October/November 2009

RESOURCE

Engineering & Technology for a Sustainable World

$1.8 Million Cow Heaven

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Managing Water ... Feeding the World

Two issues ago, I noted that adequate food, water, energy, and sustainable systems and environmental quality are pressing global issues that agricultural and biological engineers have the knowledge, expertise, and experience to address. For those who know me well, it has probably been surprising that I have waited until my third column to discuss water, because water management has been the focus of my career.

After the air we breathe, water and food are the two most essential requirements for human life, and water and food production are inextricably linked. With a rapidly expanding population, careful and expert management of water in agriculture is essential to ensure an adequate food supply for the world while maintaining environmental quality. The world population is projected to increase by 40 percent, to 9 billion, by 2050. The U.S. population is projected to be 438 million in 2050, a 31 percent increase. Globally, it is estimated that agriculture uses 66 percent of all water withdrawals and 86 percent of the water that is consumptively used. It is reported that nearly 90 percent of withdrawals in the western United States are for agricultural use. In addition to population growth, our supply of clean, safe, and available water is at risk as climate change threatens some traditional food-producing areas; as the growing economies of the world's two most populous countries—China and India—lead to increased demands for foods that are more water-intensive to produce; and as the availability of arable land for food production decreases because of expanding urbanization and competing demands on the crops produced, e.g., crops for feeds, fuels, and fibers.

Addressing these challenges and assessing future water uses in a changing world will require that we refine and develop methods to easily and accurately measure water use and availability in real time, to evaluate the status of hydrologic systems in real time, to obtain reliable information on the practices of water users, and to develop models that reproduce observed phenomena. Integration of science, technology, and decision-support tools with quantification of social and economic responses are essential. As agricultural and biological engineers, we can work with economists and social scientists to provide this integration.

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Events *Calendar*

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2010

Jan. 10-13 **Agricultural Equipment Technology Conference.** Orlando, Florida, USA.

Feb. 21-24 **21st Century Watershed Technology: Improving Water Quality and Environment.** San Jose, Costa Rica.

June 13-16 **9th International Drainage Symposium.** (Held in association with the annual meeting of CSBE/SCGAB.) Quebec City, Canada.

June 20-23 **ASABE Annual International Meeting.** Pittsburgh, Pennsylvania, USA.

Sept. 12-15 **International Symposium on Air Quality and Waste Management for Agriculture.** Dallas, Texas, USA.

Nov. 14-17 **TMDL 2010: Watershed Management to Improve Water Quality.** Baltimore, Maryland, USA.

Dec. 5-8 **Irrigation Symposium.** Phoenix, Arizona, USA.

ASABE ENDORSED EVENTS

2010

June 13-17 **The Canadian Society for Bioengineering - Societé canadienne de génie agroalimentaire et de bioingénierie (CSBE/SCGAB) XVIIIth World Congress (annual meeting).** Quebec City, Canada. For information visit www.cigr2010.ca.

June 13-16 **8th World Congress on Computers in Agriculture.** (Held in association with the annual meeting of CSBE/SCGAB.) Quebec City, Canada. Visit www.cigr2010.ca.

2011

Sept. 21-23 **11th International Congress on Mechanization and Energy in Agriculture.** Istanbul, Turkey.

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COVER FEATURE

UPDATE

DEPARTMENTS

LAST WORD

ON THE COVER
The new dairy facility at MSU's Kellogg Biological Station features robotic milkers and other advances to increase animal comfort and boost productivity. *(Photo by Sue Mitrovich)*

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Fielding a New Farm System

The KBS Pasture-Based Dairy

Val Osowski

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The dairy herd at the Michigan State University Kellogg Biological Station (KBS) in Hickory Corners, Mich., has hoofed it to a new pasture-based dairy facility. Construction of the new facility began last fall and was completed this past summer. The pasture dairy consists of two pastures: a 65-ha (160-acre) pasture for lactating animals, and a 14-ha (35-acre) pasture for developing heifers and dry cows. A free-stall barn with a milking parlor is located in the middle of the larger pasture. At full capacity, the facility houses 120 cows.

"Although the conventional dairy operation at KBS has been very successful over the years, we felt there was a need to establish a dairy research and education facility that would complement other sustainable agricultural research programs at KBS," said Mat Haan, project coordinator. "We see transitioning to a pasture-based system as a niche market for us; it's something that's not being done in many places. We also want to develop a system that better addresses the needs of small- and medium-sized dairy farms."

Robotic milking

The most novel aspect of the new dairy is the robotic milking system installed in the dairy's parlor. "There are a number of robotic dairies in New York and Minnesota and in the states surrounding them," Haan said. "The first robotic dairy in Michigan opened this spring at a conventional dairy operation in the Port Huron area."

Robotic milking systems, developed in Europe, became commercially available in the early 1990s. They spread throughout Europe, reached Canada in the late 1990s, and were introduced in the United States about eight years ago.

Kellogg Biological Station, Hickory Corners, Mich. *(Photo courtesy of Walter Hull)*

Robotic milkers allow the producer to monitor management and milk production with precision. Each cow wears an electronic identification collar, which allows each cow to be monitored individually. "The system has sensors that monitor every cow," Haan pointed out. "It measures body weight, total milk yield, and milk quality. Every time a cow is milked, the farmer gets a lot of information that might not be available in a conventional milking parlor. The information is readily accessible and integrated, allowing the producer to make better management decisions."

Another benefit of a robotic system is that the farmer doesn't have to be present for scheduled milkings. "Because the robotic milker is a voluntary system, cows are free to come and go as they choose throughout the day," Haan said. "If a cow decides she wants to be milked at 2:00 a.m., she can do that, as opposed to the farmer bringing the whole herd together and working them through the parlor in one big group. With a robotic milking system, a cow has the choice of when she is milked."

The KBS dairy contains two robotic milking units, and each unit milks the cows one at a time. The cows take turns visiting the milking stalls, enticed by the high-energy feed pellets that they get at each milking. Once the cow is in the stall, a floor scale activates the machine, reading data from the cow's ID collar and triggering the

Cows "chase energy" by nature, and voluntary milking relies on the promise of high-energy food treats to entice cows to milking. Sensors read ID tags around the cows' necks and do not allow them back into the milking stalls until a minimum time has elapsed. Milking intervals are programmed by the farmer. Cows that are rejected by the system return to the pasture and try again later. Each cow has an ID number dyed into her side to allow easy surveillance by the 15 video cameras mounted in the barn. ***(Photos by Glenn Laing and Sue Mitrovich)***

release of the proper amount of feed for that cow. Another command sends up soft brushes to scrub the udder. Next, the milking cups are lined up on the udder's four teats by laser sensors. Once positioned, the milking cups attach automatically, and milk flows into the collection tank.

One by one, as the four quadrants of the udder empty, the cups disengage. Eight minutes after she stepped into the stall, the cow is on her way out to graze in the pasture until she decides she'd like to be milked again. If she comes back too soon, the system won't reward her with the feed ration—she'll have to try again later. If she waits too long, the system will send a signal to the farmer to fetch her from the field. Within days, cows learn how often they need to visit the milking stall.

If another cow pulls rank and blocks access to the milking area, as dominant herd animals sometimes do, the system will tempt the animal out of the way with a pleasure even more seductive than power—the back-scratching massage post that's strategically placed out of the lane leading to the milking station.

Additional advantages

From the farmer's point of view, the system is a great labor saver. "At a conventional dairy operation, someone has to be there to milk the cows at 5:00 a.m., again at noon or so, and then again at 5:00 or 6:00 p.m.—three times a day, 365 days a year," Haan said. "With the robotic system, if a dairy farmer needs to attend a child's school function or a local community meeting, there's that flexibility. It gives farmers a chance to be more involved in their communities and with their families, because they don't have to be tied down to regular milkings. It's a win-win for the animals, the farmers, and the communities in which they live.

"Another aspect of the new farm is its pasture-based system, a departure from today's norm. Conventional dairy wisdom focuses on big cows, producing to the maximum; profits depend on cows being confined and fed a high-grain diet year-round to boost milk production per cow. That philosophy has led to fewer cows producing more milk. But a pasture-based system can work well, too, by slashing costs for feed and labor to offset the lower production per cow of grass-fed animals.

"During the several months of the year they are pastured, grazing cows do all the labor. They drop their manure over the fields naturally as they graze and eat the food where it grows, so no hauling of feed is needed.

"Farm managers boost the fields by planting a mix of quality pasture perennials and irrigating for optimum growth. The cows are rotated from one small pasture to another, so the forage material is always ample, and manure is evenly distributed. Cows are also prevented from entering streams or lakes to avoid surface-water pollution from manure, which was a problem in the past. "Foot troubles are a chief cause of cows being culled from dairy herds. But because walking on grass six or seven months out of the year is much easier on the animals' feet and legs than standing on concrete, the longevity of the herd can double on pastures."

The new farm operation, funded by a grant from the W. K. Kellogg Foundation, will be the site for studies on social dominance, herd learning, pasture grasses and other research, beginning with a study of how these cows adjust to the changes in the farm.

"Cows are much smarter than we give them credit for," Haan said. "With freedom of choice, they tend to make good choices. They can learn very complicated dynamics and interactions.

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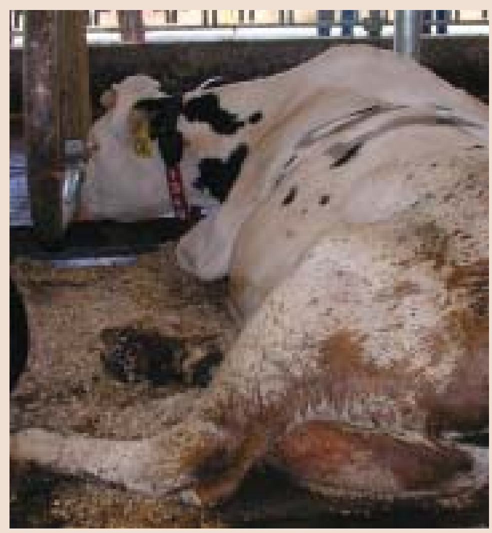
The building area of the free-stall barn is 1,967 m^2 (21,176 ft^2). Designed by Curry-Wille and Associates, it is the first working agricultural building to seek Leadership in Energy and Environmental Design, or LEED, certification. Among other energy efficient and resource conservation features, the barn uses an automatic sidewall curtain system that raises or lowers to regulate temperature, which maximizes sunlight and reduces the need for electric lighting. *(Photos by Laing and Mitrovich)*

$1.8 Million Cow Heaven

According to *Kalamazoo Gazette* reporter Rosemary Parker, it's all about catering to cows. "Waterbeds in the stalls. Laser-guided, robotic milk machines. Automatic manure scrapers. A back-scratching massage station. Lush pastures and a whenever-you-feel-like-it milking schedule.

