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RESOURCE

engineering and technology for a sustainable world

Nourish the Planet

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Cultivating courageous creativity

Nourish the Planet, the theme of this issue of *Resource*, encapsulates what agricultural and biological engineers aspire to do, both individually and professionally. Individually, most ag and bio engineers work on a very small portion of the Earth, but our profession touches all aspects of maintaining a thriving planet. Providing the world with safe, ample, and nutritious food, while regenerating the planet's natural resources, is a complex challenge that requires courageous creativity. In this issue, you will find perspectives on the topic by a diverse group of contributors. The challenges of nourishing the planet are daunting, but no other profession than ours is better equipped or better qualified to tackle them. I hope you will be as inspired by these articles as I am.

I stated that "courageous creativity" is required for two reasons. First, we will all need courage to face the impending challenges with clear vision, and courage to persevere in a changing landscape. The second reason is more personal. In my experience, creativity is not something that you either have or don't have. Instead, it can be developed, just as any ability can be developed with practice. The difference is the type of practice required. Creativity is accessed by stepping away from the world and quieting your mind. However, taking that time out, even if it's just 30 minutes a day, requires courage. It's a rebellious act when everyone else is tied to their ubiquitous electronic devices.

For example, I recently completed a six-month sabbatical. I stepped away from my job as a professor and lived in a 500 square foot cottage in Asheville, North Carolina. That experience allowed me to spend my days differently, and I spent a good part of each day reading. One memorable book was *Deep Work: Rules for Focused Success in a Distracted World* by Cal Newport, whose message is that in order to work deeply, we all need downtime, that is, time away with no distractions. Newport cites studies confirming that downtime aids insight, downtime helps recharge the energy needed to work deeply, and the work that downtime replaces is usually not that important. Many thought leaders, from Carl Jung to Bill Gates, took time away from the world to recharge as part of their routine schedules.

Tim Kreider, an essayist and cartoonist, wrote a 2012 blog for *TheNew York Times* in which he explained that "idleness is not just a vacation, an indulgence, or a vice; it is as indispensable to the brain as vitamin D is to the body ... It is, paradoxically, necessary to getting any work done." The work getting done is not answering e-mails but rather what Newport called "deep work," the ability to focus without distraction on a cognitively demanding task. What more cognitively demanding task is there than the new thinking needed to nourish the planet while facing ever-increasing demands on the Earth's resources?

Working harder does not get more done. We need to work differently to accomplish bigger things. Newport encourages us to select a small number of "wildly important goals" and then focus our energy on those goals. Work that does not serve our wildly important goals is suspect at best. What more wildly important goal is there than nourishing the planet? I encourage you to embrace idleness as a means of fostering the courageous creativity that we will need in the coming years.

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Sue Nokes
suenokes@myasabe.org

events calendar

ASABE CONFERENCES AND INTERNATIONAL MEETINGS

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2020

Feb. 10-12	**Agricultural Equipment Technology Conference (AETC).** Louisville, Ky., USA.
July 12-15	**ASABE Annual International Meeting.** Omaha, Neb., USA.
Oct. 25-29	**The 2nd ASABE Global Evapotranspiration Symposium.** Nanjing, China.
Nov. 30-Dec. 4	**6th Decennial National Irrigation Symposium.** San Antonio, Tex., USA.

2021

Feb. 8-10	**Agricultural Equipment Technology Conference (AETC).** Louisville, Ky., USA.
Jan. 10-15	**Soil Erosion Research under a Changing Climate.** Aguadilla, Puerto Rico.
July 11-14	**ASABE Annual International Meeting.** Anaheim, Calif., USA.

ENDORSED EVENTS

2020

May 20-21	**Watershed Management Conference.** Henderson, Nev., USA.

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ON THE COVER:
ASABE member John Lumkes, Purdue University, snapped this photo of Abby Adair working in Kigali, Rwanda during a Land O'Lakes Global Food Challenge, which connects faculty and students with global aspects of food security and international development.

