperature and the subsequent transfer of the heat to stormwater runoff, and 2) to compare the hydrologic and thermal response of similar sized areas of asphalt and sod. Asphalt and sod plots (15 $\times$ 9 m) have been instrumented to measure rainfall intensity and spatial depth, rainfall temperature, solar radiation, wind speed, air temperature, pavement temperature at various depths and locations, sod temperature at various depths and locations, soil moisture, runoff temperature, and flow rate. The system is designed to capture both natural and simulated rainfall/runoff events. Two seasons of simulated field experiments have been conducted. Natural rainfall/runoff events will be monitored during the summer of 2007.

A LaGrangian-stochastic model was developed to simulate thermal runoff from impermeable surfaces. The model employs an approach based on the framework of the mass response functions (MRFs) originally developed for non-point source pollutant transport in watersheds. The model is the first attempt to apply MRFs to thermal runoff modeling. The model has been applied to the data collected from the field study conducted at WMARS. The model successfully reproduced the temperature of impermeable surface and runoff.

Rock cribs are a current mitigation strategy to reduce runoff temperature prior to runoff entering thermally sensitive waters. A laboratory study was conducted to quantify the effectiveness of rock cribs on reducing runoff temperature. Their effectiveness depends on the influent temperature, the initial crib temperature, the amount of water in the crib prior to stormwater entering the crib, and the size of the crib. Results from the laboratory experiments have been used to validate and modify a numerical routine that predicts heat transfer between the stone and the water and, ultimately, the effluent water temperature. The model will be used to develop design standards for the use of rock cribs as temperature reduction devices.

New Polymer Technologies for Controlling Soil and Phosphorus Loss from Farm Fields

*AM Thompson, JM Norman, C Baxter, TC Hunt, A Roa-Espinosa

Funding: UW Consortium for Ext. and Res. in Agric. and Natural Resources (CERANR)

Collaborators: UW Biological Systems Eng.; UW Soil Sci.; UW-Platteville; Soil Net LLC

Soil erosion from agricultural lands and the subsequent transport of sediment and sediment-bound nutrients (particularly P) are serious problems that contribute to surface water pollution and threaten agricultural sustainability. Raindrop impact on bare soil destabilizes soil aggregates and leads to surface sealing, increasing runoff volumes and soil loss. Surface-applied polyacrylamide (PAM) decreases soil erosion by stabilizing soil structure and reducing surface sealing. Previous research has shown

that surface-applied PAM reduces erosion at relatively high application rates (20-80 kg/ha). The purpose of this study was to evaluate the effectiveness and longevity of a new PAM technology, applied at a low rate of 5 kg/ha, to reduce sediment and P loss from rain-fed agricultural fields. Plot-scale field rainfall simulations (75 mm/hr) were conducted on individual plots at three test intervals (2 days, 3 weeks and 10 weeks after PAM application) on two soil types (Ashdale silt loam and Plano silt loam). The new polymer formulation, Soil Net EM-1000-50, reduced runoff volumes an average of 100%, 59% and 55% at the 2-day, 3-week and 10-week test intervals, respectively. Sediment loss was reduced an average of 100%, 80% and 74% at the 2-day, 3-week and 10-week test intervals, respectively. P loss was reduced an average of 100%, 75% and 83% at the 2-day, 3-week and 10-week intervals, respectively. Overall, larger rainfall depths were applied to treatment plots prior to runoff generation compared to controls. The most significant differences were observed at the 2-day test interval when an average of 141 mm of rainfall was applied to the PAM-treated plots before runoff started, compared to 82 mm for the controls. The polymer treatment was more effective on the Ashdale silt loam, which had received manure during the two years preceding the rainfall simulations. Manure application was the primary difference between the two soils (manure was not applied to the Plano silt loam), suggesting that the PAM treatment reacts more favorably to manured soils. The low cost of this new PAM technology (~$25/ha), coupled with its success in reducing runoff, sediment and P loss over a 10-week period, makes EM-1000-50 an attractive, economically feasible management practice for agricultural producers in rain-fed regions.

Effectiveness of Urban Lawns to Hydrologically Disconnect Impervious Areas

*AM Thompson, R Bannerman, KW Potter

Funding: WI Dept. of Natural Resources

Collaborators: UW Biological Systems Eng.; WI Dept. of Natural Resources; US Geological Survey; UW Civil & Env. Eng.

Accurate stormwater runoff prediction depends on the amount of impervious surface area within a watershed and the level of connectedness of that impervious area. Although the degree of imperviousness is relatively simple to quantify, the level of connectedness is not. The issue is further complicated by the lack of understanding of the hydrologic response of urban semi-pervious areas. The goal of this project is to quantify the rainfall/runoff response of urban residential lawns and determine their ability to hydrologically disconnect impervious surfaces. Two seasons of field experiments on residential lawns in Dane County, WI, have been conducted.

During the first season, lawn run-on from rooftop downspouts was simulated on six residential lawns in Madison, WI. Runoff was measured at two distances from the downspouts for three run-on rates, and inundated areas were delineated as a function of distance from the downspout. During the second field season, experiments were conducted to further quantify the relationship between inundated area and distance from a downspout. Experiments were conducted on six young lawns (< 10 yrs old) in Cross Plains, WI, and on six well-established lawns (> 50 yrs old) in Madison, WI, at two run-on rates. Inundated areas were periodically delineated until steady-state conditions were achieved.

Regression models were fit to the combined distance-area data sets, and a power function (area = $1.20 \times \text{distance}^{1.26}$) produced the highest R^2. An infiltration-loss model was used to estimate runoff depths, and several estimates for infiltration were evaluated by comparing predicted and observed runoff depths. An average abstraction rate for all lawns was estimated and applied to the model. The observed steady-state infiltration rate for each test resulted in a RMSE of 1.0 cm. The average steady-state infiltration rate for each lawn resulted in a RMSE of 2.0 cm. Lawn-specific abstraction rates did not significantly improve the RMSE (1.98 cm). Use of the predictive relationship for inundated area as a function of distance increased the RMSE to 2.2 cm. Measured infiltration rates from standard double-ring tests and reported infiltration rates for loam soils resulted in RMSEs of 3.3 cm and 5.7 cm, respectively.

Infiltration and Pollutant Removal Capacity of Engineered Soils for Use in Urban Bioretention Basins

*AM Thompson

Funding: UW Graduate Sch.; WI Dept. of Natural Resources

Collaborators: UW Biological Systems Eng.; WI Dept. of Natural Resources

Bioretention is a relatively new management practice to treat urban stormwater. A bioretention basin is a gravity flow system which combines plants, mulch, engineered soil (sand, soil and compost), and piping at the base to allow drainage. Stormwater runoff is focused into and temporarily stored in the basin, allowing contaminated water to infiltrate through the engineered media. As it infiltrates through the media, physical, chemical, and biological processes treat this water. After passing through the media, the water either infiltrates into the surrounding native soil where it can enhance groundwater recharge, or excess water is discharged to a stable outlet. The goals of this study were to determine physical and hydraulic properties and pollutant removal capabilities of engineered soils.

Laboratory experiments using flow-through columns were conducted on engineered soils with percentages of sand, soil and compost ranging from 30-60%, 20-50%, and 20-50%, respectively, Columns were 15.2 cm in diameter, contained 30.5 cm of engineered soil, and were maintained at a constant water head of 30.5 cm. Infiltrative capacity, saturated hydraulic conductivity, porosity, bulk density, and moisture-holding capacity were measured. All soil mixtures provided rapid infiltration rates and high saturated hydraulic conductivity. Porosity, bulk density, and moisture-holding capacity were primarily influenced by the percentage of compost in each mixture.

Flow-through studies using synthetic stormwater were conducted to determine pollutant removal rates from the same engineered soil mixtures. Columns were 5.1 cm in diameter and contained 10.2 cm of engineered soil. Synthetic stormwater was prepared by dissolving cadmium, copper and zinc at concentrations

of 0.5, 0.5 and 6.25 ppm, respectively (representative of typical urban stormwater). The synthetic stormwater was passed through the engineered soil columns at a rate approximately equal to the saturated hydraulic conductivity for 8 hours, and the removal efficiencies of each dissolved metal species were monitored over time. Each engineered soil mixture provided more than 95% removal of all three metals. Concentrations were increased by more than an order of magnitude to determine breakthrough curves of each metal. The ability of the engineered soils to remove dissolved contaminants over longer periods of time is related to the composite cation exchange capacity of the mixture. Soils with higher exchange capacities removed the metals more efficiently for longer periods.

Surface Water Quality Impacts of Management Intensive Rotational Grazing

*AM Thompson, FW Madison

Funding: USDA Natural Resources and Conservation Service; UW Ctr. for Integrated Agric. Systems; WI Dept. of Agric., Trade, and Consumer Protection

Collaborators: UW Biological Systems Eng.; UW Soil Sci.; UW Agronomy

Management Intensive Rotational Grazing (MIRG) is a farming system that has grown in acceptance in Wisconsin. Herd sizes are increasing, and animals are being over-wintered in a variety of settings, some of which may create environmental problems. The objective of this project is to further understanding of the environmental impacts of MIRG through: 1) quantification of sediment and P loads from over-wintering areas, and 2) quantification of spatial and temporal variations in soil and vegetation characteristics in over-wintering areas. Two research sites representing different soil and physiographic regions in Wisconsin were selected: 1) one on coarse-textured soils in central Wisconsin and 2) one on red clay soils in eastern Wisconsin.

Surface runoff monitoring stations were installed between November 2004 and March 2005 at the outlet of each over-wintering area. Heat tape and insulation pipes were installed, and electricity was run directly to the runoff collection sites to improve runoff monitoring during periods of freezing and thawing. On both sites, intensive topography surveys were conducted to build digital elevation models of the watersheds.

Flow rate and water quality samples were collected on the central Wisconsin farm for spring snowmelt and runoff events in 2005 and 2006 and on the eastern Wisconsin farm in 2006. Intensive soil and vegetation sampling was conducted on both farms in October 2005 and May, June, August and September 2006. Five paddocks in each over-wintering watershed were chosen, based on proximity to the watershed outlet and the percent of the paddock draining to the outlet. Twenty samples were taken in each of five paddocks. Sampling locations were determined by applying a stratified sampling scheme to each of the roughly equal area partitions staked out in each paddock and were recorded by GPS coordinates. At each sampling location, leaf area index (Li-Cor LAI-2000), forage yield (rising plate meter), stem density, thatch cover, and thatch thickness were measured. Surface soil samples (top 6 cm) were taken at each sampling location and analyzed for soil P and nitrate-nitrogen in October 2005. Surface soil samples (top 2 cm) were taken at each sampling location and analyzed for pH, organic matter, available P, and total P in September 2006. Soil surface roughness (rill meter) and soil compaction (constant rate cone penetrometer) were measured in May, June, August and September 2006.