"The robotic milkers cost $170,000 to $200,000 each. Each unit can handle 60 cows at three milkings per cow in a 24-hour period. They are engineered to last 20 years, making them less expensive than a hired hand over the same time period. In addition, they don't call in sick, and there are no scheduling problems around holidays.



"The demonstration farm uses a cutting-edge mix of technology, animal psychology, and old-fashioned farming practices. It's designed to reduce costs, increase the productive life of cows, and give an economic edge," writes Parker.

***Top,* a cow rests on water mattress bedding made of mostly recycled material. The inside pack is shredded rubber tires; the outside is covered with wax to repel moisture; the multi-colored strip around the edge is made from recycled disposable diapers. Forty-two L (13 gal) of water in each 1.2 m x 2.1 m (4 ft x 7 ft) cushion provide comfort. Chopped straw on the mattress keeps the cow clean and dry. Well trained, a cow comes and goes when she wants to be milked, rests as she wishes, and goes to the back-scratching massage station, *left,* at will.**

The Agricultural Safety and Health Challenge

Melvin L. Myers

Agricultural engineers led the way to reduce a tremendous fatality problem facing farmers in the 1960s. The challenge was large, because the fatality rate among farmers was extremely high. In 1964, through members' leadership, ASAE established standards for slow-moving vehicle (SMV) emblems for farm equipment traveling on roadways (an ASAE Historic Landmark), rollover protective structures (ROPS) for tractors (another ASAE Historic Landmark; and other standards, including guards for power take-offs (PTOs). Most states adopted the SMV emblem as a requirement on public roads. The Occupational Safety and Health Administration (OSHA) adopted the ROPS and other standards in 1976. However, the OSHA standards only applied to employees and not to farmers without full-time, paid employees; thus, unsafe equipment and conditions remained on American farms. The imperative for reducing the huge toll of farm-related deaths remains today, even though an early initiative to abate this toll was mounted by the USDA's Cooperative Extension Service, followed later by the U.S. Department of Health and Human Services' National Institute for Occupational Safety and Health (NIOSH).

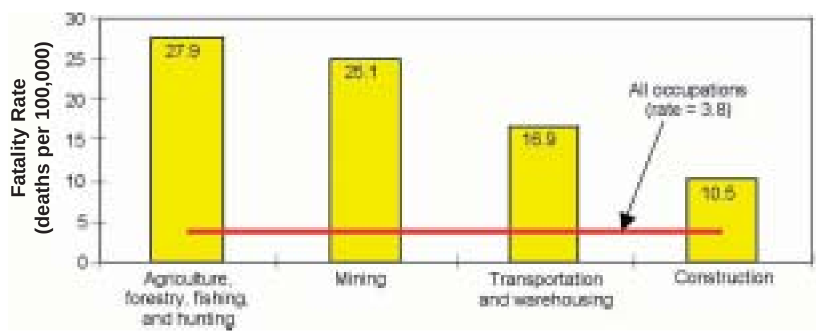


Figure 1. Occupational fatality rates for the industrial sectors with the highest rates and for all occupations in the United States, 2007. (*Source: Census of Fatal Occupational Injuries*)

The Imperative

The problem of occupational fatalities has not gone away. As shown in figure 1, data reported by the Bureau of Labor Statistics for the year 2007 indicate that the agricultural sector has the highest rate of occupational fatalities among high-rate sectors, at 28 deaths per 100,000 workers (n = 585). This includes the self-employed and is more than seven times the average rate for all occupations (3.8 deaths per 100,000 workers). To put it another way, the agriculture sector was responsible for 11 percent of the 5,112 fatalities in private industry while representing only 1.6 percent of national employment. Preliminary data for 2008 indicate a worsening of the fatality problem among agricultural workers, with a 10 percent increase to 651 deaths. This represents an increase to 14 percent of the fatalities in private industry, which otherwise declined to 4,549 total deaths.

The high rate of agriculture-related fatalities changed little from 2003 to 2007, as shown in figure 2. According to the National Safety Council, the principal sources of agricultural fatalities are tractors, non-tractor machines, confined spaces, livestock, and electrocution. Figure 3 shows that crop and animal production accounts for 45 percent and 29 percent, respectively, of the fatalities, while the remaining 26 percent of deaths occur in forestry and logging; hunting, fishing, and trapping; and agricultural support activities. While the frequencies are accurate, the high rates for the latter three subsectors are suspect; the Census of Agriculture only includes crop and animal production, and accurate denominator data are thus lacking. Nonetheless, the damage is huge and increasing, and our national challenge is to reduce the high number of deaths and the fatality rate of agricultural workers.

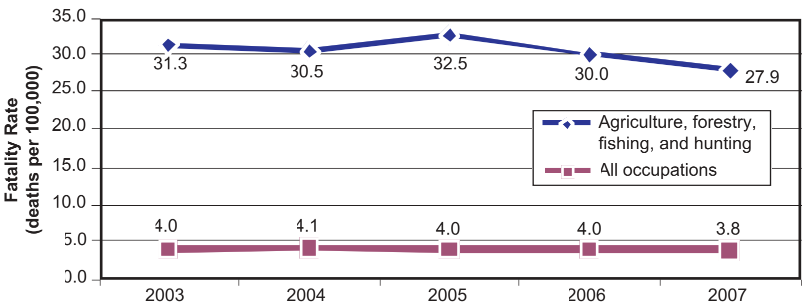


Figure 2. Occupational fatality rates for the agriculture, forestry, fishing and hunting sector and for all occupations in the United States, 2003-2007. (*Source: Census of Fatal Occupational Injuries)*

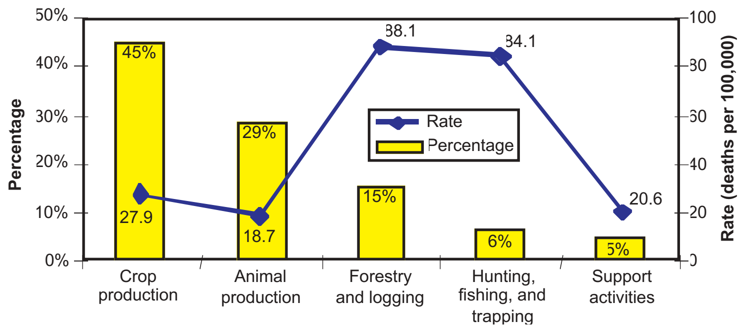


Figure 3. Percentages and Rates of Fatalities for Five Subsectors of the Agriculture, Forestry, Fishing and Hunting Sector in the United States, 2007. (*Source: Census of Fatal Occupational Injuries)*

Extension Successes

One of the great successes in U.S. agriculture is the extension system, which delivered university-based research findings to state-level specialists, who then reached out to a network of county extension agents to inform farmers of these findings, resulting in a remarkable improvement in agricultural production. In 1971, Secretary of Agriculture Clifford Hardin appointed a task force to explore ways to improve agricultural safety. As a result, in 1974, the USDA and the U.S. Department of Labor (including the newly created OSHA) signed a memorandum of agreement establishing cooperative efforts in farm safety education.

Employing the extension system, the U.S. Congress appropriated $1,020,000 for fifty-one $20,000 formula grants under the Smith-Lever Act to the Cooperative Extension Service to support safety programs in each of the 50 states and Puerto Rico in 1976. Indexed for inflation, the original appropriation was equivalent to $3.9 million in 2009 dollars. Level funding existed through 2006. The immediate effect was that each of the states and Puerto Rico had extension safety program leaders. However, the funding for extension farm safety programs was never increased, and since inflation diminished the value of the funds available per state (equivalent to $270,000 in 2009 dollars), by 1990 the number of extension farm safety specialists dropped to fewer than 30. In 2006, farm safety efforts led by extension agents familiar with farming ceased entirely when Congressional appropriations dropped to zero. Today, there are less than a handful of full-time extension farm safety specialists. Meanwhile, a newly founded Agricultural Safety and Health Council of America has sought to help re-establish extension safety efforts at the USDA.

Cooperative Extension Service programs continue the struggle to address farm safety by training workers in appropriate field practices and equipment use and maintenance. However, even though the USDA encourages applied research and development in the area of occupational safety and health, especially as it relates to production agriculture and rural populations, NIOSH now provides the leadership and funding for occupational safety and health research. Members of the Cooperative Extension Service interact with NIOSH research experts to keep abreast of cutting-edge research and new directions. Meanwhile, North Central Education/Extension Research Activity Committee 197, comprised of research and extension faculty in colleges of agriculture at land-grant universities, has developed and authored a national agenda for action, identifying a list of 12 priorities, as yet unfunded, for farm safety research and extension. The committee's follow-on white paper, "Agricultural Equipment on Public Roads," identifies research and outreach directions and priorities aimed at the reduction of occupational safety and health hazards and the risks associated with agricultural equipment on public roads, thereby presenting a challenge to agricultural and biological engineers.

Current Research

NIOSH launched its program in occupational safety and health research in agriculture in 1990, with 1992 appropriations totaling $21.5 million. As has been the experience of the Cooperative Extension Service, inflation has eroded this annual appropriation down to a current purchasing power of $14.0 million. Conversely, indexed to 2009 dollars, the appropriation would be equivalent to $33.1 million, a shortfall of $11.5 million from the original budget. To guide the NIOSH program, in 1991 U.S. Surgeon General Antonia Novello convened a conference—FarmSafe 2000: A National Coalition for Local Action—to address agricultural safety and health issues. Conference participants recognized that preventing

Engineered rollover protection saves lives. ***(Source: Southeast Center for Agricultural Health and Injury Prevention, University of Kentucky)***

injury and disease is superior to rehabilitating injured persons after the fact. NIOSH employees conduct the research, as do eight Centers for Agricultural Disease and Injury Research, Education, and Prevention located regionally across the United States.

The NIOSH program addresses not only farming but logging and fishing as well. OSHA has standards for logging, outdated for over 20 years and not covering all forestry operations. The U.S. Coast Guard has standards for commercial fishing vessel safety that focus on survival during a vessel casualty, also outdated for over 20 years and lacking in casualty prevention. As for farming, the NIOSH programs aim directly at the farmer for preventive action. However, engineering controls take priority, since there is limited evidence demonstrating that farm safety and health education, campaigns, programs, or related activities lead to a stable reduction of risk on the farm.

