Departmental Research Programs

The Department of Biosystems Engineering has a full complement of professors who have active research programs in various areas within the broad spectrum of Biosystems engineering (please refer to the **Facilities** page for more information about the research programs of individual professors). Research topics relate to agricultural engineering, biomedical engineering, bioresource engineering, and environmental engineering.

Collectively, the Department of Biosystems Engineering is perhaps best known for its contributions to i) Post-Harvest Handling & Storage of Grains & Oilseeds and ii) Microbial Generation of Biofuels & Bioproducts. Other research strengths include iii) Machinery Systems, iv) Soil & Water Engineering, v) Agricultural & Alternative Structures, vi) Agriculture & the Environment, and vii) Medical Textiles.

i) Post-Harvest Handling & Storage of Grains & Oilseeds

The Department of Biosystems Engineering is home to the world-renowned Canadian Wheat Board Centre for Grain Storage Research (CWBCGSR) that was established in 1999 through a Canada Foundation for Innovation (CFI) award led by Dr. D. Jayas as well as partner funding from the Manitoba Research Innovation Fund, Western Economic Diversification, Canadian Wheat Board, Manitoba Hydro, Agriculture and Agri-Food Canada (AAFC), and the grain industry (total $5M). This 1340 m^2 facility is uniquely equipped with a set of laboratories to conduct research related to the storage of grains and oilseeds. Another CFI New Opportunity Grant ($300K) led by Dr. J. Paliwal in 2003 further enhanced the infrastructure. Over the last decade, this research facility has become an international research hub researching various aspects of post-harvest grain quality assessment and preservation. It has hosted visitors from more than 20 countries to learn about the Canadian approach to management of stored grains and oilseeds. Several of these visits have resulted in collaborative research projects and joint publications.

The federal government recently relocated the Stored Product Entomology Group (SPEG) of AAFC's Cereal Research Centre (CRC) to the CWBCGSR. This influx of researchers will have a positive impact on the research in entomological aspects of stored-grain ecosystems. This expertise is critical and creates an integrated interdisciplinary group non-existent anywhere else in the world. Stored-grain, being a man-made ecosystem, requires interdisciplinary teams to fully understand the interactions within the grains and to manage the stored grain.

Although the CWBCGSR is the visible centerpiece, other labs support the research activities related to post-harvest handling and storage of agricultural commodities. The *Bioprocessing Engineering Lab* (led by Dr. S. Cenkowski) examines processing and drying of foods using superheated steam which has several advantages over conventional hot-air drying. Mathematical modeling and computer simulation are used to predict and compare the performance of various systems. Research conducted in the *Imaging and Food Quality Assessment Lab* (led by Dr. J. Paliwal) focuses on providing safe and healthy food to humans and livestock. The imaging is supported by the *Microspectroscopic Imaging Lab* (led by Dr. J. Morrison) which uses computational

methods to research topics related to biological imaging, pattern recognition, spectroscopy and hyperspectral imaging. Expertise in grain storage structures within the Department is provided by Dr. Q. Zhang. Dr. Fuji Jian provides expertise in modeling of the grain storage ecosystem. At the present time, the Department of Biosystems Engineering at the University of Manitoba is the best source of grain storage expertise in Canada.

ii) Microbial Generation of Biofuels & Bioproducts

The search for biofuels and bioproducts (biofuels, bio-plastics, bio-resins, etc) to displace petroleum-based products is emerging as a key area of study. Biorefining for bioproducts is a growing industry globally (growing at 14.8% annually in the US) due to a variety of drivers, including environmental sustainability, rural economic development, biodegradability of products, and value added processing. The Department has gained international prominence for its research in the area of bioengineering for biofuel and bioproducts. This initiative is led by Dr. D. Levin with strong collaborations with Dr. N. Cicek and Dr. S. Cenkowski, Dr. R. Sparling in Microbiology, and Dr. B. Fristensky in Plant Science. In related work, Dr. N. Cicek oversees the *Waste Management Lab* which is dedicated to research involving livestock waste, industrial waste and municipal wastewater. Research has been done to utilize these waste streams to produce value-added materials such as struvite fertilizer or bioplastics.