Potential environmental impacts from over-wintering depend on animal density, amount of time in over-wintering areas, and texture of soils. Surface water quality monitoring will continue through 2007.

Use of Cold Plasma to Functionalize Fibers for Filtration Research

*FS Denes, RM Rowell, C Hunt

Funding: USDA Forest Service, Forest Products Lab; UW-Madison

The main objective of these investigations is the use of low-pressure, non-equilibrium plasma-cross-linked surfaces of cellulose fiber previously embedded into poly(acrylic acid) to improve their ability to absorb contaminants from water. A rotating and a stationary parallel plate plasma reactor is considered to functionalize cellulose and low-cost wood fibers.

The plasma-modified fibers will be used to remove both cations and anions, as well as other toxic organics, from contaminated water. These investigations are performed in collaboration with PPL-Madison and industrial partners for the evaluation of scaling-up possibilities of the plasma technology.

Removal of Heavy Metals from Acid Mine Drainage in a National Forest

*RM Rowell, T Boving

Funding: Coop. Inst. for Coastal and Estuarine Env. Technol. (CICEET)

Filters containing modified bark have been placed in a drainage site in Rhode Island. City water runoff is run through two filter units, removing soluble heavy metal ions (Mn, Zn, Fe, Al). The filters were installed in fall, 2006. The first set of data shows that the fiber-based filters, along with a change in pH to 5, removes more than 80% of the iron and aluminum.

Use of Cold Plasma to Functionalize Fibers for Filtration Research

*FS Denes, RM Rowell

Funding: private US company

Cold plasma is being used to modify the surface of wood fibers to improve their ability to sorb contaminants from water. A small rotating reactor functionalizes low-cost wood fiber that will then be made into fiber webs using the Rando web-forming technology. The chemically modified fiber mats will be used to

remove both cations and anions, as well as other toxic organics, from contaminated water. We will work with the University of Wisconsin on water runoff on campus.

Evaluation of Temporal and Spatial Sediment Dynamics in Agricultural Fields using Lanthanide Tracers

*KG Karthikeyan, PD Gaebler, PE Cabot, SM McClure, JD Grande, PS Miller

Funding: USDA Natl. Res. Initiative

Collaborators: UW Biological Systems Eng.; UW Agric. Res. Stations; Case Western Reserve U.; USDA Agric. Res. Service

A fully integrated hillslope scale hydrologic monitoring project is being performed to evaluate sediment transport mechanisms by combining a network of surface runoff sensors monitoring the temporal and spatial occurrence of runoff with lanthanide (rare earth element [REE] oxides) tracer analysis, and radiometric (^{7}Be, ^{210}Pb, ^{137}Cs) fingerprinting. These methods have been combined on a hillslope with a Plano silt loam soil at Arlington, WI, under two tillage orientations (contour and up-and-down slope) and two corn-harvesting schemes (grain and silage). Multi-year data were collected from a series of natural rainfall/runoff events. The major goal is to determine spatial patterns of runoff and sediment movement for different agricultural management systems. To delineate hydrologically active areas and sediment source areas during an event, an array of surface runoff sensors was placed in each plot. The 40-ft hillslope was divided into three pieces within which different types of soil-REE (Gd, Nd, Pr)-oxide mixtures were applied. Both surficial soil and edge-of-field samples were collected to quantify translocation of tagged soil within the field and off-site sediment, respectively. Surficial soil samples were collected from nine bands, 60 cm apart, covering the entire hillslope. The redistribution of REE-tagged soils and REE concentration in suspended sediments are being used to delineate source regions and determine characteristic transport distances. Preliminary data indicate a good correspondence between the sedigraph peaks and contributions from the various REE segments. Our results suggest the suitability of using REE-tagging technique to acquire information on spatial and temporal patterns of sediment movement in agricultural fields.

A Spatially Explicit Model Simulating Soil Phosphorus Erosion, Transport and Deposition

*KG Karthikeyan, PS Miller, CC Molling, JM Norman, LW Good

Funding: USDA Natl. Integrated Water Quality Program, Integrated Res., Educ. and Ext. Applications

Collaborators: UW Biological Systems Eng.; UW Soil Sci.; WI Discovery Farms Program; UW Agric. Res. Stations

Agricultural land use can be a significant contributor to non-point-pollution of surface waters. A main pollutant is phosphorus (P) which enters surface waters via runoff in both dissolved and particulate-bound forms. The goal of this research is to use a process-level model to quantify P losses from farm fields under different management options and then to extend the use of this model to recommend practices that will minimize water quality degradation. The objectives are to add sediment loss and P-chemistry components to an existing Precision Agricultural Landscape Modeling System (PALMS) and to evaluate key runoff parameters with measurements on several field plots. PALMS, a spatially explicit runoff and erosion model, has been modified to include equations representing P mobilization, deposition, dissolution, and transport. 4D-P is a spatially and temporally distributed agricultural P-cycling model built as part of PALMS. 4D-P is an extension of the P-modeling systems developed and incorporated in EPIC and SWAT. Five sub-modules comprise 4D-P: INITP, a 3-D P soil initializing sub-module; PSSL, a P-cycling single soil layer sub-module; PMOVE, a chemical transport sub-module; PTILL, a tillage and fertilizer sub-module; and PSUM, a chemical transport aggregator that tracks and accounts for P redistribution across the landscape. Each module will track P cycling at various time steps from seconds for PMOVE to single event occurrences such as tillage operations in PTILL. Results from the model are being compared to observations taken with runoff/erosion collectors at three Wisconsin farm fields over four years. Annual PALMS estimates of P loss are being compared with those from SNAP+, maps of the spatial patterns of P erosion and deposition from PALMS are being created, and field management changes that may affect amounts and patterns of P loss and deposition are being evaluated.

Evaluation of Temporal and Spatial Sediment Dynamics in Agricultural Fields using Naturally-Occurring and Fallout Radionuclides

*KG Karthikeyan, PE Cabot, A Stubblefield, PJ Whiting, G Matisoff, PD Gaebler, SM McClure, JD Grande

Funding: USDA Natl. Res. Initiative

Collaborators: UW Biological Systems Eng.; UW Agric. Res. Stations; Case Western Reserve U.; USDA Agric. Res. Service

Sediment yield from specific erosional mechanisms is difficult to quantify in agricultural settings. However, management and understanding of erosional processes can benefit from improved process description. Novel techniques for tracing and fingerprinting soil movement in response to thunderstorm activity are being tested in agricultural fields. Two erosion plots (one with contour tillage, one with up-down tillage) were installed on a hillslope planted to corn on a Plano silt loam soil at Arlington, WI. Within the framework of an erosion plot study, soil depth distributions and runoff concentrations of the radionuclides ^{137}Cs, ^{210}Pb, and ^{7}Be were determined, lanthanide-tagged soil applied, and a surface runoff sensor network installed. The objectives were to quantify rill and sheetwash erosional mechanisms for different agricultural management techniques and to investigate the implications of our findings for phosphorus export. Radionuclides have characteristic depth-distributions in surface soils as a result of the time and mechanism of delivery and land use practices. Thus, the radionuclide concentrations of runoff sediment can be used to estimate from what depth sediment eroded. Preliminary

data show strong temporal variation in sediment ^{7}Be activity in relation to storm intensity and sediment yield. ^{7}Be activity varies inversely with sediment yield. We interpret this to indicate periods of peak runoff resulting in rill incision and the access of low ^{7}Be sediment deeper in the profile. Radionuclide data are being modeled using the Simultaneous Rill-Sheet Erosion Model. The program uses the depth distributions in a mass balance approach to determine the depth and area of rill and sheet erosion on the plot that best matches the sediment and radionuclide yield for each event.

Storage of Sediments and Particulate-Bound Phosphorus in an Agricultural Landscape

*KG Karthikeyan, PE Cabot, P Nowak, RC Lathrop

Funding: US Env. Protection Agency (STAR Program) – Nutrient Sci. for Improved Watershed Mgmt. Program

Collaborators: UW Biological Systems Eng.; UW Rural Sociology; WI Dept. of Natural Resources

This study fosters more effective landscape targeting of non-point problems by analyzing sediment and phosphorus (P) accumulation in landscape "depressions." These depressions are of particular interest to the study of P delivery from farm fields because they may be acting to reduce the overall watershed area that contributes to non-point source pollution. Thus, the study elucidates the disproportionate influence of specific landscape features by abetting or mitigating non-point source pollution. The potential for colluvial storage zones and unchanneled landscape depressions to alter the temporal pattern of constituent delivery and to interrupt the sediment and P transfer continuums was assessed. A more complete understanding of these continuums is needed in watersheds dominated by colluvial landscape features in order to accurately manage for P delivery from upland agricultural areas to downstream receiving waters.

This study examined the influence landscape depressional zones and colluvial sinks have on sediment and P redistribution in a small (50.6 ha) internally-drained Wisconsin agricultural subwatershed. Colluvial storage and erosion-contributing locations were cored and evaluated using ^{137}Cs methodology. A sediment accumulation rate of 2.0 mm/yr for 1952-2004 was estimated in depressional zones using ^{137}Cs stratigraphic analysis and integrated with total P (TP), water-extractable P (WEP) and P sorption characteristics for sampled soils. Erodible hillslope soils surrounding depressions not only exhibited a greater particulate P (PP) loss potential, but also represented a significant dissolved P (DP) source from surface increments (<10 cm), as supported by elevated surficial WEP levels, equilibrium P concentration at zero sorption (EPC_0), and degree of P sorption saturation (DPS_{WEP}). For instance, WEP levels were 14.9-1.0 mg/kg in depressional soils as compared with 38.2-0.2 mg/kg for erodible soils. Below 10 cm, WEP in erosional areas was almost negligible. Watershed morphology dictated that PP and DP transported from erosional locations would be delivered to internally-drained areas. Results indicated subsurface infiltration and colluvial immobilization dominantly affect both PP and DP fate in depressional zones, as evidenced by greater overall TP (primarily PP) and subsurface (>10 cm) WEP. Mean soil TP in plow-layer increments (0-30 cm) was 921 mg/kg in depressional zones, reflecting P enrichment in the upper solum, as compared with 523 mg/kg in erosional locations. The estimated sediment accumulation rate was used to approximate TP accumulation in depressional zones at rates between 3.14 and 2.16 mg/kg/yr. Depressional zones appeared to act as DP sinks, as labile P penetrated deeper (>30 cm) in the soil profile where soil P sorption capacities were still large. Depressional locations also exhibited lower EPC_0 and DPS_{WEP} values than erosional sites, thereby functioning as P sinks. In general, internally-drained watersheds may store PP and DP for long periods, depending on soil sorption capacities remaining large and a lack of runoff spillage events, thus acting as significant buffers against off-site P migration. P-buffering soils cannot store P indefinitely, however, and eventually will become oversaturated and contribute to runoff P losses. Not accounting for depressional zone influences in low-relief watersheds may also yield overestimated sediment and P loss predictions by modeling approaches.