The family farm also places children at risk whether they are workers or bystanders. To address this problem, Congress appropriated another $5 million for research at NIOSH in 1997, with a current purchasing power of $3.7 million and an equivalent appropriation in 2009 equal to $6.7, a $1.7 million shortfall. In addition to employee-based research to protect farm children at risk, NIOSH supports research grants and a Children's Center for Rural and Agricultural Health and Safety.

The National Academy of Sciences conducted a review of the NIOSH program in 2006 and 2007. It found the research to be relevant to occupational safety and health in agriculture, but it concluded that its impact on health outcomes, including fatalities, has not yet been realized. More emphasis is needed to get the research into practice, much as the extension system was designed to do. Allied to this concept is agromedicine, which links the medical profession with state extension agents to bring preventive practice to the farm. Safety engineering research is needed to arm state and local practitioners with controls that provide an impact on fatality reduction by freeing workplaces of occupational hazards in agriculture, forestry, and fishing. Tragically, the fatality rate remains high, and funding has not kept pace with the challenge to prevent unnecessary deaths as well as non-fatal injuries and occupational diseases. Engineers have a significant role to play in preventing these injuries and diseases.

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For further reading

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Considering Sustainability in Seafood and Other Food Products

James S. Diana

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My wife, daughter, and I decided to go to a mid-scale seafood restaurant for dinner. Being aware consumers, we had with us our *Seafood Watch*, a pocket guide distributed by the Monterey Bay Aquarium to help consumers make informed decisions about seafood alternatives. After perusing the menu, I chose salmon filets; my wife, shrimp; and my daughter, tilapia. Checking the pocket guide, we saw that wild salmon from Alaska and tilapia from U.S. farms were among the best choices, and shrimp from the United States and Canada were listed as good alternatives, but farmed salmon and tilapia from Asia were included in the "group to avoid eating." The menu gave no indication of the source of the seafood, so we asked our server, who didn't know. Since this is an area in which I have considerable experience, I assumed that the salmon was most likely farmed Atlantic salmon, and the tilapia and shrimp were probably farmed in Asia. However, I also have additional knowledge, which led me to believe that these sources may not be as problematic or necessary to avoid as the *Seafood Watch* indicates. Defining "sustainability" for seafood and other food products can be complicated.

What is sustainable?

The rating scales produced by the Monterey Bay Aquarium, Blue Ocean Institute, and Marine Stewardship Council are attempts to define sustainable practices for fisheries and aquaculture. However, simple definitions don't fully explore the question, "What is sustainable?" For example, should we consider wild-caught species of fish to be sustainable, when many fish populations are heavily overexploited? Should we encourage consumers to avoid farmed shrimp, when some shrimp farmers use sophisticated techniques to clean the water, reduce farm effluents, and control diseases? Obviously, generalized evaluations cannot take into account each system that is currently used to produce seafood. All they can do is summarize large-scale differences, and these differences are not immune to the political process. In fact, it is interesting to see how many "best choices" or "good alternatives" tend to be U.S.-based, while the "poor alternatives" tend to be from overseas countries. This perception is particularly problematic, since overseas countries have been important in aquaculture and fisheries for many years, and many of them have production methods as refined as those used on U.S.-based farms.

I recently reviewed the literature to evaluate the relationship between aquaculture production and biodiversity conservation. This review included the market trends in wild-caught and farm-grown seafood products, as well as a summary of the most common issues related to seafood production. From a biodiversity perspective, I found five negative trends created by aquaculture:

1. Escape of production stock into the surrounding environment and their potential hazard as an invasive species or in altering the genetic characteristics of existing stocks.
2. Problems with effluents, eutrophication of water bodies, and changes in receiving waters.
3. Conversion of sensitive land areas to ponds or other culture systems.
4. Use of fish meal and other resources, which results in overexploitation of wild fish stocks.
5. Disease or parasite transfer from captive to wild stocks.

I also noted four positive aspects for aquaculture, which include:

1. Species produced in aquaculture reduce the pressure on wild stocks by market replacement.

2. Organisms stocked from aquaculture systems can help enhance depleted wild stocks of various species.
3. Effluents and waste from aquaculture may actually increase the local production, abundance, and diversity of species in receiving waters.
4. Aquaculture can be a more sustainable alternative to destructive land use patterns, such as slash-and-burn agriculture, and it can provide a reasonable economy and higher quality of life for the rural poor in many developing countries.

All of these issues, and more, play into the definition of sustainable seafood. Keep in mind that there is no food production system that is truly sustainable. All of them have significant impacts, including waste products that accumulate, and all are negative in terms of the energy used and other characteristics of sustainability.

Ensuing problems

The issue of sustainability becomes further confused because it is difficult to make accurate and objective comparisons among different agricultural crops. For example, the guides produced by the Monterey Bay Aquarium and the Marine Stewardship Council list their criteria for evaluating the sustainability of each seafood type, but in the end they judge the level of each characteristic subjectively. In addition, it is extremely difficult to compare the various kinds of food production systems. For example, how would you compare wild-caught seafood to aquaculture seafood? Clearly, the criteria would differ considerably for a fishery that moves offshore, collects wild species along with considerable by-catch, and then brings it all back to port as compared to farming tilapia in a pond on dry land. An even more important question is how to compare traditional agriculture crops, such as wheat, beef, or pork, to aquaculture. In this case, we don't even have similar rearing systems and therefore similar production means. All of these considerations cloud the issue of what constitutes a sustainable food product.

A different approach

My colleagues and I at the University of Michigan, as well as several other research groups throughout the world, have been focusing on some of these questions by applying more objective methods, such as life-cycle assessment, to evaluate the sustainability of seafood crops. Life-cycle assessment is an attempt to document the total materials and energy of a production system, including those that are used in building the farm, growing the crop, and disposing of the waste as well as in the marketing, sales, and ultimate consumption of the product. These analyses not only evaluate energy use and materials consumption but can also estimate the global warming potential, eutrophication potential, and a number of other environmental metrics of sustainability. Since a life-cycle assessment is quantitatively based, it can be used to compare widely diverging production systems. For example, a Swedish group has analyzed a number of different food products for their life-cycle energy inputs and has determined that beef requires 20.0 kW hours of energy per kg (2.2 lb) produced, chicken 9.7, pork 40, lamb 43, and wild seafood somewhere between 5.3 and 61.1. Comparatively, our preliminary estimates for recirculating aquaculture show an energy input of 7.8 kW hours per kg (2.2 lb) of shrimp produced, while outdoor aquaculture requires 4.3 kW hours of energy per kg (2.2 lb) of shrimp produced. Shrimp appear comparable to chicken in the energy cost for producing a kg of "meat" and are considerably lower than pork, lamb, or beef. They are also considerably lower than most wild seafood crops.

Of course, energy use isn't the only characteristic to evaluate in determining sustainability; there are a number of environmental costs, as well as water use. Water use in aquaculture is generally much lower than in domestic agriculture, which relies largely on irrigated farming. In addition, of the five negative trends for aquaculture listed earlier, most involve risks of environmental damage and are related to biodiversity, such as the risk of exotic species escaping into a new environment, the risk of genetic contamination of existing stocks by aquaculture stocks, and the risk of disease transfer. Life-cycle assessment doesn't evaluate such risks. Nevertheless, these risks are a major concern in assessing the

Aquaculture workers in Kenya use seines to harvest fish from their ponds. Effluent from fish ponds is a major environmental concern related to aquaculture, and one way to avoid that (and save considerable water) is to use nets to harvest the fish instead of draining the ponds. ***(Photos courtesy of the author)***

Tilapia ponds in Kenya, an agrarian scene, are not all that dissimilar from agricultural plots that are viewed positively as green space outside cities in the United States.

sustainability of aquaculture, and they tend to be the risks that are most prevalent in people's concerns about eating fish from aquaculture sources.

Aquaculture has received negative publicity that is out of proportion to its actual damages and to its importance as a food production method. In fact, aquaculture is the fastest growing food production system in the world. Since 1985, aquaculture systems have collectively increased production by almost 10 percent per year. All other farming systems are far below that growth rate. This trend is reflected in the seafood we eat: in 1985, about 12 percent was produced by aquaculture; today it is more than 50 percent. While aquaculture is well established, and growing, many people still consider it a new food production technique, and they're partly correct. Although fish farming originated in Asia more than 4,000 years ago, modern intensive aquaculture is a relatively new production system. As a new system, it receives considerable criticism, particularly in terms of food safety.

Testing 1, 2, 3

To put this criticism in context, here are some ideas to consider when comparing different food production systems. One is the general perception of fish farms and other farms. Cage culture facilities along the coast are generally despised by coastal managers, who consider them eyesores and disruptive to navigation and recreation. Fish pond facilities are similarly viewed as eyesores and as a negative change in the natural system. Of course, all agriculture changes the natural system; that is the nature of every agriculture system. However, when we see farms, such as row crops, on the periphery of major cities, we view them positively, even fondly. We create ordinances to maintain green space, and we consider agricultural transformation to be a kind of green space. It is interesting that the perception of fish farms and agricultural fields is quite different, yet both result in the same thing—a major change in the natural ecosystem that was made to produce a food crop.

Another concern about aquaculture is related to the damages to water systems by fish cages. Again, these accusations are made without considering the larger context. Damage to the benthic biodiversity underneath the cages occurs when the solid waste production exceeds the decomposition capability of the receiving waters. In such cases, the benthic organisms are smothered by sediments, and benthic biodiversity declines. However, this problem, while real, is minimal when compared to the effects of land-based agriculture. For example, agriculture in the Mississippi River basin has resulted in long-term excessive nitrogen loads to the Gulf of Mexico. These nitrogen loads have created a dead zone in the gulf that annually exceeds 8,000 square miles in area—much larger than the total area affected by fish cages. In fact, I estimate that the benthic area damaged by all the fish cages in the world today is less than 5 percent of the marine benthic area damaged by Mississippi basin agriculture alone, and dead zones exist off virtually all major river systems throughout the world. Clearly, the negative effects of land-based agriculture on benthic biodiversity in the ocean far exceed the effects of cage culture. Some people are calling for reductions in nitrogen loading to aquatic systems, and some environmental groups are calling for a boycott of farmed Atlantic salmon because of its effect, at least in part, on benthic biodiversity. But no one is calling for a boycott of wheat, corn, or rice because of the loss of biodiversity in the sediments of the Gulf of Mexico.