The team has made a number of significant contributions to the field of biomass-based biofuels and bioproducts over the past six years. Among them are: 1) improvements to and in-depth study of biohydrogen production via cellulose fermentation; 2) the application of comparative bioinformatic and proteomic analyses to develop novel industrial microorganisms; 3) the development of novel proteomic tools for comparative proteomics analyses of biofuel and biopolymer synthesizing microorganisms; 4) the development of strategies for pretreatment of lignocellulosic feedstocks for production of biofuels and bioproducts via consolidated bioprocessing.

In 2010, Drs. Levin and Sparling were awarded significant funding ($2.3M) by Genome Canada for a program titled, “Microbial Genomics for Biofuels and Co-products from Biorefining Processes”. The Genome Canada funding expanded the capacity of the team to conduct complete genome sequence analyses of novel and under-characterized bacteria. In 2012, a new pan-Canadian research network, called BioFuelNet, was funded by the Networks Centres of Excellence program. Drs. Levin, Cicek, Cenkowski, and Sparling are members of BioFuelNet, and Dr. Levin leads the “Prairie Platform”, one of four research nodes within the network ($5M). Drs. Levin and Cicek have received infrastructure funds from CFI through the Leading Opportunity Fund Program (~$1.1M), ARDI ($940K), and Western Diversification ($1M) to develop state-of-the-art facilities in this area. They have also received significant NSERC Funding (Through Strategic Grants, CRD grants, and Discovery grants) totaling ~$1.5M over 5 years to support research activities. In addition to scientific recognition, this research team also has a high public profile. Their work has been showcased on both the CBC and CTV national news, by the Life Sciences Association of Manitoba (LSAM) in their Bioproducts Showcase, and in a documentary film titled, “Drive for Free: The Alternative Fuel Revolution”.

iii) Machinery Systems

Driven by global farm demand and the trend of increasing size of average farming operations, it is projected that the agricultural machinery industry will see robust growth. The Department of Biosystems Engineering has collaborated with several local companies in the machinery sector. The existing departmental facilities in this area are (1) the *Soil Dynamics & Machinery Lab* (led by Dr. Y. Chen), which includes a soil bin and discrete element modeling software to study machine-material interactions associated with soil engaging tools such as seeding, tilling, and manure injection equipment; (2) *Agricultural Ergonomics Lab* (led by Dr. D. Mann), which includes a tractor-driving simulator and an eye-tracking system to study ergonomic and safety issues associated with agricultural machines; and (3*) Measurement, Modeling and Data Analysis Lab* (led by Dr. J. Morrison), which has infrastructure to support applied image analysis for applications such as machinery safety, machinery optimization and precision agriculture.

iv) Soil and Water Engineering

The *Soil & Water Engineering Lab* (led by Dr. R. Sri Ranjan) is dedicated to the areas of irrigation, drainage, remediation of contaminated soils and groundwater, and instrumentation for soil and water monitoring. The lab includes a Rhizotron for measuring water and nutrient status within the root zone, permeameters, suction cup lysimeters, electrical conductivity meters, electromagnetic field survey instruments, water flow and level sensors, and TDR probes. In addition to the instrumentation available in the lab, Dr. Sri Ranjan has instrumented field plots near Winkler that enable innovative studies in field water management.