In-Stream Sediment and Phosphorus Dynamics in Agricultural Watersheds

*KG Karthikeyan, NL Huisman, PE Cabot

Funding: USDA CSREES

Suspended sediments originating from agricultural lands are one of the primary agents responsible for transporting nutrients and other non-point source pollutants. In-stream sediments, in particular, play a critical role in linking phosphorus (P) transport between the landscape and downstream water bodies.

Three experimental techniques, i.e., radiometric (^{7}Be, ^{210}Pb, ^{137}Cs) fingerprinting, P uptake-release, and catchment-scale monitoring, are being concurrently applied to systematically characterize and quantify in-stream processes controlling sediment and P movement in small agricultural watersheds. Specific objectives are: a) to determine short- and long-term deposition/resuspension rates, sediment age (residence time), origin, and transport distance in suspended sediments from both rainfall/runoff and snowmelt events; b) to obtain a relationship between sediment age/origin to P uptake and buffer capacity; c) to determine P dynamics (exchangeability, fractionation, bioavailability) in bed and suspended sediments in streams receiving drainage from contrasting animal feeding operation types (small dairy farms *vs*. regulated large farms); and d) to assess the state of equilibrium of flow from monitored catchments with respect to P status of the sediments.

Appropriate sites have been selected to isolate upland fields, small and large animal operations, as well as representing different stream orders (first, second and third). Four sampling stations will be monitored throughout the study. Two stations are located at a controlled cross-section, and two stations will be monitored using a 1-ft and a 1.5-ft Parshall flume. Installation of field instrumentation included automated rain gages, Parshall flumes, and continuous streamflow (ISCO-type) samplers. Baseflow samples are being collected since December 2006. Results generated will facilitate a better understanding and quantification of nutrient and sediment transport processes as a function of spatial scales and P input characteristics.

Development of In-Field Sensors to Evaluate Temporal and Spatial Sediment Dynamics of Runoff Generation in Agricultural Fields

*KG Karthikeyan, SM McClure, PE Cabot, PD Gaebler, PS Miller, JD Grande

Funding: USDA Natl. Res. Initiative

Collaborators: UW Biological Systems Eng.; UW Agric. Res. Stations; Case Western Reserve U.; USDA Agric. Res. Service

It has been proposed that only a fraction of a given hillslope contributes at any given time to the runoff and sediment delivery from a particular event. To delineate the extent of these hydrologically active areas (HAAs), sensors have been used to monitor runoff in both real time and on smaller spatial (fraction of an acre) scales. The major objective of this research was to develop an in-field surface runoff sensor suitable for an agricultural field expected to deliver, depending on conditions, enormous amounts of sediments within a very short time. This study is part of a larger, on-going project being conducted to evaluate sediment transport dynamics by combining a network of surface runoff sensors with lanthanide-tagged soils and radiometric fingerprinting. Field sites include four paired plots of similar topography but distinctly different agricultural management practices: corn harvested for grain and silage, with tillage orientations along the contour and up-and-down the slope. The runoff sensors contain an IC chip design comprising a voltage regulator and a hex Schmitt trigger. The sensor operates in a current loop calibrated to be 4 mA when no water is present and 20 mA when water bridges a section of the circuit. To delineate HAAs and sediment source areas during an event, an array of the aforementioned sensors was placed in each plot. Several storm events of varying magnitudes were sampled during summer 2006 to assess the temporal and spatial occurrence of runoff. Preliminary data from this study suggest that the field runoff sensor design: a) was capable of registering water-ponding levels during most events until sediment deposition terminated functionality; b) could be used to confirm HAA concepts of runoff, sediment and pollutant generation; and c) could be useful for evaluating process-based erosion prediction models.

Characterization of Phosphorus Forms in Snowmelt Runoff from Three Corn Management Systems

*KG Karthikeyan, JC Panuska, PS Miller, RC Lathrop, JM Norman

Funding: US Env. Protection Agency (STAR Program) – Nutrient Sci. for Improved Watershed Mgmt. Program

Collaborators: WI Dept. of Natural Resources; UW Soil Sci.

Information on phosphorus (P) transport in agricultural landscapes has been mainly generated for rainfall/runoff events from both plot and field-scale studies. Data on P losses and the forms of P from snowmelt and rain-on-snow runoff events (i.e., frost/melt events) are limited. The processes governing detachment and transport of sediment differ significantly between the snowmelt and growing season time periods. In this study, a systems approach was used on three hydrologically isolated hillslope tracts (3.7 × 36.6 m) where natural snowmelt and rain-on-snow runoff were collected using bulk overland flow samplers. All fields were planted in corn (with conservation tillage-fall chisel plow) but had extremes in residue cover created by different harvesting schemes. The corn harvesting schemes considered in this study were grain (CG, high residue), silage (CS, low residue), and silage with fall manure application (SM, intermediate). Runoff samples were analyzed for total solids, volatile solids, and different forms of P (dissolved *vs*. particulate bound). During the frost/melt period, an inverse relationship was noted between runoff amount and percent residue cover, with the largest median runoff volume generated from sites with CG treatment. Early in the melt process, frozen soil limited soil loss and favored transport of clay-sized particles and organic matter, while overall soil loss increased later in the melt process. Median total P (TP) and dissolved reactive P (DRP) concentrations for SM were greater than those for the CG and CS treatments, which were similar. The DRP loading from the SM plot was thought to result mainly from the pre-melt manure P input. Transport of particulate-bound P was the principal mechanism for P export. The SM treatment had the highest sediment TP concentrations, suggesting that melt runoff from fields with recently applied manure is likely to have higher P content than from fields with greater crop residue coverage. The total sediment and P loss during the frost-free period were greater (~98%) than those for the frost/melt period (~2%). The greatest difference in runoff, chemical concentrations and loading among sites during the frost-free period existed between the CG and the CS sites. The highest sediment TP concentrations were found in the smallest (<2 and 2-10 μm) particle size classes.

Soluble Phosphorus Extraction and Recovery from Anaerobically Digested Dairy Manure

*KG Karthikeyan, K Gungor

Funding: WI Fertilizer Res. Council

The major goal of this study was to investigate the feasibility of developing a phosphorus (P) recovery system for anaerobically digested dairy manure (digestate). Effluent samples were collected from six on-farm anaerobic digesters in July 2005 from five dairy operations in Wisconsin: Double S, Gordondale, Stencil, Tinedale, and Wholesome. Wholesome dairy has two digesters (Wholesome-East and Wholesome-West), while the other operations have only one. All effluent samples, with the exception of Double S, were obtained directly downstream of the digesters. Since the Double S digester has no direct access to the effluent, the sample was collected downstream of the solids separator. Average water-extractable P (WEP) of these digester effluents was comparable: 2.9, 2.9, 2.8, 2.8, 2.4, and 2.5 g/kg for Double S, Gordondale, Stencil, Tinedale, Wholesome-East, and Wholesome-West, respectively. However, differences were observed in the ratio of WEP to total P (TP). The WEP/TP ratios

were 36.9, 26.5, 43.1, 35.6, 32.4 and 38.2% for the corresponding samples. The lowest and highest WEP/TP ratio was for samples from Gordondale and Stencil, respectively. P fractionation of Gordondale effluent was performed using a Retsch automated sieve shaker. Six sieves with openings of 1000, 500, 250, 106, 53, and 25 μm were used. Percentage of P retained by each sieve was 34.8% (1000 μm), 21.6% (500 μm), 11.0% (250 μm), 5.4% (106 μm), 5.2% (53 μm), and 22.0% (25 μm). P in anaerobically digested effluent was partitioned into two major size fractions: 67.4 and 22% of P in size ranges of >250 and 25-53 μm, respectively.

Digestate sample (liquid portion from the mechanical separator) was collected from the downstream portion of anaerobic digester at Gordondale and was used for struvite recovery experiments in spring 2006. The digestate contained a total solids level of 3.5% with most of the P distributed in the finer-sized fractions (<53 μm). The digestate was directly subjected to chemical treatment for P recovery. Sodium hydroxide and magnesium chloride were used to promote formation of large settleable flocs containing P. Results indicate that adding 1-2 g of magnesium/g of manure P and 3.2 g of NaOH per liter of digestate was able to concentrate as much as 70% of P from the liquid to the sludge fraction, with a minimum settling period of 4 h. Furthermore, this treatment sequence resulted in lowering the WEP fraction as compared to that in untreated digestate. Applying manure with low WEP/TP ratio to agricultural soils would reduce P availability in runoff.

Determination of Phosphorus Speciation in Dairy Manure using X-ray Powder Diffraction and X-ray Adsorption Near Edge Structure Spectroscopy

*KG Karthikeyan, K Gungor
Funding: USDA CSREES

Intensive manure application is an important source of diffuse phosphorus (P) pollution. P availability from animal manure is influenced by its chemical speciation. The major objective of this study was to investigate P speciation in raw (influent) and anaerobically digested (effluent) dairy manure with an emphasis on calcium (Ca) and magnesium (Mg) phosphate phases. Influent and effluent from an on-farm digester in Wisconsin were sampled and sieved, and the 25-53 μm size fraction was dried for X-ray powder diffraction (XRPD) and P K-edge X-ray adsorption near edge structure (XANES) analyses. Struvite ($MgNH_4PO_4X6H_2O$) was identified in both the influent and effluent manure using XRPD. Qualitative analysis of P K-edge XANES spectra indicated that the Ca orthophosphate phases, except dicalcium phosphate anhydrous (DCPA) or monetite ($CaHPO_4$), were not abundant in dairy manure. Linear combination fitting of the P standard compounds showed that 57.0 and 43.0% of P was associated with DCPA and struvite, respectively, in the influent. In the effluent, 78.2% of P was present as struvite and 21.8% of P was associated with hydroxylapatite. The P speciation shifted towards Mg orthophosphates and least soluble Ca orthophosphates following anaerobic digestion. Similarity between the aqueous orthophosphate (aq-PO_4), newberyite ($MgHPO_4X3H_2O$), and struvite spectra can cause inaccurate P speciation determin-ation if dairy manure is analyzed using only XANES spectros-copy; however, XANES can be used in conjunction with XRPD to quantify the distribution of inorganic P species in animal manure.