How can we deal with all of these complex issues?

Can new regulations impose greater sustainability on agriculture and aquaculture? In my view, that is not the way to proceed. *Seafood Watch* or the Marine Stewardship Council's seafood guides are useful ways to inform consumers about the environmental effects of food choices. Similar guides should be produced for other land-based agriculture systems, as well as for comparisons among agriculture systems. Such guides encourage consumers to think about what they eat and consider how they can influence sustainability by purchasing foods that are produced in a more sustainable manner, avoiding those produced less sustainably. Major retailers such as Walmart and Whole Foods are focusing on purchasing only seafood produced in a more sustainable manner. This business trend should provide economic incentives for countries that export seafood, as well as for farmers who produce seafood. Producers who use less sustainable methods will receive a much lower price, or they will simply be excluded from markets that consider sustainability in their purchasing decisions. Regulations are still important, particularly for zoning where certain uses can occur and for establishing the maximum capacities for certain uses in a given area, but an incentive system would be far more effective than government regulations at moving aquaculture toward sustainability.

Finally, as we consider market-managed sustainability in food production, it is also important to consider where the food is produced and the living conditions of the people in those areas. In the case of seafood production, the value generated by export of seafood from developing countries far exceeds the combined export value of coffee, tea, bananas, rice, and meat. Thus, seafood production is an important economic driver in developing countries. At the same time, 75 percent of all the seafood harvested or produced in developing countries is consumed within those countries. So seafood has become a major part of the nutritional balance in developing countries as well as a major export commodity, which is important for improving the economic status of those countries.

In the United States, as in other countries, we are not able to produce all of the food we eat. Other countries export food for our consumption, and currently the quality of life in many of those countries is fairly low. This low quality of life leads to poor environmental conditions, poor food production conditions, and fewer concerns about sustainability in relationship to food production. As developing countries experience economic growth because of the increasing export value of their food crops, we can also expect them to become more concerned with sustainability and environmental quality. Thus, not only will the market help improve sustainability, it will also help level the imbalance in the quality of life between developed countries and developing countries. All of these are important issues related to seafood consumption, sustainability, and the human condition.

Back to the restaurant

Most likely, each type of seafood that my daughter, my wife, and I decided to eat was produced by an aquaculture system. Most likely, those aquaculture systems were located in the developing world, particularly Asia. However, despite the advice of our pocket guide, we really don't know the damages or benefits that might accrue from any given production system in any given country. International certification of seafood sources would offer a means to better inform the consumer and manage seafood sustainability, but we move toward a more sustainable society when we evaluate the environmental costs and social benefits of all our food production methods. For a start, while life-cycle assessment can't answer all the questions related to sustainability, we need to conduct complete life-cycle assessments for all of the food products that we might be concerned about eating in a restaurant or at home. This process will involve a major information-gathering effort by a number of organizations, but this information is essential for achieving real sustainability.

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Contributions to this feature were made by **Gregory A. Keoleian**, professor, and **Wenting Sun** and **Ling Cao**, students, at the UM School of Natural Resources and Environment.

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Pressure-Assisted Thermal Sterilization of Low-Acid, Shelf-Stable Foods

Jeremy Somerville and V. M. (Bala) Balasubramaniam

Consumers today are more focused on health and wellness, and they desire convenient food products with fresh-like quality attributes. In response to increased consumer demand for minimally processed products with fewer preservatives, the food industry is looking for alternative technologies for the sterilization of low-acid, shelf-stable foods. Many traditional low-acid, shelf-stable foods found on supermarket shelves are thermally processed using retorts. While thermal processing has a proven track record of microbial safety, a common disadvantage of this process is the long time it takes for the product to reach the desired processing temperature by slow conduction and convection heat transfer. Long processing time is necessary to ensure killing of harmful pathogenic spores of *Clostridium botulinum* and other species that cause spoilage in canned foods, but prolonged thermal exposure also degrades many consumer-desired quality attributes, such as texture, color, and flavor. Further, harsh thermal treatment can also destroy vitamins, nutrients, and other heat-sensitive phytochemicals important for health.

Noted as one of the best innovations in food processing in the last 50 years, pressure-assisted thermal sterilization (PATS) offers food processors the ability to produce superior quality, shelf-stable food products that overcome limitations of their traditional thermally processed counterparts (table 1). The technology may also provide the opportunity to provide a "cleaner" ingredient label. To achieve a commercially sterile food product, PATS utilizes a combination of high pressure, moderate temperature, and time. Pressures ranging from 500 to 900 MPa (72,500 to 130,000 psi) and temperatures of 90° to 120°C (194°F to 248°F) are applied to low-acid food products for about five minutes. When pressure is applied to a food sample, there is an accompanying reduction in the sample's volume, which results in an increase in sample temperature due to physical compression of the food. The rapid temperature increase during compression, and the temperature decrease in the product upon decompression, is a unique benefit of the process as compared to traditional thermal processing. This allows the food to be sterilized with less thermal exposure.

Description	Advantage
Pressure	Rapid & uniform distribution throughout the sample.
Thermal distribution	Reduced thermal impact. Result in better quality product.
Physical compression	Instant temperature increase and subsequent cooling upon depressurization.
Product handling	Suitable for both particulate and pumpable food.
Process time	Less dependence of product shape and size.
Functionality	Opportunities for new process/product development.
Reaction rate	Pressure accelerates traditional thermal inactivation kinetics.

Table 1. Advantages of pressure-assisted thermal sterilization.

Process equipment

Like the traditional retort process, PATS is essentially a batch process at this time. The equipment consists of a pressure vessel with two end closures, a yoke (the structure for restraining the end closures), a high-pressure pump and intensifier for generating the desired target pressures, and instrumentation for temperature and pressure control. The system utilizes a preheating bath for conditioning the initial temperature of the product before loading it into the pressure vessel. Commercial-scale PATS equipment is not yet available, but pilot-scale equipment of up to 55 L (14.5 gal) capacity is available (as shown on page 14).

The PATS process

Pressure-assisted thermal sterilization of a low-acid product generally starts with removing as much as air as possible from the food, and vacuum packaging the product in a high-barrier, flexible pouch or container. The chosen packaging material should have at least one flexible interface that will ensure pressure transfer through the package to the food material. A variety of existing flexible packaging structures may be used, allowing the technology to be applied to both liquid and solid foods.

The prepackaged product is preheated to a desired temperature prior to the pressure-assisted processing. The pressure chamber is also preheated to minimize heat loss to the environment and ensure uniform treatment. After preheating, the packaged product is placed in a load basket, loaded into the pressure chamber, and the chamber is closed and sealed. The pressure cycle starts by pumping a pressure-transmitting fluid, at the desired starting temperature, into the chamber and allowing the remaining air to escape through a vent valve. Water is the most commonly used pressure-transmitting fluid in commercial-scale pasteurization equipment due to its availability, non-toxicity, and low cost. Since sterilization utilizes temperatures above 100°C (212°F), a mix of water and glycol is often used as the pressure-transmitting fluid in research-scale high-pressure equipment. Once the remaining air has been removed, the vent valve is closed and more fluid is pumped into the chamber using hydraulic pumps and pressure intensifiers to create the desired pressure. Depending on the power of the hydraulic pump, the ramp rates to the target pressure can range from a few seconds to several minutes. At the end of the pressure cycle, when the pressure has been released from the system, the chamber is opened and the load basket is removed. The product is then chilled to ambient temperature to prevent any further thermal degradation.

Pressure-assisted thermal sterilization has the potential to preserve the fresh-like characteristics of food products.

The principle behind PATS

During PATS, both pressure and thermal effects are applied simultaneously. Thus, any chemical, enzymatic, or microbial reactions are influenced by both pressure and heat. Temperature changes during treatment can cause both volume and energy changes. On the other hand, pressure treatment primarily affects the volume of a product being processed. Pascal's principle provides that, on a macroscopic level, pressure is transmitted nearly instantly and undiminished throughout the sample. Process time is also independent of sample size and shape, assuming uniform heat transfer within the sample. Most food products have high moisture content. These products are generally not severely deformed under pressure, as water is only compressed by 10 percent at 300 MPa (43,000 psi) and by 17 percent at 600 MPa (87,000 psi), leading to a good chance for shape retention at the macroscopic level (see photo below on facing page). However, food products that are porous and contain large amounts of air, such as strawberries, marshmallows, and leafy vegetables, will be left distorted by pressure treatment because the air will be forced out of the product due to the difference in material compressibility between the food matrix and the air. According to Le Chatelier's principle, any phenomenon (such as phase transition, chemical reaction, etc.) accompanied by a decrease in volume is enhanced by pressure.

Microbial efficacy

In general, pressure treatment at ambient temperature is an effective means for inactivating vegetative microorganisms. High pressures of 300 to 700 MPa (43,500 to 101,500 psi) applied at around ambient temperature may lead to death of bacterial cells by damaging the cellular membrane, disrupting homeostatsis, and inactivating and denaturing proteins and important enzymes. Inactivation rates are also dependent on the bacteria species, and significant differences have been reported among various strains within the same species. On the other hand, a combination of both high pressure (500 to 900 MPa; 72,500 to 130,500 psi) and heat (90°C to 120°C; 194°F to 250°F) is required to inactivate bacterial spores. As in thermal processing, *Clostridium botulinum* spores are the target pathogen for PATS treatment.

The general nature of the food system is also an important factor in the efficacy of using high pressure for inactivation of microorganisms. In general, low pH (more acidic) foods and foods with large amounts of free water (high water activity > 0.95) favor spore inactivation, as increasing pH and decreasing water activity provide a "protective" system for the microorganisms and will generally require longer processing times or greater pressure-heat combinations to achieve proper microbial inactivation.

A promising future

Pressure-assisted thermal sterilization technology can significantly advance the quality preservation of low-acid, shelf-stable food products. During 2009, the FDA approved a petition for PATS processing of a mashed potato product. While there are currently no PATS processed shelf-stable foods commercially available on the market, PATS shows promise of providing a viable processing route for heat-sensitive products that would suffer severe loss in quality with traditional thermal processing. Products such as soup, stews, mashed potatoes, pasta, and cheeses that can only be heated by slow conduction are good candidates for PATS technology. The potential for pressure to deliver a "clean" ingredient label, fresher flavor, and better nutrition offers a tremendous advantage to processors. Initial PATS products that can be successfully introduced into the commercial markets are those yielding high profit margins due to their fresh-like qualities resulting from treatment. With further research in the coming years, PATS may lead the way to shelf-stable products with nutritious, fresh-like quality attributes for the consumer to enjoy.