v) Agricultural & Alternative Structures

The Department of Biosystems Engineering is home to the *Alternative Village* (led by Dr. K. Dick), an outdoor laboratory that is dedicated to research, testing, and training related to alternative energy technologies and building envelope systems. The centerpiece of the Alternative Village is the Straw-Bale Building, however, the site also includes numerous other structures including a greenhouse with a heat storage wall. Dr. Q. Zhang has conducted extensive studies on this low-tech, energy-efficient type of greenhouse under winter conditions in southern Manitoba. Dr. Zhang and his collaborators have concluded that solar energy greenhouses could be used for year-round vegetable production with minimum heating requirement. On-going research is proposed i) to develop innovative technologies to enhance solar energy collection and storage and reduce heat losses in solar energy greenhouses, ii) to integrate direct solar conversion technologies and biomass-based combined heat & power technologies with greenhouses to provide heating and lighting for year-round vegetable production, iii) to develop the processes and formulations of densified biomass fuels using biomass materials locally available for producing heat and power, and iv) to develop innovative processes and technologies to utilize biomass residues, natural materials, and municipal solid wastes to produce novel building materials for greenhouse construction.

vi) Agriculture & The Environment

The traditional discipline of agricultural engineering includes the area of "structures and environment" which is described as the application of engineering principles to solving problems related to agricultural structures (i.e., barns, greenhouses, grain bins) and the environment within these structures. Dr. Q. Zhang is the professor with the expertise in the area of structures and environment.

Control of the environment within livestock barns includes appropriate heating and ventilation systems to ensure ambient conditions are maintained in ranges suitable for maximum animal growth. Challenges are experienced when large, mature sows are expected to co-exist in the same barn as young piglets. Research has been done in the Department of Biosystems Engineering to use localized heat sources, such as heat mats, to provide the elevated temperatures for piglets without raising the temperature in the entire barn. Air quality within the barn is another critical aspect of the environment. Gases such as ammonia and hydrogen sulfide are always present in livestock barns due to the presence of animal waste. Research has been done to investigate the effectiveness of various air-quality mitigation strategies. This includes evaluation of materials such as SuperStraw which is a bedding material that is alleged to reduce odour and the design and evaluation of various filtration systems. Air quality is an issue both inside the barn (for the health of the animals and the farm workers) and outside of the barn (i.e., odour). In previous years, Dr. Mann researched the use of biofilters for control of livestock odour. Dr. Zhang has recently developed odour annoyance models to quantify odour impact, developed dispersion models to predict odour impact and developed technologies for odour mitigation. The resulting computer program is capable of predicting the odour impact in the vicinity of swine operations. Dr. Q. Zhang oversees an *Odour Research Lab* that is used to quantify and analyze odour samples, and to evaluate various odour-reduction technologies.

The hog industry is currently concerned with the airborne transmission of pathogens. Dr. Zhang (with involvement of Dr. Levin) has made significant contributions to the knowledge of bioaerosol behavior and the development of technologies for reducing airborne microorganisms. Specifically, electrostatic particle ionization was shown to both remove aerosols in the air and to significantly reduce the porcine reproductive and respiratory syndrome (PRRS) virus concentration. Dr. Zhang has also been collaborating with Chinese researchers in exploring the mechanisms and applications of slightly acidic electrolyzed water for deactivating disease pathogens in livestock facilities. Dr. Zhang plans to develop an airborne transmission model for forecasting animal disease spread.

vii) Medical Textiles

As a result of an academic merger with the Department of Textile Sciences, the Department of Biosystems Engineering has an active program in the area of medical textiles. Research led by Drs. Liu and Zhong is characterized by the application of nano-technology in the development of health care products. Pathogenic microorganisms are one of the leading causes of morbidity and death worldwide and are a substantial societal and economic burden. The health care environment is dependent on technologies and

materials that match the changing nature and complexity of disease patterns, changes in treatment regimens, and health care delivery systems. In this context, a priority is protection from increasing threats of biological agents. Respiratory masks, bandages that allow rapid wound healing and skin regeneration and first responder protective clothing that minimize the threat of exposure to biological materials in dry or liquid form, are essential in providing protection. Nano-based medical textiles research will address serious healthcare problems, including the study of pathogenic disease mechanisms and methods to protect patients and health care workers from microorganisms.