Reducing Phosphorus Concentration in Lactating Dairy Diets Based on By-Products of the Corn Distilling Industry

*KG Karthikeyan, LE Armantano, A Ozkaynak, A Roa-Espinosa
Funding: USDA CSREES
Collaborators: UW Biological Systems Eng.; UW Dairy Sci.; Soil Net LLC

Ethanol production from corn is a growing industry and has recently garnered considerable interest. Stillage, the by-product of ethanol production, is used as an animal feed, but the excess phosphorus (P) content in stillage could lead to dietary P levels that are incompatible with P-based nutrient management plans. It is desirable, therefore, to reduce the P content of thin stillage while retaining as much mass and nutritive value. The major goal is to determine the effectiveness of well-known physical-chemical treatment methods to reduce P levels in thin stillage. A secondary objective is to characterize P distribution in different forms in thin stillage. Thin stillage from a local ethanol producer with a total solids (TS) level of 7% and a total P (TP) concentration of 1300 mg/L was used. About 98% of the P in thin stillage was in the dissolved form, which, in turn, was dominated by the inorganic P fraction. The dissolved organic P level was between 200-450 mg/L with about 58% existing as phytate P (determined by enzymatic hydrolysis). Batch tests are being performed to determine the ability of chemical coagulants (alum, $FeCl_3$, lime) and flocculants (cationic/anionic polymers) to reduce P levels in thin stillage. Preliminary data indicate that lime is significantly more effective than the acidic coagulants (alum, $FeCl_3$) and can reduce as much as 85% of TP in the supernatant. However, lime addition resulted in lowering the supernatant TS and suspended solids (SS) levels only by 16 and 31%, respectively, which could be significantly improved to 23 and 72% for TS and SS by adding an anionic polymer. While alum addition effectively sequesters P in the settled fraction, no solids pre-concentration was observed. It seems that a suitable coagulant-flocculant treatment combination could be formulated to reduce P content in thin stillage which would create more opportunities for its use in lactating dairy diets. The intent is to concentrate P stream to facilitate shipment to areas of lower livestock density where it could be used as a fertilizer or perhaps as a P supplement in non-ruminant diets.

Manure Solidification and Phosphorus Concentration Using Biopolymers

*KG Karthikeyan, V Sharma, A Roa-Espinosa
Funding: WI Fertilizer Res. Council
Collaborators: UW Biological Systems Eng., Soil Net LLC

This project focuses on using polymers as flocculants with major emphasis on the suitability of biopolymers to concentrate phosphorus (P) and solids in dairy manure. Specifically, biopolymers synthesized from readily-available crop sources and fibers

prepared from local residue sources will be tested for their ability to solidify flushed dairy manure. Manure samples were collected on a dairy farm near Madison at three different collection points: a) flushed manure upstream of a mechanical solid-liquid separator; b) liquid stream from the separator prior to discharge into a storage lagoon; and c) solid-stream from the separator. These samples are being analyzed for various physico-chemical characteristics including pH, solids content, and P concentration in various forms. Biopolymers of varying charge and charge-densities synthesized from crop sources were obtained from our project collaborator, Dr. A. Roa-Espinosa, Soil Net LLC. Bench-scale flocculation studies are underway to determine the effect of biopolymer dosage, pH, and manure solids content in influencing concentration of P. Further studies include solidifying flocculated manure solids using fibers and determining P extractability, exchangeability, and availability in the solidified manure product. Our treatment system is expected to produce solidified manure with high P content and of sufficient stability to facilitate off-farm transport to P-deficient areas or long-term storage. This treatment technology is expected to result in a flexible, easy-to-adopt, economical practice for agricultural producers.

Sorption of the Antibiotic Tetracycline to Humic Mineral Complexes

*KG Karthikeyan, C Gu, JA Pedersen

Funding: WI Groundwater Coordinating Council; UW Water Resources Inst.

Collaborators: UW Biological Systems Eng.; UW Soil Sci.

Antibiotics are used extensively in human therapy, veterinary medicine, and as animal husbandry growth promoters. Detection of antibiotics as emerging contaminants in surface and ground waters raises concerns about their presence. Our recent statewide survey detected eight compounds in five classes in decreasing order of frequency : tetracyclines and trimethoprim > sulfonamides > macrolides > fluoroquinolones. Our ability to predict the fate and mobility of antibiotics is hampered by a lack of information on fundamental processes governing their environmental reactivity. The sorption process is particularly important as it influences the mobility and transport of antibiotics in surface and subsurface environments and affects their propensity to undergo transformation reactions.

The high affinity between natural organic matter and soil minerals typically results in an association of these two phases in soils and subsurface environments. This study investigated the surface interaction of Elliott soil humic acid (ESHA) with Al hydrous oxide (HAO) and the ability of these complexes to sorb the antibiotic tetracycline. Strong interaction between ESHA and HAO led to ESHA-promoted dissolution of HAO and surface charge reversal. The ESHA-HAO sorption-desorption isotherms were successfully described using a modified Langmuir model. A surface coverage affinity parameter and a hysteresis coefficient were required to account for the heterogeneity of HAO surface and ESHA and sorption-desorption reversibility, respectively. Ligand exchange was proposed as the major interaction mechanism, and the edge Al atoms on HAO surface were considered as the sorption sites for ESHA macromolecules. Sorption results were compared for the binary ESHA-tetracycline and HAO-tetracycline systems and the ternary HAO-ESHA-tetracycline system. The coating of ESHA on HAO significantly suppressed tetracycline sorption levels, attributable to altered HAO surface charge characteristics and competition between ESHA and tetracycline for potential sorption sites. We expect our results to increase understanding of environmental behavior of tetracyclines, one of the most frequently detected antibiotic compounds.

EXTENSION

Dairy Production

Research and Extension Grants

*DW Kammel

As a chair of the modernization work group of the UW Cooperative Extension's Dairy Team, I was asked to help coordinate and develop proposals for the Dairy Industry Revitalization Grants as part of a USDA request. I am the primary contact for the following projects.

- Dairy Industry Revitalization Grants, USDA:
  Dairy Modernization Website, $17,000;
  Dairy Modernization Construction Cost Database, $14,200;
  Dairy Producer Modernization Survey, $15,000.
- Developing Dairy Modernization Planning Teams, USDA, $60,800.
- Dairy Modernization Team Training, USDA, $12,025.
- Regional Dairy Modernization Workshops, USDA, $6,250.
- Odor Control Workshops, USDA, $9,775.
- A Comparison of Traditional and Composted Bedded Barn Housing Systems for Dairy Cattle, WIS0M218. UW Consortium Project: P Clark, LE Bauman, PT Kivlin, DW Kammel, $22,091.
- A Comparison of Tillage Methods Used Within Composting Bedded Pack Barn Systems for Dairy Cattle, WIS0M222. UW Consortium Project: S Kelm, LE Bauman, PT Kivlin, DW Kammel, $50,290.

Milking Parlor Management User Group

*DJ Reinemann, K Bolton

Funding: UW Coop. Ext. Service

Collaborators: UW Biological Systems Eng.; UW Coop. Ext. Service

The objective of this project is to develop a self-sustaining user group focused on milking parlor management. The modern milking parlor is a data collection center for the dairy farm. Twice daily visual inspection of cows occurs in parlors that are not automated. In automated parlors, milk yield and other animal health and behavior data are collected during milking using a variety of sensors. These data have the potential to substantially improve the profitability of a dairy farm as well as improve detection of animal health issues and thereby improve animal welfare. These potentials are seldom used to their fullest capacity, however. National and international competitiveness in dairy production will increasingly rely on better information management to improve profitability, food safety, and animal welfare.

Development of an International Web-Based Educational Program for Machine Milking

*DJ Reinemann

Funding: Assn. of Equipment Manufacturers

The goal is to combine the efforts of international experts to develop a web-based educational program for milking and milk quality advisors. An international group of experts was assembled to develop a comprehensive curriculum covering the principles of machine milking, milking machine design standards, and milking machine testing, and began creating digital instructional media from the milking machine curriculum already developed by my Milking Instruction and Research Lab. We are coordinating this effort with milking manufacturers and milk plants in the U.S., Australia, New Zealand, and the U.K.

Dairy Production and Profitability

*BJ Holmes, DJ Reinemann, DW Kammel, SA Sanford

Funding: UW Coop. Ext. Service; Dairy Industry Revitalization Grant through UW Dairy Team

Collaborators: UW Biological Systems Eng.; UW Dairy Sci.; UW Ctr. for Dairy Profitability; UW Milking Res. and Instruction Lab; U. of Minn.; U. of Ill.; Iowa State U.; MidWest Plan Service; Four-States Dairy Programming Group

Increasing profitability on dairy farms requires proper selection of facilities for housing, feeding, and milking. The following strategies have been proposed.

- Enhance milk production efficiency by improving cattle environment, including long day lighting which has the benefit of improving the safety of workers as they work in the barn.
- Reduce electric hazards and expenses by improving the efficiency of electrical energy use.
- Increase milk harvesting profitability by properly selecting milking equipment and facilities.
- Improve efficiency of feed storage and handling through better methods of providing balanced diets and ample feeding space.
- Enhance dairy industry modernization by encouraging selection of profitable facilities.
- Protect water quality with improved methods of handling and storing manure, silage leachate, and milking center wastewater.

In collaboration with companies, other universities, and other UW departments, faculty planned and participated in conferences on a variety of dairy-related topics. We have developed publications and software to inform farmers and their advisors on farmstead planning, feed storage, feeding, animal housing, milking, energy efficiency, and manure handling systems.

Faculty have aligned themselves with self-directed teams such as the UW Cooperative Extension Dairy Team and the Four-State Dairy Programming effort. Faculty have assumed leadership roles within the Dairy Team. Extension educational programs related to dairy will be coordinated within a team.

The Dairy Modernization workgroup of the UW Cooperative Extension Dairy Team developed and is marketing a collection of

materials on a CD (*Milking Parlor Start-up*, *Low Cost Parlor and Dairy Housing and Manure Management Alternatives*) for use by agents, instructors at vocational/technical schools, and farmers to help with decision-making when transitioning from stall barn milking to milking in a remodeled parlor and housing cows in freestall barns. A full size model, low-cost parlor stall has been built and displayed at many farm shows throughout the state. This exhibit has attracted much attention to the Dairy Modernization program.

Funding through a USDA-supported project is helping to develop:

- Low-cost milking parlor display;
- Dairy modernization website;
- Design and management options for low-cost, retrofitted milking parlors;
- Dairy producer modernization survey for farms under 100 cows;
- Developing dairy modernization planning teams;
- Dairy modernization planning team training;
- Regional modernization planning workshops;
- Odor control workshop;
- MWPS *Dairy Freestall Housing and Equipment Handbook* revision development;
- Milking technology workshops and CD development;
- Milking parlor management user group;
- Heat abatement in dairy barns;
- Developing dairy modernization planning teams in northern Wisconsin.