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Challenges in Biosensor Development

Detection limit, detection time, and specificity

Madhukar Varshney and Kumar Mallikarjunan

Biosensors are widely used to detect the presence of biological entities (pathogens, harmful chemicals, and toxins) in a sample, but their application is subject to several limitations, including detection limit and detection time. The detection limit is the minimum amount of a biological entity that can be detected. The detection limit is especially important when the threshold limit of a pathogen—the amount that could make a person sick—is very low. A biosensor is only useful if its detection limit is lower than the threshold limit of the pathogen in question.

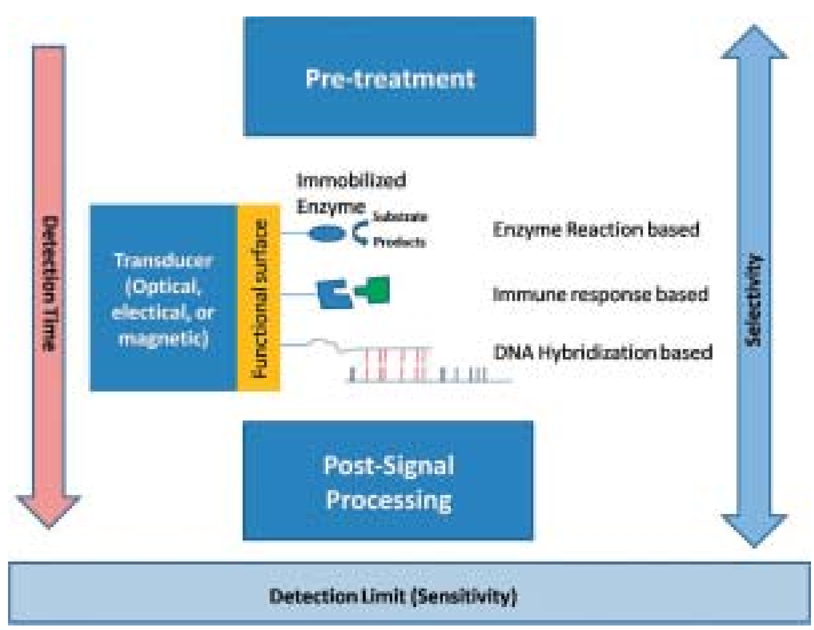
In addition to a sensor's detection limit, the detection time is another important parameter to keep in mind. Like detection limit, detection time brings it own challenges when designing biosensor systems, such as finding a suitable technology while maintaining the highest sensitivity and specificity. In fact, specificity is the most desired quality of a biosensor. It describes the sensor's ability to differentiate between target and non-targeted biological entities in a sample. In the case of food products, other proteins, fat, fibers, and non-harmful bacterial cells may interfere with the functioning of a biosensor. The specificity of a biosensor lies in detecting only the target molecule.

Real-time detection of harmful bacteria (pathogens) in food products is an appealing idea, but is it possible?

Yes, but only if the system is fast enough to detect pathogens in a few seconds or minutes without requiring any elaborate reagents or equipment. A discussion of some of the recent developments in biosensors follows, addressing the challenges related to detection limit, detection time, and specificity. The terms "sensitivity" and "detection limit" will be used interchangeably.

Detection time

The detection time of a biosensor becomes significant when testing product quality on the production line in a food processing industry; for in-field detection of harmful molecules of significance to homeland security, community infection, and food contamination; and for in-vitro diagnosis of disease-related biomarkers. In the food industry, products are typically held for quality inspection before shipping. The quality control test must be fast in order to reduce the cost of



Conceptual description of a rapid biosensor.

storage and to minimize the delay before the product is shipped to market. Detection time is therefore essential for reducing the overall cost of the food product and for pricing the product competitively with other, similar products.

Detection time is also important in the case of medical point-of-care devices. Point-of-care devices are generally used outside the laboratory for continuous monitoring of a patient's symptoms for a specific disease, to assist with decision-making before starting a new drug, or to provide ongoing evaluations during surgery. In such cases, the speed of detection can save a patient's life, but the significance of low detection limit and high specificity can't be overlooked, either. The most desirable scenario is a combination of low detection time with extremely low detection limit and high specificity. Balancing these goals is the most challenging task facing researchers who design and develop biosensors. Most often, one goal is emphasized at the expense of the others.

In order to detect extremely low concentrations of pathogens, toxic materials, or analytes of significance, the conventional techniques are still most trusted in industry, academia, and government labs. However, these techniques are not always suitable for applications in which detection time is crucial. For example, in the case of disease diagnostics, conventional techniques such as 2-D gel electrophoresis and mass spectroscopy are not suitable in a hospital environment, where immediate test results are desired. Lateral flow immunoassay (described later) could be an alternative to conventional techniques to detect disease markers in less than 10 minutes. Although exchanging conventional techniques with more rapid methods may compromise the detection limit, it would improve the detection time, which may be highly desired in certain applications.

Recently, Olivier Lazcka and his coworkers from the Institute of Microelectronics of Barcelona Autonomous University summarized the detection technologies that have been used for pathogen detection in the last 20 years. The most popular methods, by far, are those based on culture and colony counting methods and the polymerase chain reaction (PCR), followed by enzyme-linked immunosorbent assay (ELISA) and other biosensor technologies such as optical, electrical, electrochemical, and mass-based. Colony counting methods are more time consuming than PCR methods, but both provide conclusive and unambiguous results. These methods are considered conventional techniques, and they are trusted due to their high specificity and reliability of detection. Other biosensor technologies have also been getting attention from researchers due to their promise of reliability (equivalent to conventional methods) and short detection time. However, much more work is required before these biosensor technologies will completely replace the conventional techniques. In this direction, several technologies have great potential for application as rapid biosensors, such as fiber-optic, surface plasmon resonance (SPR), piezoelectric, electrochemical, fluorescence resonance energy transfer, Fourier transform infrared spectroscopy, light scattering, impedance, cell-based sensors, and resonator- based sensors. These new technologies can be combined with conventional methods to reduce the detection time from days to hours without compromising the detection limit.

RECENT DEVELOPMENTS

- **Using new reagents**
- **Reducing the size of devices**
- **Combining micro- and nanotechnology**
- **Concentrating the target molecule**
- **Using lateral flow immunoassay**
- **Using amplification techniques**

Detection Limit

As mentioned earlier, the detection limit is often compromised by the detection time in the development of rapid biosensors. Current efforts are focused at reducing the detection limit of biosensors while keeping their sensitivity and reliability similar to that of conventional techniques. Recent improvements in the technology combined with new reagents have reduced detection limits without increasing the total detection time. For example, the development of highly bright photostable semiconductor nanocrystal quantum dots has significantly improved the sensitivity of fluorescence-based biosensors. Quantum dots are superior to organic fluorescent molecules in terms of brightness, stability, and multi-color emission with a single-excitation source that both improves the sensitivity of fluorescence-based detection techniques and provides multiplex detection.

Micro- and nanotechnology

In addition to the use of new reagents, shrinkage of the devices also helps in achieving performance goals. The use of micro- and nanotechnologies has been shown to improve the sensitivity of rapid biosensors to the level of conventional methods. Recently, Carl Batt and his group at Cornell University developed a microchip for real-time PCR detection of bacteria. The system is comprised of silicon microstructures integrated onto a microchip that contains two distinct regions: one for DNA purification, and the other for real-time PCR. This complete, integrated system includes a microprocessor, pumps, valves, a thermocycler, and fluorescence detection modules on a single chip. The microchip is used to purify and detect bacterial DNA by real-time PCR amplification using SYBR Green fluorescent dye. As few as

2 x 10^3 *Salmonella typhimurium* cells can be detected using this system with an average detection time of 45 min.

The combined use of micro- and nanotechnology in the area of biosensors holds great promise for improving the sensitivity of biosensors, reducing cost, and reducing detection time. Microfluidics improves mixing rates and mass transport, which is expected to result in shorter analysis time. Multiple-analyte detection also shortens the detection time. In addition, the high surface-to-volume ratio, low power consumption, small sample volumes, and mass production of such devices will reduce the overall cost of detection. In terms of detection sensitivity, micro- and nano-devices enhance the surface phenomena that can detect a single molecule that otherwise may be lost during detection using macro-technologies.

"The combined use of micro- and nanotechnology in the area of biosensors holds great promise for improving the sensitivity of biosensors, reducing cost, and reducing detection time."

Reproducibility of test results is also important. Improvement in the reproducibility of results with a reduction in total detection time is possible using parallel processing and automation of detection technologies. Parallel processing is achieved by running several tests simultaneously on a chip, or by breaking one test down into various steps and then running all of them simultaneously. In both cases, automation can significantly reduce total detection time as well as improve the test-to-test variation in results. Thus, micro- and nano-fabricated devices have a great potential to combine high sensitivity with low detection time in the development of rapid biosensors with additional advantages of automation, improved repeatability, and reduced cost of detection.

Concentrating the target molecule

Among other methods that are used to narrow the gap between the detection limits of conventional methods and biosensor technologies, immunomagnetic separation (IMS) is considered very promising. IMS is based on micro- and nano-sized magnetic beads coated with biorecognition elements (antibodies, protein, nucleic acid probe, aptamers) that are specific for the target biomolecule. The modified magnetic beads are used to separate and concentrate target biomolecules from a crude sample. This helps not only in the concentration of target biomolecules from a large sample volume but also in their separation from the non-target molecules that are present in a complex sample. Other means to achieve concentration are the use of dielectrophoresis, immuno-affinity columns, filtration, centrifugation, and designing special features into microfabricated devices.

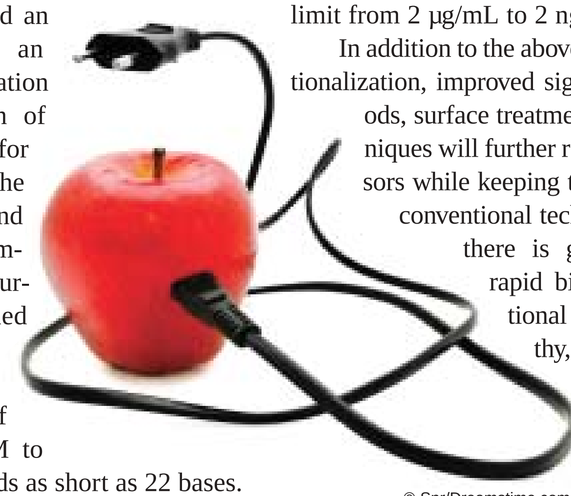
In an effort to concentrate bacterial cells prior to detection, the Bashir group at the University of Illinois at Urbana-Champaign, combined dielectrophoresis (DEP) with impedance microbiology for the design of an on-site incubation microfluidic biochip. The chip is embedded with an array of platinum interdigitated microelectrodes and is used for the detection of *Listeria monocytogenes*. Concentration and capture of the cells inside the biochip is achieved by applying DEP force, which successfully concentrates bacterial cells by a factor of 104 to 105 in a detection chamber of 400 picoliters. The detection time for 8.0 x 104 CFU/mL (colony forming unit per milliliter) of *L. monocytogenes* is less than two hours. In this way, combining DEP with impedance detection significantly improves both the detection limit and the detection time as compared to conventional impedance and colony counting methods, respectively.

Lateral flow immunoassay

Among other rapid methods, lateral flow immunoassay (LFI) is well known for its qualitative as well as quantitative detection of biological entities. LFI consists of prefabricated strips of a carrier material containing dry reagents. When a sample containing biological entities flows over these strips, the reagents are activated and two separate lines become visible, signifying the presence of target molecules and a control. These strips are widely used for diagnostics purposes (point-of-care devices), for example: to verify pregnancy; to detect organ failure, infection, or contamination with specific pathogens including biowarfare agents; to detect the presence of toxic materials in food, feed, or the environment; and to detect drugs of abuse. They are designed for single use and have the advantage of rapid detection (10 to 20 minutes). LFI devices are easy to used and avoid the long incubation periods and multiple washings commonly required in other immunoassays. They are particular important in the development of point-of-care devices that are used for continuous disease monitoring, as well as for the detection of biomolecules or analytes important in emergency situations, such as to confirm heart attack or renal failure. For the detection of pathogens in food products, LFI can be combined with enrichment steps to detect extremely small amounts of bacterial cells. Although the enrichment steps increase the total detection time, this method still reduces the detection time from several days (common for colony counting methods) to one or two days. Several rapid detection kits are available in the market for the detection of pathogens in food products.

Amplification techniques

Among other ways to reduce detection time while maintaining high sensitivity, amplification techniques are also used in the design of biosensors. Recently, Zhang Fang and colleagues developed an electrochemical system based on an amplification technique. The amplification technique utilizes the agglomeration of gold nanoparticles as conductive tags for the electrical detection of DNA. The gold particles are attached to one strand of DNA and are later attached to a complementary probe attached to a glass surface. More gold particles are added around these gold particles, and aggregates are formed between the fingers of electrodes. The detection range of the electrochemical system is 50 fM to 10 pM for the detection of DNA strands as short as 22 bases. In other work conducted in our lab, nanoparticles of 150 nm in diameter are used as a mass tag. These particles are specifically added to the place where prion protein molecules (responsible for mad cow disease) are present on the surface of microsized resonators. The resonators are like diving boards, which resonate at a natural frequency. The natural frequency is a function of the mass of the cantilever and is very sensitive to any change in the mass on the surface. The addition of the mass tags causes a large change in the frequency, leading to the detection of extremely small amounts of prion proteins. The use of mass tags has improved the detection limit from 2 μg/mL to 2 ng/mL of prion protein.



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In addition to the above-mentioned methods, surface functionalization, improved signal-to-noise ratios, blocking methods, surface treatments, better reagents, and other techniques will further reduce the detection times of biosensors while keeping their reliability equivalent to that of conventional techniques. In the meantime, although there is growing emphasis on developing rapid biosensor technologies, the conventional techniques will always be trustworthy, and they will likely retain the advantage of detecting extremely small amounts of analytes, which is not possible with rapid biosensor technologies.

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The value of livestock manure?

In Brief: *Livestock operations, particularly dairies and hog operations with substantial volumes of slurry manure, may be able to benefit by processing the manure in a methane digester. The methane can be used to fuel on-farm electricity generators or upgraded into natural gas for sale. Farmers would be able to obtain carbon credits at a $5-per-ton rate. The processed manure can still be utilized for cropland, with little loss in nutrient value, but since the odor has been removed, the manure may take on a greater value.*

Manure. Every livestock operation deals with it and depending upon the nature of the operation, manure can either be an asset or a liability. The 2008 Farm Bill directed the USDA to evaluate the role of manure as a fertilizer resource, its environmental impact, and its potential as a feedstock for bioenergy. If an operation is producing manure, will it have more value as a fertilizer or energy feedstock?

The environmental and controversial impacts of manure are well known to all livestock operation managers as well as neighbors, both urban and rural. Application limits to cropland, water pollution, odors, and similar issues increase the liability factor exponentially. However, USDA economists say there is an increasing interest in capturing the methane from manure and converting it to electricity. But when that is done, is manure being lost as an inexpensive form of fertilizer? The USDA study found that manure is applied to less than 6.5 million ha (16 million acres) of cropland, about 5 percent, and corn receives about half of the manure applications, mostly from dairy and hog operations.

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Recent high prices for commercial fertilizers make manure more cost effective, except for transportation costs. For large operations, Nutrient Management Plans require time and resources to develop and implement. Once the manure is applied, the primary issue is the nutrient value which can vary and will likely not be in the correct ratio for crop requirements. Handling and stockpiling are always health and environmental concerns.

The USDA economists determined that livestock production costs would rise 2.5 to 3.5 percent if manure was not applied nearby and had to be hauled any distance. However, as livestock operations enlarge and costs are controlled, the economists doubt that consumers would ever feel the impact of any change in whether manure was diverted from cropland nutrients to energy feedstocks.

Among the potential energy benefits and potential uses of manure:

- Dry manure has been used as a fuel for heat and cooking for millennia.
- Methane can be captured from biogas and burned for electricity generation, on farm or fed into the electric grid.
- Manure is shippable to a central conversion facility.
- Methane can be upgraded to natural gas for insertion into a pipeline.

Currently, there are only a handful of energy plants operating at livestock facilities. Less than 3 percent of dairies have them and less than 1 percent of hog confinement facilities have them. One Minnesota-based commercial plant uses 6.6 percent of turkey litter in the United States. But on-farm facilities may allow livestock farmers to produce their own electricity and reduce their overall energy costs, with the help of state grants to reduce capital construction costs.

A lactating dairy cow will produce about 68 kg (150 lb) of manure daily, and if applied to cropland at a rate of 140 kg per ha (125 lb N per acre), 1.1 ha (2.64 acres) would be required per cow. But with many dairies expanding in western states without cropland, manure has to be hauled at great expense. Hogs will each produce 544 kg (1,200 lb) of manure in a finishing operation, and although hog production is widespread in the western U.S. Cornbelt, it is also widespread in many states where cropland is insufficient to dispose of the manure as a fertilizer. A broiler will produce 5 kg (11 lb) of manure, and few poultry operations also have cropland, but the relatively dry manure can be transported at minimal expense. Two-thirds of cattle are fed at operations without cropland, so the 4.9 tons of manure produced per head have to be transported to cropland.

While nearly 6.5 million ha (16 million acres) of cropland depend on manure for a partial nutrient supply at least, the normal process may be interrupted, or the nutrient components changed, if the manure is initially processed by a methane digester. Bacteria in the digester break down the manure and emit methane, which is siphoned off for use. The USDA economists say farmers may qualify for carbon credits if they capture methane and prevent its flow into the atmosphere, and those credits would be valued about $5 per ton of manure. But once the methane is produced and used to heat mini power plants, what about the rest of the nutrients? They are still there, and available to supply N, P, and K for crop production. The digestion process reduces pathogens, neutralizes weed seeds, and greatly reduces odors, which may increase the value of the manure.

For more information contact Stu Ellis, The University of Illinois Extension; thefarmgate@illinois.edu.

Cotton bests other spray-on erosion control mulches

In Brief: *Agricultural engineer and* **ASABE member Greg Holt** *helped develop the erosion control industry's first cotton byproduct hydromulch "spray-on blanket." Holt is at the ARS Cotton Production and Processing Research Unit in Lubbock, Texas.*

Hydromulch is the bright-green mulch used in spray-on slurries that cover bare lands at construction sites and roadside projects, to prevent erosion until vegetation can be established. In the past, hydromulches were made mostly from wood and paper byproducts.

GeoSkin hydromulch is made from cotton gin byproducts. It is a combination hydromulch-spray-on blanket that, in recent tests, controlled erosion and promoted grass seedling establishment better than conventional roll-on blankets and required significantly less labor.

The total runoff from these four mulches, including soil and mulch ingredients, was: cotton, 352 kg/ha (314 lb/acre); straw, 8,881 kg/ha (7,922 lb/acre); wood, 8,543 kg/ha (7,620 lb per acre); and coconut, 4,218 kg/ha (3,782 lb/acre).

The cotton byproduct hydromulch was produced using technology developed from cooperative research efforts between ARS; Cotton Incorporated of Cary, N.C.; Summit Seed, Inc., of Manteno, Ill.; and Mulch & Seed Innovations, LLC, of Centre, Ala. ARS has applied for a patent on the process.

The technology has served as a foundation for developing a broader line of cotton byproduct hydromulches for erosion control, including a premium hydromulch for steep slopes, and more recently, a midgrade product for flat- to mid-slope terrain.

ARS has helped develop the first "spray-on blanket" cotton byproduct hydromulch. Hydromulches, usually made from wood and paper byproducts, cover bare lands at construction sites and roadside projects to prevent erosion until vegetation can be established. Above, Summit Seed, Inc., employee Dan Pralle sprays a test plot with one of the cotton-based hydromulches developed during the research study on value-added processing of cotton gin byproducts. ***(Photo by Greg Holt, courtesy of USDA-ARS)***

One of Holt's studies showed that cotton-based hydromulches established a good stand of grass, compared to other hydromulches and a straw blanket, which didn't do as well.

Cotton Incorporated is the research and marketing organization representing upland cotton. The organization partially funded some of Holt's studies.

For more information contact Don Comis, USDA-ARS Public Affairs Specialist; Donald.Comis@ars.usda.gov.