Maintaining Forage Quality from Harvest through Storage and Feeding

*BJ Holmes, RT Schuler, KJ Shinners, RE Muck

Funding: UW Coop. Ext. Service; UW Biological Systems Eng.; USDA Dairy Forage Res. Ctr.

Collaborators: UW Coop. Ext. Team Forage; UW Agronomy

Forage is an extremely valuable component of the feed for dairy and beef animals. The quality of forage as delivered has a significant impact on the production efficiency of these animals. However, losses in feed quantity and quality through harvest, storage, and feeding are very high on many dairy and livestock farms. The following practices contribute to these losses.

- Hay exposed to precipitation.
- Hay harvested too moist.
- Hay stored without adequate protection from precipitation.
- Hay and corn silage harvested too dry or too wet.
- Haylage and corn silage inadequately packed and/or covered in bunker silos, piles, and silo bags.
- Haylage and corn silage improperly removed from bunker silos, piles, and silo bags.
- Corn silage improperly processed.
- Improper use of inoculants and additives that are intended to enhance forage fermentation and preservation.

Presentations were made at Midwest Forage Association meetings, Forage Field Days, and county extension meetings to encourage producers to improve management in these areas. Articles on these subjects have appeared in conference proceedings, the *Crop Manager* newsletter and on the UW Cooperative Extension Team Forage website, <www.uwex.edu/ces/crops/uwforage.htm>. Computer spreadsheets were developed as decision aids and are also available at this website.

A major effort was made to plan and prepare papers for the NRAES "Silage for Dairy Farms" conference held in 2006. At this conference, one speaker promoted the concept of spreading cut forage in wide swaths without use of conditioning rolls. Members of our group have been trying to counter this concept as not viable with current equipment.

Forage production members of Team Forage have encouraged producers to select appropriate varieties, to properly adjust equipment, and to harvest at the correct stage of maturity to enhance yield and quality. Our group has been working to preserve and feed as much of that yield and quality as possible. As recommended practices are adopted, the efficiency of forage production and livestock feeding will improve. The Harvest and Storage Work Group of Team Forage has established a website, <www.uwex.edu/ces/crops/uwforage/storage.htm>, for access to publications and software related to these topics.

Electric Power and Energy Systems

Energy Conservation and Renewable Energy Education

*PW Walsh, SG Gruder

Funding: WI Energy Conservation Corp.

Collaborators: UW Coop. Ext. Service; WI Focus on Energy; UW Coop. Ext. Service Solid and Hazardous Waste Educ. Ctr.; WI Renewable Energy Network

The Wisconsin Focus on Energy program promotes adoption of energy conservation and renewable energy technology by Wisconsin's citizens, businesses, and governments. In collaboration with public and private sector partners, this program works through UW Cooperative Extension Service offices to deliver energy education to Extension's statewide clientele regarding adoption of improved energy management techniques, technologies to save and generate energy, and incentives available through Wisconsin Focus on Energy, <www.focusonenergy.com>, to stimulate adoption of energy conservation and renewable energy technology.

Farm Energy and Stray Voltage Program

*DJ Reinemann, MA Cook, R Reines, R Kasper, J Roberts, D Hansen

Collaborators: UW Biological Systems Eng.; WI Public Service Commission; WI Dept. of Agric., Trade, and Consumer Protection; Midwest Rural Energy Council

The objective of this program is to promote safe, efficient use of electrical energy in rural areas. Issues addressed include energy conservation and load management technologies for farms and food processing plants, electrical safety and power

quality on farms, detection and mitigation of stray voltage, renewable energy sources, and distributed generation prospects for farms. Educational activities include the following:

- Presentations at Wisconsin Farm Technology Days and other agricultural events;
- Presentations at county, state, and national seminars;
- Support of Midwest Rural Energy Council educational efforts;
- Stray Voltage Investigators Training courses;
- Support of other state agencies with rural energy activities.

Machinery and Harvesting

Agricultural Field Machinery

*RT Schuler, KJ Shinners, JW Nelson

Funding: UW Coop. Ext. Service; WI Farm Technol. Days, Inc.

Collaborators: UW Biological Systems Eng.; UW Soil Sci.; UW Agronomy; UW Dairy Sci.; various county Extension agents

The agricultural machinery Extension program focuses on proper operation, maintenance and selection of agricultural field machinery. Specific machines and systems receiving the most attention in 2006 were mower-conditioners, rakes and mergers, forage harvesters, balers, grain combines, and conservation tillage equipment.

Of particular interest in 2006 was adjustment of mower-conditioners to produce a wide swath for more rapid drying and higher quality forages. Energy-saving methods were highlighted in much of the material presented on these topics. Interest in use of bio-diesel has increased, but special maintenance practices are required to insure minimum down time. Examples of maintenance practices include more frequent service of fuel filters and water traps. An added concern with bio-diesel use is micro-organism growth in the fuel which creates performance problems.

Forage harvesting remains the primary interest of Wisconsin forage producers. New cutting and conditioning technology (specifically, intensive conditioners and impeller conditioners) continues to generate questions on its merits. Large square bale usage increased because of very high productivity. However, these bales must be baled at lower moisture for proper storage due to their greater density compared to small rectangular bales. Producers have raised many questions on ways to reduce storage losses in large square bales. With higher energy costs, producers are looking for energy conserving steps when operating this equipment.

Wisconsin's annual Farm Technology Days (FTD) provide an opportunity to work with the farm machinery industry to demonstrate field machinery and to reach thousands of farmers. Field demonstrations at FTD allow comparison of machines harvesting forage as chopped alfalfa silage and baled hay. In 2006, demonstrations included mower-conditioners, forage harvesters, balers, silage baggers, rakes, mergers, and TMR mixers which focused on forage production. Other demonstrations were ride-and-drive for small tractors and skid steers and auto guidance system on a sprayer.

Environmental Quality

Improving Water Quality

*BJ Holmes, DW Kammel, JO Peterson, DJ Reinemann, RT Schuler, JC Panuska

Funding: UW Coop. Ext. Service

Collaborators: UW Biological Systems Eng.; UW Soil Sci.; UW Env. Resources Ctr.; UW Nutrient and Pest Mgmt.; UW Ctr. for Dairy Profitability; USDA Natural Resource Conserv. Service; WI Dept. of Agric., Trade, and Consumer Protection

The collaborators developed a series of educational materials and seminars and participated in events to educate communities and agencies about water quality. The following topics are included.

- Proper storage and handling of fertilizers, pesticides, and fuel to minimize losses to water resources.
- Regulations and standards to store and handle manure which are aimed at reducing the amount of manure and nutrients entering surface and ground water.
- Equipment demonstrations and management practices of conservation tillage techniques which have proven effective in reducing soil erosion.
- Work with committees to establish standards for proper management of milking center wastewater and silage leachate/runoff from feed storage areas.
- A survey of grazier outwintering practices which could affect surface runoff of nutrients.
- Investigation of environmentally friendly cleaning and sanitizing agents.
- Reduction of wastewater volume from milking parlors.
- Home water quality testing and interpretation for students in the Farm and Industry Short Course livestock housing class.
- Demonstration of ground water flow and contaminant transport using sand tank models.
- Development, testing, and teaching how to use field runoff softwater models.

Safety and Health

AgrAbility of Wisconsin

*RT Schuler, CA Ehle

Funding: USDA CSREES; UW Coop. Ext. Service

Collaborators: UW Biological Systems Eng.; Easter Seals WI; WI Div. of Vocational Rehabilitation; WI Dept. of Agric., Trade and Consumer Protection

AgrAbility of Wisconsin staff has provided direct assistance to about 1600 disabled farmers and disabled members of their families since 1991. Disabilities addressed include arthritis, lower back pain, spinal cord injuries, respiratory and cardiac problems, amputations, cancer, and visual and hearing impairments.

This partnership of the UW Cooperative Extension Service

and the FARM Center of Easter Seals Wisconsin (ESW) provides education and assistance to farmers with disabilities and to disabled members of their families. Extension staff provides education and awareness of AgrAbility through extension/outreach activities. ESW's role is to provide on-farm help via worksite assessments and development of individual plans.

The Wisconsin Division of Vocational Rehabilitation (DVR) provides on-site support to farmers to implement their assistive technology plans and to refer them to the AgrAbility program. Examples of assistance provided are computer software, air-suspension tractor seats, added tractor steps, powered feed carts, milking pipelines, personal transport machines, and tractor lifts. During the past year, the value of the assistive technology provided by DVR to Wisconsin farmers exceeded $3 million. DVR counselors receive training from AgrAbility staff regarding accommodations most effective for farmers with disabilities.

The Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) staff provides financial analysis of the farmers when requested by DVR staff. In addition, DATCP staff refers farmers to AgrAbility through their Farm Center.

AgrAbility is promoted through staffed displays at machinery shows and demonstrations and presentations at county, area, and statewide events. The quarterly newsletter *Plowing Ahead* is prepared, posted at website <www.bse.wisc.edu/agrability>, and sent to county Extension offices, DVR offices, rural hospitals, and current and former clients. Staff members provide an in-depth awareness program through radio programs, newspaper articles, and visits to key community people and events. An advisory committee meets annually and provides excellent support and increased awareness.

During the 2005-06 budget year, services were provided to 354 farmers with disabilities, with 101 new clients and 253 continuing clients. Completed farm or worksite visits totaled 158 where 76 were completed at the request of DVR with funding. Surveys were mailed to the 110 farmers whose cases were closed during 2005-06. With a 44% response rate, 71% indicate they do a better job of farming, 51% still farm and 25% live independently.

Mutual of America recognized the partners of AgrAbility of Wisconsin with a Community Partnership Award (2005 Merit Finalist) presented in April, 2006. This award is given to partners that include a non-profit organization, ESW in this case. Four partners were recognized: DATCP, DVR, ESW, and UW Cooperative Extension Service.

National AgrAbility Project

*RT Schuler, CA Skjolaas, ME Novak, MF Beck, KM Pereira
Funding: USDA CSREES; UW Coop. Ext. Service; contributions from agri-businesses
Collaborators: UW Biological Systems Eng.; Natl. Easter Seals

The National AgrAbility Project (NAP) provides training and educational support for the 21 state AgrAbility projects with 29 states involved. These projects provide education and assistance to farmers and ranchers with disabilities and build service capacity with health, agricultural, and government service providers. The national project is a joint effort between the Cooperative Extension staff and staff from a non-profit disability organization, National Easter Seals (Washington, DC) and is funded by USDA CSREES. Training and education are offered through a national workshop, monthly newsletters, quarterly technical news, teleconferences and project listserv. Information for state project staff and the general public is at website <www.agrabilityproject.org>. This website provides access to an assistive technology database listing close to 1,000 products. A monthly newsletter is distributed electronically to project staff only. Four quarterly publications on disability, AT, and agriculture are developed. The 2006 National Workshop, held in Jackson, MS, was planned by NAP staff, the host state, and a committee of state project staff.

NAP is in its third year of another 4-year grant from USDA CSREES to continue the National AgrAbility Project responsibilities. Evaluations of key aspects of the project are on-going.

Youth Agricultural Safety and Health

*CA Skjolaas, RT Schuler
Funding: UW Coop. Ext. Service
Collaborator: UW Biological Systems Eng.

Youth are at risk of serious and fatal farm injuries. Each year several Wisconsin children and youth, from preschool through high school age, are seriously hurt and even die from farm work or worksite-related injuries. Youth must learn proper, safe behaviors in a farm environment, both to avoid hazards as bystanders and to work safely. Youth must also learn fundamental injury and illness prevention techniques, such as hazard control, and must be motivated to apply such techniques throughout their lifetimes.

This program includes presentations to youth at a variety of meetings, both in and out of a school setting. Presentations and planning assistance are provided to youth safety day camps throughout the state. Safety materials were developed for Extension agents and, within 4-H and vocational agricultural programs, for children and youth. Close contact is maintained with agricultural education instructors and county Extension staff who work with youth. The tractor and machinery certification program described under the section "Youth Education" (below) is part of this overall youth safety and health programming.

Farm Machinery Systems Safety

*RT Schuler, CA Skjolaas
Funding: UW Coop. Ext. Service
Collaborator: UW Biological Systems Eng.

Tractors and other machines are involved in the majority of incidents resulting in temporary or permanent injury and even death on farms. The most effective method of prevention, of course, involves hazard control (removing or guarding hazards). Safe operation is still necessary but cannot be depended upon to completely prevent machine-related injuries. Numerous presentations, media interviews and information requests on machinery safety are handled. The website <www.wiscash.uwex.edu>

contains safety information available from the UW Center for Agricultural Safety and Health, including annual summaries of state farm-related fatalities since 1993 which highlight machinery-related fatalities. In-depth instruction on machine hazards and hazard control is a major component of the UW's Farm and Industry Short Course, "Agricultural Safety and Health," taught each year by the Biological Systems Engineering Department.

Youth Education

Mechanical Sciences (Youth Development)

*RT Schuler, JW Nelson, M Miller

Funding: UW Coop. Ext. Service; WI Rural Insurance

Collaborators: 4-H Youth Development; Natl. Eng., Sci. and Leadership Mgmt. Team; Lincoln Welding; Deere and Co.

In 2006, 35 4-H youth participated in the state mechanical events, which included tractor, small engine, and aerospace. Many county youth development volunteers and 15 county agricultural and youth development Extension agents supported these events. Winners at the state level advance to the National 4-H Engineering, Science, and Leadership Event held each year in West Lafayette, IN. Wisconsin staff is responsible for the small engine activity at the national event and is part of the management team that plans and conducts this event.

Two half-day workshops were conducted at a state 4-H conference in Madison. Small engines and aerospace had a maximum enrollment of 25 each in 2006.

Approximately 11,000 youth participate in these Mechanical Science projects at the county level. About 1000 volunteers within the various counties direct them. Biological Systems Engineering Department staff provides technical support for the 4-H mechanical science projects including woodworking, tractor, small engine, electricity, bicycle, and aerospace.

Future Farmers of America Agricultural Mechanics Events

*RT Schuler, JW Nelson, CA Skjolaas

Funding: UW Coop. Ext. Service

Collaborators: UW Biological Systems Eng.; WI Future Farmers of America

In 2006, 20 teams took part in the Wisconsin Future Farmers of America Agricultural Mechanics event. Each year the top teams from four area Agricultural Mechanics contests take part in a statewide event organized by department staff. Guidelines are developed for the four area events. The state event also gets input from faculty at UW-River Falls, UW-Platteville, and the Fox Valley Technical College who direct area events. Biological Systems Engineering Department staff provided training for agricultural educators in Wisconsin.

Tractor and Machinery Operation Certification Program

*CA Skjolaas, RT Schuler

Funding: UW Coop. Ext. Service

Collaborator: UW Biological Systems Eng.

Federal child labor laws require specific training relating to tractor and machinery operation for youth ages 14 to 15 working on farms other than those of their parents. In addition, Wisconsin law requires such training for youth 12 to 16 years old who operate tractors or other farm machines on public roads. Training programs are conducted by county Extension agents working with youth and by agricultural education instructors with help from many volunteers. Greater standardization was brought into the program statewide and help was offered to counties that had not previously offered programs. Supplemental materials, such as an instructor training manual, were developed, and instructor training was offered statewide. These efforts have resulted in more than a thousand youth successfully completing certification programs annually.

Publications

Peer Reviewed Publications

Altay, F, S Gunasekaran, 2006. Influence of drying temperature, water content, and heating rate on gelatinization of corn starches. *J Agric and Food Chem* 54(12):4235-4245.

Bohnhoff, DR, 2006. Concrete piers: Making post-frame buildings greener. *Frame Bldg News*, Jan, pp. 57-63.

Bohnhoff, DR, 2006. Post frame: As green as it gets. *Frame Bldg News*, Jan, pp. 64-65.

Bohnhoff, DR, 2006. UW and LBS full-scale research initiative. *Frame Bldg News*, Nov, pp. 36-42.

Bonilla, CA, DG Kroll, JM Norman, DC Yoder, CM Molling, PS Miller, JC Panuska, JB Topel, PL Wakeman, KG Karthikeyan, 2006. Instrumentation for measuring runoff, sediment and chemical losses from agricultural fields. *J Env Quality* 35:216-223.

Cabot, PE, KG Karthikeyan, PS Miller, P Nowak, 2006. Sediment and phosphorus delivery from alfalfa swards. *Trans ASABE* 49:375-388.

Cabot, PE, FJ Pierce, P Nowak, KG Karthikeyan, 2006. Monitoring and predicting manure application rates using precision conservation technology. *J Soil and Water Conserv* 61:282-292.

Cho, J, FS Denes, RB Timmons, 2006. A plasma processing approach to molecular surface tailoring of nanoparticles: Improved photocatalytic activity of TiO_2. *Chem of Materials* 18(13):2989-2996.

Connelly, RK, JL Kokini, 2007. Examination of the mixing ability of single and twin screw mixers using 2D finite element method simulation with particle tracking. *J Food Engr* 79(3):956-969.

Connelly, RK, JL Kokini, 2006. Mixing simulation of a viscous Newtonian liquid in a twin sigma blade mixer. *AIChE J* 52(10):cover, 3383-3393.

Connelly, RK, JL Kokini, 2006. 3D numerical simulation of the flow of viscous Newtonian and shear thinning fluids in a twin sigma blade mixer. *Advances in Poly Technol* 25(3):182-194.

Contreras-Govea, FE, KA Albrecht, RE Muck, 2006. Spring yield and silage characteristics of kura clover, winter wheat, and in mixtures. *Agronomy J* 98(3):781-787.

Gunasekaran, S, L Xiao, MM Ould Eleya, 2006. Whey protein concentrate hydrogels as bioactive carriers. *J Appl Poly Sci* 99(5):2470-2476.

Gunasekaran, S, T Wang, C Chai, 2006. Swelling of pH-sensitive Chitosan-PVA hydrogel. *J Appl Poly Sci* 102(5):4665-4671.

Gunasekaran, S, H-W Yang, 2006. Effect of experimental parameters on temperature distribution during continuous and pulsed microwave heating. *J Food Eng* 78(4):1452-1456.

Gunasekaran, S, H-W Yang, 2006. Optimization of pulsed microwave heating. *J Food Eng* 78(4):1457-1462.

Helgren, JM, DJ Reinemann, 2006. Survey of milk quality on U.S. dairy farms utilizing automatic milking systems. *Trans ASABE* 49(2):551-556.

Hoffman, PC, CR Simpson, KJ Shinners, 2006. Evaluation of hay feeding strategies on feed sorting behavior of dairy heifers fed mock lactation diets. *Professional Animal Scientist* 22(1):71-79.

Karthikeyan, KG, MT Meyer, 2006. Occurrence of antibiotics in wastewater treatment facilities in Wisconsin. *Sci of the Total Env* 361:196-207.

Ko, S, S Gunasekaran, 2006. Error correction of confocal microscopy images for *in situ* food microstructure evaluation. *J Food Eng* 79(3):935-944.

Li, J, MM Ould Eleya, S Gunasekaran, 2006. Gelation of whey protein and xanthan mixture: Effect of heating rate on rheological properties. *Food Hydrocolloids* 20(5):678-686.

Mabee, WE, DJ Gregg, C Arato, A Berlin, R Bura, N Gilkes, O Mirochnik, X-J Pan, EK Pye, JN Saddler, 2006. Update on softwood-to-ethanol process development. *Appl Biochem and Biotechnol* 129-132:55-70.

McSweeny, JD, RM Rowell, S-H Min, 2006. Effect of citric acid modification of aspen wood on sorption of copper ion. *J Natural Fibers* 3(1):43-58.

Muck, RE, BJ Holmes, 2006. Bag silo densities and losses. *Trans ASABE* 49(5):1277-1284.

Pan, X-J, K Ehara, J Kadla, N Gilkes, J Saddler, 2006. Organosolv ethanol lignin from poplar as radical scavenger: Relationship between lignin structure, extracting condition and antioxidant activity. *J Agric and Food Chem* 54:5806-5813.

Pan, X-J, N Gilkes, J Saddler, 2006. Effect of acetyl groups on enzymatic hydrolysis of cellulosic substrates. *Holzforschung* 60:398-401.

Pan, X-J, N Gilkes, J Kadla, K Pye, S Saka, K Ehara, D Gregg, D Xie, D Lam, J Saddler, 2006. Bioconversion of hybrid poplar to ethanol and co-products using an organosolv fractionation process: Optimization of process yields. *Biotechnol and Bioeng* 94:851-861.

Rowell, RM, 2006. Chemical modification of wood: A short review. *Wood Material Sci and Eng* 1(1):29-33.

Rowell, RM, 2006. Chemical modification of wood: A journey from analytical technique to commercial reality. *Forest Products J* 56(9):4-12.

Shrestha, R, AM Thompson, A Roa-Espinosa, 2006. Effectiveness of polymers and additives on reducing suspended sediment. *J Soil and Water Conserv* 61(3):169-177.

Singh, AP, RS Lakes, S Gunasekaran, 2006. Viscoelastic characterization of selected foods over an extended frequency range. *Rheologica Acta* 46(1):131-142.