Process for making activated carbons patented

***In Brief:** Activated carbons, commonly produced from nonrenewable coal and from plant byproducts like wood and coconut shells, are used to purify liquids and gases, recover chemical pollutants, and clean up environmental contaminants. ARS has been issued a patent on a new technology that uses renewable and inexpensive animal byproducts to produce activated carbons.*

The ARS has patented a new technology that turns poultry litter and bedding wastes into activated carbons that can absorb some environmental pollutants. Poultry manure pellets *(top)* are converted to activated carbon pellets *(left)* and can then be ground into either granular *(center)* or powdered *(right)* form, depending on end use and filtering task. *(Photo by Stephen Ausmus, courtesy of USDA-ARS)*

Chemist Isabel Lima and Wayne Marshall (now retired) at the ARS Southern Regional Research Center (SRRC) in New Orleans, La., developed the method for turning agricultural bio-waste into activated carbons. This material, called biochar, is the charred remains of poultry litter, supplied by poultry facility operators in the form of bedding materials made of sawdust, wood shavings, peanut shells, droppings, and feathers.

U.S.-grown broiler chickens and turkeys produce an estimated 15 million tons of litter annually.

The process of turning the bio-waste into activated carbons involves grinding the waste materials into a fine powder that is subsequently pelletized. The material is then heated in an oxygen-free furnace at 704ºC to 816ºC (1,300ºF to 1,500ºF), creating a completely sanitized product.

Poultry waste's high phosphorous content may be considered a pollutant when large amounts of the phosphorus enter groundwater and rivers and streams via runoff. But the relatively high concentration of phosphorus adds a negative charge to the activated carbon that is ideal for attracting positively charged ions from metals such as cadmium, copper, zinc, and lead.

The technology works when the highly porous and chemically active surfaces of the activated carbons come into contact with, and adsorb, pollutant molecules in gases and liquids.

Based on published preliminary estimates, the cost of producing the biochar would be about 65 cents per pound of broiler-litter-based carbon, which is competitive with commercial alternatives. Evaluations also have shown that the materials perform at least equal to or better than available carbon products on the market.

The activated carbons produced from animal byproducts may be utilized as adsorbents in any air or liquid waste stream cleanup application in which traditional activated carbon is used, according to the inventors.

For more information contact Rosalie Marion Bliss, USDA-ARS Public Affairs Specialist; Rosalie.Bliss@ars.usda.gov

New technology cuts industrial odors, pollutants

***In Brief:** A North Carolina State University (NCSU) researcher has devised a new technology that could be the key to eliminating foul odors and air pollutants emitted by industrial chicken rendering facilities and—ultimately—large-scale swine feedlots.*

ASABE member Praveen Kolar, assistant professor of biological and agricultural engineering at NCSU, has developed an inexpensive treatment process that significantly mitigates odors from poultry rendering operations. Rendering facilities take animal byproducts—skin, bones, feathers—and process them into useful products such as fertilizer. However, the rendering process produces extremely foul odors.

These emissions are not currently regulated by the government, and the smell can be extremely disruptive to a facility's community. Chemical "scrubbers" to remove odor-causing agents are not very effective, Kolar says. Furthermore, some of the odor-causing compounds are aldehydes, which can combine with other atmospheric compounds to form ozone—triggering asthma attacks and causing other adverse respiratory health effects.

Kolar, working with **ASABE member James Kastner** at the University of Georgia, has designed an effective filtration system that takes advantage of catalytic oxidation to remove these odor-causing pollutants. Specifically, the researchers use ozone and specially designed catalysts to break down the odor-causing compounds. This process takes place at room temperature, so there are no energy costs, and results in only two byproducts: carbon dioxide and pure water.

The researchers developed the catalysts by coating structures made of activated carbon with a nanoscale film made of cobalt or nickel oxides. "We used activated carbon because its porous structure gives it an extremely large surface area," Kolar explains, "meaning that there is more area that can be exposed to the odorous agents. The cobalt and nickel oxide nanofilms make excellent catalysts, because they increase the rate of the chemical reaction between the odor-causing compounds and the ozone, making the process more efficient. They are also metals that are both readily available and relatively inexpensive."

Kolar's next goal is to apply this research to industrial hog farms on a large scale. The research, "Room-temperature oxidation of propanal using catalysts synthesized by electrochemical deposition," was published in the August 2009 issue of *Transactions of the ASABE*.

For more information contact Matt Shipman, matt_shipman@ncsu.edu.

USDA announces $58 million to improve water quality and quantity in agricultural production

***In Brief:** The new program will provide funding for 63 water conservation projects in 21 states.*

The USDA's Natural Resources Conservation Service (NRCS) Chief Dave White announced nearly $58 million for water conservation and water quality improvements on agricultural working lands. The funding was made available through the Agricultural Water Enhancement Program (AWEP).

"We must take steps to protect and preserve our water resources, and the Obama administration is committed to using this program to provide financial and technical assistance to farmers and ranchers to improve water conditions on their land," said White.

AWEP promotes ground and surface water conservation and improves water quality by helping farmers and ranchers implement agricultural water enhancement activities. With the services and resources of other conservation partners, AWEP allows the Federal Government to leverage investment in natural resources conservation.

Landowners can obtain funding through AWEP for several types of projects:

- Water quality or water conservation plan development, including resource condition assessment and modeling.
- Water conservation restoration or enhancement projects, including conversion to the production of less water-intensive agricultural commodities or dry land farming.
- Water quality or quantity restoration or enhancement projects.
- Irrigation system improvement or irrigation efficiency enhancement.
- Activities designed to mitigate the effects of drought and climate change.
- Other related activities deemed to help achieve water quality or water conservation benefits on agricultural land.

AWEP was established by the 2008 Farm Bill, and funding comes from the Environmental Quality Incentives Program (EQIP). The NRCS administers the program for USDA. NRCS implements AWEP by entering into EQIP contracts directly with agricultural producers.

All AWEP recipients must meet EQIP requirements. Though participating AWEP producers do not need to have existing EQIP contracts, they must be eligible for EQIP. All partner proposals were selected competitively. Proposals for priority areas may have received higher rankings, and include property undergoing conversion of agricultural land from irrigated to dry land farming; projects that help producers meet regulatory requirements; and projects located where there is a high percentage of agricultural land and producers in a region or area.

For further information, contact Terry Bish, 202-720-5974, or Sylvia Rainford, 202-720-2536.

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Approved AWEP Projects and Funding by State

Ark. - 1 project - $1,383,417
Calif. - 15 projects* - $18,079,101
Colo. - 1 project - $333,000
Fla. - 1 project - $1,000,000
Ga. - 2 projects - $2,000,000.00
Iowa - 1 project - $158,950
Idaho - 4 projects - $6,920,000
Ill. - 1 project - $49,440
Ind. - 2 projects* - $554,000
Mich. - 1 project* - $1,500,000
Miss. - 2 projects - $2,400,000
N.C. - 1 project - $100,000
N.D. - 5 projects - $2,253,352
Neb. - 5 projects - $2,590,000
N.J. - 1 project - $400,000
N.M. - 4 projects - $3,328,537
N.Y. - 1 project $500,000
Okla. - 1 project - $275,000
Oreg. - 8 projects* - $3,605,879
Texas - 5 projects - $10,425,000
Wash. - 1 project - $53,600

Total - 63 projects - $57,909,276

**Project numbers indicate multi-state projects. Visit www.nrcs.usda.gov regarding specific AWEP projects.*

The pulse of biotechnology

Bioelectrics research could make us healthier

***In Brief:** Naz Islam, a professor in the University of Missouri College of Engineering, collaborates with life-sciences researchers on bioelectric studies. The research may have applications in cleaner, safer agricultural and medical practices.*

Imagine a technology that, in a few controlled zaps, could cure cancer, purify water, boost alternative-energy production, and wrangle agricultural pests—without harmful side effects for humans.

It may seem sci-fi. And certainly the electromagnetic gadgets kept in the basement of the University of Missouri's Engineering Building West—an anechoic chamber, portable pulsars, TEM cells—look futuristic. But Naz Islam and fellow researchers believe that better living through bioelectrics is an imminent reality. Focused pulses of electricity have the potential to replace harmful chemicals in practices ranging from pesticide use to chemotherapy.

"It's a *very* clean way of doing things," Islam said.

Last July, scientists from three continents convened at UM for the 2009 International Bioelectrics Symposium, a two-day, in-depth discussion of the effects that continuous-wave (CW) and nanosecond intense, pulsed electric fields can have on humans, plants, and animals.

Innumerable potential applications were explored by the participants, primarily members of the International Bioelectrics Consortium, which includes researchers from Virginia, France, Germany, Japan and, soon, the United Kingdom.

Islam indicates that in Germany the technology is used to get more juice out of fruit. In Japan, it kills bacteria in water supplies. Old Dominion University in Virginia has received grants from private donors and the National Institutes of Health to investigate its effects on cancer.

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Collaborative circuits

Islam has embarked on interdisciplinary bioelectrics projects that supplement his work as the principal investigator on Department of Defense-funded research of radio frequency effects on electronic systems. His expertise in electromagnetics, he discovered, has biological applications.

"You take an electromagnetic field," Islam explains. "You apply it to a cell, and then you can see the effects of electromagnetic energy—what it does to the cell."

This relatively simple principle has powered multiple undertakings.

Islam has worked with the National Center for Soybean Biotechnology to study the effects of electromagnetic energy on soybean germination—research that could have applications in biofuel production.

As well, he has worked with the UM College of Agriculture, Food, and Natural Resources to investigate how applying electromagnetic fields to trees could eliminate wood-eating nematodes, tiny insects that live on pine beetles. Success could mean a reduction in the need to treat wood with potentially harmful chemicals.

Currently Islam is collaborating with UM professors in veterinary medicine and biochemistry using electromagnetic pulses on LnCaP cells, ostensibly to shrink prostate-cancer tumors. Eventually, he hopes, the studies could lead to the eradication of cancer by electric pulse, in conjunction with—or, ideally, without the need for—drugs and surgery.

Sparking awareness

In his research, Islam enlists students taking his bioelectrics course, a lab in which 90 percent of the education entails hands-on study. Students gain awareness of the technology and its possibilities, strengthening the field for the future.

"The main thing is to generate interest," said Islam, who played a key role in bringing this year's international symposium to the university.

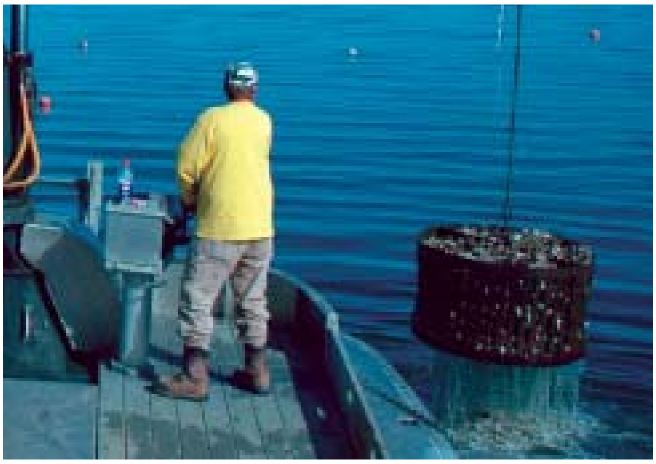
For more information contact Karen Pojmann, University of Missouri Mizzou Wire writer; MizzouWire@missouri.edu.

Traceability in the seafood industry

In Brief: *Following fish from dock to dinner table is a high-tech tracking process.*

With seemingly regular news of contaminated food products and widespread recalls, consumers and advocate groups are growing increasingly vocal about the need for greater oversight and protection in the food industry. One critical component in implementing stronger food safety measures is traceability.

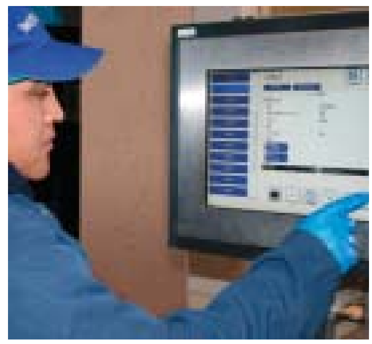
In early anticipation of the need, Pacific Seafood, an Oregon-based seafood distributor, developed and implemented a proprietary tracking system to address food sourcing questions head on. Known as Automated Production Control (APC), this in-house system complements the company's quality control measures by tracing the seafood that passes through its facilities.



Oysters catch on board in the Pacific Northwest: traceability begins.

On to the dock at Pacific Oyster, a division of Pacific Seafood, Coos Bay, Oreg.

Oysters are then loaded on to a truck as traceability continues.



Monitoring, via the APC tracking system at Pacific Seafood, follows each fish (or other seafood) after unloading at the dock.

Each fish is tracked the moment it is unloaded from a fishing vessel and weighed. It is then tracked through processing, packaging, and delivery. In addition, the company stores a range of information in an identification number that is clearly marked on the final product. In the event that a problem arises with a particular batch of fish, Pacific Seafood can quickly isolate the affected product, accelerate a recall process, and protect consumers.

The product's identification number specifies from which boat the product originated, when and where it was unloaded, the equipment and people in contact with the product, when it went into production, and where it was shipped. Along with assistance in potential product recalls, this system provides additional quality control by highlighting areas in which the processor can improve operations or quality assessment.

In developing this tracking system, Pacific Seafood took a holistic approach, incorporating company priorities and industry regulations, both current and anticipated, into the design. The system is critical to efficiently meeting food safety regulations, and it can be adapted to accommodate new regulations as they are introduced. And, in addition to furnishing protection for consumers, the traceability system provides a further benefit for the company: a clear ability to identify a product's source.

For more information, contact Kirsten Forsberg, kirsten@lanepr.com.

Flavorful fruit and veggie wraps inspire tasty creations

***In Brief:** Colorful, paper-thin sheets of edible fruit and vegetable wraps add elegance and appeal to appetizers, entrées, desserts—and more. Your choice: mango, strawberry, tomato-basil, carrot-ginger, or perhaps red bell pepper?*

Made from fruit and veggie purées and other natural ingredients, the wraps and a related product—meltable sheets that form flavorful glazes—are strong yet pliable, which makes them easy to work with. For example, sheets of the rich-red strawberry wrap can be cut into squares, then rolled to form cones to fill with seedless grapes, sliced strawberries, and pineapple chunks for individual servings of fresh-fruit salad. A drop of honey keeps the cone from unrolling.

Wraps and glazes have a role with entrées, too. The apple-honey-maple glaze provides a pleasing blend of flavors for the spiral-sliced hams sold by a major supermarket chain.

Tara McHugh and Carl Olsen, both with the ARS Western Regional Research Center in Albany, Calif., and entrepreneur Matthew de Bord, founder of Origami Foods, LLC, Stockton, Calif., are co-inventors of the patent-pending process that Origami now uses for making these wraps and glazes.

Above, all-natural, colorful carrot-ginger wraps for California rolls. Edible wraps from purées of carrot and other fresh vegetables and fruits have been developed with the help of ARS researchers from the Processed Foods Research Unit, Albany, Calif. *(Photo by Peggy Greb, counrtesy of USDA-ARS)*

All of Origami's wraps contain at least 75 to 90 percent fruit or vegetables, are low in calories and fat, and free of additives, preservatives, and artificial flavors or colors.

For more information contact Marcia Wood, USDA-ARS Public Affairs Specialist, Marcia.Wood@ars.usda.gov.

Principal research engineer John Pierson works to improve refining and de-gumming techniques to convert poultry processing residuals into fuel. *(Photo by Gary Meek, courtesy of Georgia Tech)*

Turning poultry waste into fuel

***In Brief:** Researchers at the Georgia Tech Research Institute (GTRI) are developing cost-effective techniques for separating and converting poultry processing residuals into higher-value products. The techniques would provide a beneficial use for these byproducts, which are typically blended back into lower-value products.*

The ultimate goal is to extract usable, quality feedstocks from poultry processing byproducts such as brown grease extracted from wastewater pretreatment processes. "If successful, we will help reduce costs by providing a cheap and simple way for the industry to better utilize their low-quality waste oil and grease byproducts," said John Pierson, a GTRI principal research engineer.

Pierson teamed with Cumming, Ga.-based American Proteins to obtain samples of poultry-processing waste materials. They first focused their efforts on developing better ways to separate usable portions of the waste—such as free fatty acids, neutral oil, and waxes—from unusable portions, such as solids and other insoluble materials.

Using improved refining and de-gumming techniques, the researchers were able to effectively reduce the volume of waste material by 75 percent.

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For more details on this service, contact Melissa Miller, ASABE Professional Opportunities, 2950 Niles Road, St. Joseph, MI 49085-9659, USA; 269-932-7017, fax 269-429-3852, miller@asabe.org, or visit www.asabe.org/resource/persads.html.

"We are currently working on increasing the efficiency of these separation techniques, and on scaling up our separation techniques for use in a plant rather than the laboratory," noted Wallace.

In addition to developing improved separation processes, the researchers are working to convert the various fractions into biofuels at a higher yield than currently possible with typical processes. The research team is currently conducting solid-catalyst research to convert recovered usable fractions into alkane hydrocarbons or kerosene fuel, a primary ingredient for jet fuel. Initial efforts have identified promising solid-catalyst materials capable of converting selected fractions of polished brown grease more efficiently than traditional processes.

"Recovering these value-added products from waste oils is very important because it gives the industry greater flexibility in revenue generation as the recovered, value-added products can be used for traditional products or biofuels, whatever the market will bear," added Pierson.

For more information contact Daniel Campbell, dan.campbell@gtri.gatech.edu, or Mark Richards, mark.richards@ece.gatech.edu.

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“Sitting on the Brink of Change

The world is changing. In the past, changes in the engineering profession and engineering education have followed changes in technology and society. But would the United States be better served if the engineering profession anticipated advances and prepared for increased benefits to humankind? This is the subject of a publication by James Duderstadt, *Engineering for a Changing World – A Roadmap to the Future of Engineering Practice, Research and Education.* (2008, The Millennium Project, The University of Michigan)

Duderstadt emphasizes that all other learned professions have long ago moved in the direction of requiring a broad liberal arts baccalaureate education as a prerequisite for professional education at the graduate level (law, medicine, business, architecture). Following an initiative begun by the American Society of Civil Engineers (ASCE), the National Council for Examiners of Engineering and Surveying (NCEES—the organization that prepares and administers the professional engineering examinations) adopted provisions in its model law to move toward requirements for BS+30 (bachelors degree plus 30 additional credits) by 2015 as a minimum for licensure as a professional engineer in a resolution first passed in 2006. Support has grown for this has grown.

During the latter half of the 20th century, the economic leadership of the United States was largely due to its capacity to apply new knowledge to the development of new technologies. With just 5 percent of the world’s population, the United States employed almost one-third of the world’s scientists and engineers, accounted for 40 percent of its R&D spending, and published 35 percent of its scientific articles. Duderstadt reports that 40 percent of the engineering masters degree recipients and 61 percent of new engineering PhDs in the United States are foreign nationals, raising concern that U.S. citizens have declining interest in graduate studies in engineering. The United States currently accounts for less than 8 percent of new engineers produced globally each year. The enrollment of women has leveled off at about 20 percent of engineering students, but women comprise about 60 percent of those enrolled for university study. Less than 10 percent of engineering faculty are women, and only about 4 percent are persons of color. Currently, only 55 percent of those entering engineering programs eventually complete their degree in engineering. Students are market sensitive, and Duderstadt contends that the signals are not encouraging for engineering as a profession.

Duderstadt expresses a concern for a disconnect between engineering education, engineering knowledge, and engineering practice. Recruiters tend to look for certain skills with software applications and a GPA rather than looking for the broader skills of communications, effectiveness on interdisciplinary teams, understanding the global context, and ability to engage in life-long learning. ABET has changed its accreditation process away from emphasis on dictating curriculum specifications to setting goals for student learning outcomes. This encourages institutions of learning to offer innovative programs that prepare students for a changing world. Duderstadt encourages faculty to move away from traditional lectures to active learning approaches that engage problem-solving skills and team building.

Duderstadt underscores the importance of teaching students to be life-long learners because the world is changing faster and faster. An encouraging note for ASABE in Duderstadt’s report is that “biology is rapidly becoming as important as physics and chemistry” (p. 32).

Engineering programs should be accredited at both the BS and MS levels, according to Duderstadt, so that the MS degree can be recognized as the engineering “professional” degree. The strongest resistance to change is likely to come from the profession itself.

The skill set for the next generation of engineers has three components that merit mention: 1) the ability to innovate is key to the profession, 2) the integration of knowledge between the natural sciences and social sciences/humanities is critical for solving many problems currently facing society, 3) the importance of a global perspective must always be kept in mind—global markets, global organizations, global impacts.

Just as the Flexnor report of 1910 was instrumental in changing medical education and practice to what it is today, the Duderstadt publication may be key in encouraging change in engineering education and practice. As a society, ASABE should not bury its head in the sand but be aware of the issues and act accordingly. Read it for yourself!

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