Stevenson, DM, RE Muck, KJ Shinners, PJ Weimer, 2006. Use of real time PCR to determine population profiles of individual species of lactic acid bacteria in alfalfa silage and stored corn stover. *Appl Microbiol and Biotechnol* 71(3): 329-338.

Subramanian, R, K Muthukumarappan, S Gunasekaran, 2006. Linear viscoelastic properties of regular- and reduced-fat pasteurized process cheese during heating and cooling. *Int J Food Properties* 9(3):377-393.

Wang, T, S Gunasekaran, 2006. State of water in Chitosan-PVA hydrogel. *J Appl Poly Sci* 101(5):3227-3232.

Yu, F, YH Liu, X-J Pan, XY Lin, CM Liu, P Chen, R Ruan, 2006. Liquefaction of corn stover and preparation of polyester from the liquefied polyol. *Appl Biochem and Biotechnol* 129-132:574-585.

Books and Chapters

Connelly, RK, JL Kokini, 2007. Analysis of mixing processes using CFD. In: D-W Sun, ed. *Computational Fluid Dynamics in Food Processing*, Ch. 23, pp. 555-588. Boca Raton, FL: Taylor and Francis Group, LLC.

Fathallah, FA, J Meyers, LJ Chapman, B Karsh, 2006. Agricultural ergonomics. In: W Karkowski, WS Marras, eds. *The Occupational Ergonomics Handbook*, vol. 2, 2nd ed., Boca Raton, FL: CRC Press.

Gunasekaran, S, 2006. Automation of food processing. In: GV Barbosa-Canovas, ed. *Food Eng: Encycl of Life Support Systems*, pp. 745-757. Paris: UNESCO Publ.

Reinemann, DJ, 2006. Milking machines and milking parlors. In: M. Kutz, ed. *Handbook of Farm, Dairy & Food Machinery*, Ch. 17, pp. 167-189. Norwich, NY: Wm. Andrew Publ.

Rowell, RM, 2006. Forest water contamination. *McGraw-Hill Yearbook of Sci and Technol*, pp. 134-136. New York: McGraw Hill.

Patents

Denes, FS, SO Manolache, LE Cruz-Barba. Issued 11/21/06. Hard carbon films formed from plasma-treated polymer surfaces, US 7,138,180 B2.

Denes, FS. Disclosed 7/26/06. Immunization with antigen and DC-targeting antibody-coated nanobeads.

Denes, FS. Application Draft 6/14/06. Apparatus and methods for producing nanoparticles in a dense fluid medium.

Shinners, KJ, NG Barnett, WM Schlesser. Issued 8/29/06. Yield monitor for forage crops, US 7,096,653.

Steingraber, GC, PD Thompson. Issued 1/3/06. Milking claw bottom, US patent 6,981,468.

Steingraber, GC, PD Thompson. Issued 4/4/06. Milking claw top, US patent 7,021,239.

Conference Proceedings and Technical Papers and Reports

Altay, F, S Gunasekaran, 2006. Effect of drying temperature on gelatinization properties of starch extracted from corn. Presented at *NC213 – Mgmt of Grain Quality and Security in World Markets*, Nashville, TN, Feb 28-March 1.

Bacon, DAC, DJ Reinemann, 2006. Survey of milking characteristics and milk quality of Brazilian crossbred dairy cows. Presented at *EAAP/ASAS 8th Int Workshop on the Biology of Lactation in Farm Animals*, São Paulo, Brazil.

Bohnhoff, DR, 2006. Post-frame building research update. Presented at *Annl Mtg WI Frame Builders Assn*, Wausau, WI, Jan 18.

Bohnhoff, DR, 2006. New tools for post frame construction. Presented at *Natl Frame Building Expo*, Nashville, TN, March 1-3.

Connelly, RK, JB Jordan, JL Kokini, 2006. Comparison of the flow and mixing patterns in laboratory flour testing mixers using numerical simulation. Presented at *Amer Assn of Cereal Chemists Int World Grains Summit: Foods and Beverages*, San Francisco, CA, Sept 17-20.

Denes, FS, 2006, Plasma synthesized nanoparticles. Presented at *Nanotechnol Applications in Food, Food Processing and Food Packaging: 3rd Annl WI Nanotechnol Conf,* Madison, WI, June 13-14.

Gunasekaran, S, 2006. Self-indicating nanobiosensor for rapid detection of micotoxins. Presented at *Nanotechnol Applications in Food, Food Processing and Food Packaging: 3rd Annl WI Nanotechnol Conf,* Madison, WI, June 13-14.

Hermans, JL, DJ Reinemann, LE Armentano, TR Fortenbery, MA Wattiaux, 2006. Integrating bio-fuel production with Wisconsin dairy feed requirements. Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Holmes, BJ, 2006. Managing silage leachate and runoff. *Proc Arlington Dairy Day Program*, Madison, WI: UW Dairy Sci.

Holmes, BJ, 2006. New technologies for bunker silo management in North America. In: *Proc 12th Int Symp on Forage Conserv*, Brno, Czech Republic.

Holmes, BJ, 2006. Density in silage storage. In: *Silage for Dairy Farms: Growing, Harvesting, Storing, and Feeding* (NRAES-181), Camp Hill, PA, Jan 23-25. Ithaca, NY: Natural Resource, Agric, and Eng Service.

Jampala, SN, SO Manolache, MA Sarmadi, FS Denes, 2006. Deposition of reactive functionalities by plasma polymerization of nitrogen-containing compounds. Presented at *12th Int Conf on Composites/Nano Eng*, Tenerife, Spain, Aug.

Jampala, SN, SO Manolache, MA Sarmadi, FS Denes, 2006. Plasma-enhanced synthesis of surfaces that kill bacteria on contact. Presented at *231st Natl Mtg Amer Chem Soc*, Atlanta, GA, March.

Jampala, SN, SO Manolache, MA Sarmadi, FS Denes, 2006. Antibacterial surfaces using plasma-enhanced coating/ functionalization. Presented at *15th Textiles and Nonwovens Development Ctr Conf*, Knoxville, TN, April.

Kammel, DW, 2006. Flexible pen design for special needs and transition cows. In: *Proc Midwest Herd Health Conf*, Stevens Point, WI, Nov 8-9.

Karlsson, AO, R Ipsen, S Gunasekaran, Y Ardö, 2006. Rheological properties at cooking temperatures of rennet-induced casein gels from ultrafiltered skim milk. In: *Proc 4th Symp on Food Rheol and Structure*, Zurich, Switzerland.

Ko, S, S Gunasekaran, 2006. *In situ* food microstructure evaluation using confocal microscopy. Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Mein, GA, DJ Reinemann, 2006. Physiological responses of the teat to milking vacuum, liner compression and pulsation characteristics. Presented at *2006 ANEMBE Congress*, Zarragoza, Spain, May 5.

Muck, RE, BJ Holmes, 2006. Deciding on a silage storage type. In: *Silage for Dairy Farms: Growing, Harvesting, Storing, and Feeding* (NRAES-181), pp. 239-254, Camp Hill, PA, Jan 23-25. Ithaca, NY: Natural Resource, Agric, and Eng Service.

Muck, RE, KJ Shinners, 2006. Effect of inoculants on the ensiling of corn stover (ASABE Paper No. 061013). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Nowak, ME, RT Schuler, 2006. Undergraduate engineering student experience with assistive technology design (ASABE Paper No. 065006). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Panuska, JC, KG Karthikeyan, PS Miller, 2006. Dynamics of phosphorus losses in snowmelt and rainfall runoff from three corn management systems. Presented at *SERA 17, Annl Conf*, Ithaca, NY, July 31-Aug 3.

Panuska, JC, KG Karthikeyan, PS Miller, 2006. Time series characterization of particulate phosphorus losses for three corn management systems. Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Petersen, AL, AM Thompson, 2006 The effectiveness of new polymer technologies on reducing soil and P loss (ASABE Paper No. 065006). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Reinemann, DJ, 2006. New methods for UV treatment of milk for improved food safety and product quality (ASABE Paper 066088). Presented at *2006 ASABE Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Reinemann, DJ, JB Holmes, K Bolton, G Frank, 2006. Planning and starting a new milking parlor: Software to estimate milking center costs and performance. Presented at *Western Canadian Dairy Seminar*, Red Deer, Alberta, March.

Rowell, RM, 2006. Challenges in biomass-thermoplastic composites (invited presentation). *Int Degradable Plastics Symp: Status of Biobased and Synthetic Poly Technol*, Chicago, June.

Rowell, RM, 2006. Chemical modification of wood: A nontoxic approach to wood preservation (invited paper). In: FC Jorge, ed. *Proc 2nd Int Conf on Environmentally Compatible Forest Products*, pp. 227-239. Oporto, Portugal, Sept.

Rowell, RM, 2006. Removal of metal ions from contaminated water using agricultural residues (invited paper). In: FC Jorge, ed. *Proc 2nd Int Conf on Environmentally Compatible Forest Products*, pp. 241-250. Oporto, Portugal, Sept.

Rowell, RM, 2006. Future trends in sustainable agro-based composites (keynote address). *Int Conf on Agro-Based Composites*, U. of Guadalajara, Guadalajara, Mexico, Oct.

Rowell, RM, 2006. Fiber-thermoplastic composites: Production, properties and challenges (invited paper). *Int Conf on Agro-Based Composites*, U. of Guadalajara, Guadalajara, Mexico, Oct.

Rowell, RM, 2006. Chemical modification of wood composites: A non-toxic approach to wood preservation (invited paper). *Int Conf on Agro-Based Composites*, U. of Guadalajara, Guadalajara, Mexico, Oct.

Rowell, RM, 2006. Agro-composite materials: Science, technology and industry applications (keynote address). *Sustainable Materials Forum*, Singapore Env Inst, Singapore, Nov.

Rowell, RM, 2006. Advances in chemical modification of wood. In: *Pre-Symp Proc, 8th Pacific Rim Bio-Based Composite Symp*, pp. 1-54. Kuala Lumpur, Malaysia, Nov.

Rowell, RM, 2006. Advances and challenges in wood polymer composites (invited paper). In: *Proc 8th Pacific Rim Bio-Based Composite Symp*, pp. 2-11. Kuala Lumpur, Nov.

Sanford, G, J Posner, RT Schuler, 2006. Manure spreading and its effect on soil compaction and corn yield. *ASA-CSSA-SSA Int Mtg*, Nov 12-16.

Schuler, RT, 2006. Wide- versus narrow-swath harvesting – Machinery aspects. In: *Proc Silage for Dairy Farms: Growing, Harvesting Storing and Feeding* (NRAES-181), pp. 199-205, Camp Hill, PA, Jan 23-25. Ithaca, NY: Natural Resource, Agric, and Eng Service.

Schuler, RT, 2006. Swath width and its impact on feed value. Presented at *WI Custom Operators, Professional Nutrient Applicators of WI, and Midwest Forage Assn Symp and Annl Mtg*. Mosinee, WI, Jan 31-Feb 1.

Schuler, RT, 2006. Equipment strategies to speed hay drying. In: *Proc 2006 MN Forage Days*.

Schuler, RT, 2006. Make good bale packages that keep. In: *Proc 2006 MN Forage Days*.

Schuler, RT, 2006. Equipping yourself to make quality forage. In: *Proc Forage Focus 2006*, pp. 2-12, Ontario Forage Council.

Schuler, RT, 2006. What's new in corn silage harvesting? In: *Proc Forage Focus 2006*, pp. 15-20. Ontario Forage Council.

Shinners, KJ, 2006. Current and future equipment for producing high-quality forage. In: *Silage for Dairy Farms: Growing, Harvesting, Storing, and Feeding* (NRAES-181), Harrisburg, PA, Jan 23-25. Ithaca, NY: Natural Resource, Agric, and Eng Service.

Shinners, KJ, DR Mertens, J Harrison, 2006. Processing whole-plant corn silage: Machine, storage, and animal perspectives. In: *Silage for Dairy Farms: Growing, Harvesting, Storing, and Feeding* (NRAES-181), Harrisburg, PA, Jan 23-25. Ithaca, NY: Natural Resource, Agric, and Eng Service.

Shinners, KJ, GC Boettcher, JT Munk, MF Digman, GS Adsit, RE Muck, PJ Weimer, 2006. Single-pass, split-stream harvest of corn grain and stover using the machine configuration (ASABE Paper No. 061015). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Shinners, KJ, GC Boettcher, RE Muck, MD Casler, PJ Weimer, 2006. Drying, harvest and storage characteristics of perennial grasses as biomass feedstocks (ASABE Paper No. 061012). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Shinners, KJ, ME Herzmann, 2006. Wide-swath drying and post cutting processes to hasten alfalfa drying (ASABE Paper No. 061049). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Shinners, KJ, JM Wuest, JE Cudoc, ME Herzmann, 2006. Intensive conditioning of alfalfa: Drying and leaf loss (ASABE Paper No. 061051). Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Abstracts, Posters and Oral Presentations

Cabot, PE, KG Karthikeyan, PD Gaebler, SB McClure, PS Miller, JD Grande, AP Stubblefield, PJ Whiting, G Matisoff, 2006. Evaluation of temporal and spatial sediment dynamics in agricultural fields using Lanthanide tracers. Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Cabot, PE, AP Stubblefield, KG Karthikeyan, PJ Whiting, PS Miller, G Matisoff, PD Gaebler, SB McClure, JD Grande, 2006. Evaluation of temporal and spatial sediment dynamics in agricultural fields using naturally-occurring and fallout radionuclides. Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Chapman, LJ, KM Pereira, AC Newenhouse, 2006. A theory-driven, evidence-based intervention: Seven years, four thousand businesses, three safer ways to work (abstract and oral presentation). Presented at *NORA at Ten, Annl Mtg Natl Inst for Occupational Safety and Health*, Washington DC, April 19.

Chapman, LJ, AC Newenhouse, MG Miquelon, KM Pereira, CM Brunette, JJ Ehlers, 2006. Safer practices, better profits: One-year Midwest nursery grower intervention (abstract and poster). Presented at *Annl Conf Natl Inst for Farm Safety*, Sheboygan, WI: June 26-30.

Chapman, LJ, AC Newenhouse, KM Pereira, B Karsh, RM Meyer, CM Brunette, JJ Ehlers, 2006. Safer practices, better profits: A four-year Midwest berry grower intervention (abstract and poster). Presented at *Annl Conf Natl Inst for Farm Safety*, Sheboygan, WI: June 26-30.

Gunasekaran, S, 2006. Self-indicating nanobiosensor for rapid detection of mycotoxins. Presented at *Nanotechnol Applications in Food, Food Processing, and Food Packaging, 3rd Annl WI Nanotechnol Conf*, Madison, WI, June 13-14.

Karthikeyan, KG, PE Cabot, PD Gaebler, SB McClure, PS Miller, JD Grande, AP Stubblefield, PJ Whiting, G Matisoff, 2006. Evaluation of sediment transport mechanics using Lanthanide tracers and radiometric fingerprinting. Presented at *USDA CSREES Natl Water Conf*, San Antonio, TX, Feb.

McIntier, RL, RK Connelly, 2006. Comparing the effect of mixing on dough development between two mixers with different geometries (poster). Presented at *Amer Assn Cereal Chemists Int World Grains Summit: Foods and Beverages*, San Francisco, CA. Sept 17-20.

McIntier, RL, RK Connelly, 2006. Comparing the effect of mixing speed on dough development between two mixers with different geometries (poster). Presented at *Annl Mtg Inst Food Technologists*, Orlando, FL, June 24-28.

Newenhouse, AC, MG Miquelon, LJ Chapman, 2006. Work efficiency tools for nursery growers (oral presentation and poster). Presented at *Annl Mtg Int Plant Propagators Eastern Region*, Grand Rapids, MI, Oct 4-7.

Panuska, JC, KG Karthikeyan, PS Miller, 2006. Time series characterization of particulate phosphorus losses for three corn management systems. Presented at *2006 Annl Int Mtg ASABE*, Portland, OR, July 9-12.

Panuska, JC, KG Karthikeyan, PS Miller, 2006. Characterization of phosphorus forms in snowmelt runoff from three corn management systems. Presented at *SERA-17 Annl Mtg ASABE*, Ithaca, NY, Aug.

Shinners, KJ, 2006. Comparison of single-pass harvesting of corn grain and stover with conventional harvesting schemes. Presented at *28th Symp on Biotechnol for Fuels and Chemicals*, Nashville, TN, May 1.

Non-refereed publications and Newsletters

Beck, MF, 2006. Wrote for/edited *AgrAbility Quarterly* newsletters, <www.agrabilityproject.org/newsletter>.

Bohnhoff, DR, 2006. Behind the scenes: Details about developing NFBA's post-frame construction tolerances document. *Metalmag*, Feb, pp. 96-101.

Bohnhoff, DR, 2006. A closer look: Reviewing NFBA's post-frame construction tolerances document. *Metalmag*, March/April, pp. 92-99.

Connelly, RK, JL Kokini, 2006. Looking inside dough mixers. *Fluent News*, pp. 22-23.

Ehle, CA, 2006. Wrote for/edited *Plowing Ahead*, quarterly newsletter of AgrAbility of Wis. Project, <bse.wisc.edu/agrability>.

Newenhouse, AC, MG Miquelon, LJ Chapman, 2006. Container stabilization systems: A work efficiency tip sheet. *Green Side Up*, March, pp. 24-25.

Newenhouse, AC, MG Miquelon, LJ Chapman, 2006. A strap-on stool for nursery work: A work efficiency tip sheet. *Green Side Up*, Aug, pp. 38-39.

Sanford, SA, 2006. Greenhouse unit heaters: Types, placements and efficiency. *The Tomato Magazine*, June.

Sanford, SA, 2006. Reduce grain drying cost. *Farm News* (WI Public Service Commission), Sept.-Oct.

Sanford, SA, 2006. Farm energy bills gotcha? What to do [2-part series]. *The Organic Broadcaster*, Nov and Dec.

Schuler, RT, 2006. Fuel Savings: Shift up – throttle down and CVT/IVT. *WI Crop Manager* 13(1).

Schuler, RT, 2006. Swath width and mower-conditioners. *WI Crop Manager* 13(10).

Schuler, RT, 2006. Maintaining forage harvester for fuel efficiency. *WI Crop Manager* 13(11).

Schuler, RT, 2006. Micro-organism problems in diesel fuels. *WI Crop Manager* 13(15).

Schuler, RT, 2006. Mower-conditioner wide swath – conditioning *vs*. not conditioning. *WI Crop Manager* 13(15).

Schuler, RT. 2006. Biodiesel fuels in agricultural equipment. *WI Crop Manager* 13(21).

Schuler, RT, 2006. Crop processor adjustment for the 2006 corn silage harvest. *WI Crop Manager* 13(22).

Schuler, RT, 2006. Calibration and operation to obtain good yield monitor data. *WI Crop Manager* 13(26).

Schuler, RT, 2006. Comparing bio-oils used as biodiesel fuel. *WI Crop Manager* 13(27).

Shinners, KJ, RT Schuler, 2006. Getting the most from a mower-conditioner. *Hoard's Dairyman*, p. 281.

CD Technology / Software / Internet / Radio and Television Shows

Contreras-Govea, F, RE Muck, 2006. Microbial inoculants for silage, updated (Focus on Forage series). UW Coop Ext Team Forage website, <www.uwex.edu/ces/crops/uwforage/Microbial_Inoculants-FOF.htm>.

Holmes, BJ, 2006. Bunker silo cover alternatives, revised (Focus on Forage series). UW Coop Ext Team Forage, Harvest and Storage website, <www.uwex.edu/ces/crops/uwforage/storage>.

Holmes, BJ, 2006. Floor length to achieve bunker/pile filling layer thickness (calculator with documentation), updated. UW Coop Ext Team Forage, Harvest and Storage website, <www.uwex.edu/ces/crops/uwforage/storage>.

Holmes, BJ, RE Muck, 2006. Silage pile density calculator with documentation. UW Coop Ext Team Forage, Harvest and Storage website, <www.uwex.edu/ces/crops/uwforage/storage>.

Holmes, BJ, RE Muck, 2006. Bunker silo density calculator with documentation, updated. UW Coop Ext Team Forage, Harvest and Storage website, <www.uwex.edu/ces/crops/uwforage/storage>.

Newenhouse, AC, MG Miquelon, LJ Chapman, 2006. Healthy Farmers/Healthy Profits website, <bse.wisc.edu/hfhp/>, contains many downloadable tipsheets plus slide shows, press releases, and articles.

Newenhouse, AC, 2006. Guest on Larry Meiller's hour-long "Garden Talk" radio show, WPR 970 AM, Dec. 15.

Reinemann, DJ. Use of my extension/outreach web sites continue to increase with <www.uwex.edu/uwmril> for the UW Milking Research and Instruction Lab logging more than 30,000 unique visitors and more than 200,000 pages downloaded. This site has become one of the leading international resources for machine milking technology. The Midwest Rural Energy Council site, <www.mrec.org>, logged more than 20,000 unique visitors and more than 70,000 pages downloaded.

Schuler, RT, 2006. Adjusting the conditioning system on a mower-conditioner, UW Coop-Ext Team Forage web site <www.uwex.edu/ces/crops/uwforage/storage.htm>.