American Society of Agricultural and Biological Engineers
2950 Niles Road
St. Joseph, MI 49085-9659, USA
269-429-0300, fax 269-429-3852
hq@asabe.org, www.asabe.org

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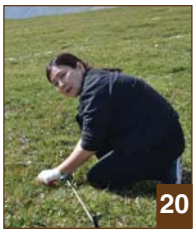
FEATURES



DEPARTMENTS

Welcome to the Discussion

Nicki Engeseth

I was honored to be asked by my fellow guest editor Tony Grift to work with him on this special issue of *Resource*, titled Nourish the Planet. From the start, I was both excited and perplexed by this topic because there are so many directions in which it could go. Now that the issue has been assembled, I think we've just scratched the surface. Many talented individuals have contributed to this special issue, and the articles are very diverse, demonstrating how rich the topic is. While reading through this issue, I hope you are inspired by the many ways we can work together to feed the world's people while protecting the global environment in other words, how we can nourish the planet.

Previously, I had the pleasure of working on a group project with faculty members from the University of Illinois' Department Agricultural and Biological Engineering, including Tony. Coming from a food science background, I was impressed by how systematically Tony and his colleagues approached that project. Increasing agricultural production was our ultimate goal; however, our collaborative group focused on creating a strategy of not only enhancing yield but also delivering high quality, highly nutritious products. In the field of food science and human nutrition, we often discuss the need for interdisciplinary solutions to ensure that the growing population will have access to abundant, safe, affordable, and nutritious food. Tony and his colleagues are doing just that. That's why I was so excited when Tony approached me to work with him on this issue he talks the talk, and he walks the walk.

Guest Editor Nicki Engeseth, Professor and Head, Department of Food Science and Human Nutrition, University of Illinois at Urbana-Champaign, engeseth@illinois.edu.

As I read through the submissions for this issue, I was impressed by the variety of approaches that the authors took in addressing the topic. Many of them focus on specific ways to provide healthy food to a rapidly expanding population while preserving or even rebuilding the natural environment. Their ideas include affordable technology, precision agriculture, effective packaging, and redesigning food processing systems to minimize nutrient degradation while maintaining safety. Engineering new crops (such as golden rice) and re-introducing indigenous crops (such as bambara groundnuts) are creative solutions that address nutritional deficiencies.

Consumer education about food production, food processing, and nutrition is also important. In fact, education might be the most important issue of all. Consumers need to know that food processing is not a bad thing in general, processing ensures the safety, storage life, and convenience of food products. Consumer education can also lead to a reduction in food waste. If people knew more about how their food is produced, they would value it more, and waste it less.

The common theme of this issue is our collective responsibility to produce nutritious foods that are acceptable and available to people of varying cultures and socioeconomic levels. No matter how innovative, nutritious, or affordable it may be, a food product will not be consumed if it doesn't appeal to people. Combining nutrient content with consumer appeal requires food scientists, nutritionists, and engineers as well as experts outside of food production to work together to understand consumers and create successful new ways to nourish the planet.

Not Enough Good Food, or Too Much Bad Food

Tony Grift

Guest Editor and ASABE Fellow Tony Grift, Professor, Department of Agricultural and Biological Engineering, University of Illinois at Urbana-Champaign, grift@illinois.edu.

Dr. Francesco Branca, Director of Nutrition for Health and Development for the World Health Organization, has stated that "malnutrition is a complex issue, but it is the main cause of death and disease in the world." Malnutrition can mean not enough good food, or it can mean too much bad food. In the developed world, obesity-related cardiovascular disease has been the leading cause of preventable death since 2012 (previously, smoking was the leading cause), and obesity is increasing. We are literally eating our hearts out.

In addition to cardiovascular disease, other health consequences of obesity are well known: osteoarthritis, diabetes, as well as cancers of the breast, ovary, prostate, liver, gallbladder, kidney, and colon. In the U.S., childhood obesity has reached worrisome levels, increasing from 5% in 1950 to 20% today, and about half of those obese children will become obese adults. This situation will not improve on its own, as our jobs become more sedentary and our culture promotes the consumption of high-calorie, high-fat, low-cost foods a deadly combination. The medical costs of treating all these sick people are already high and will soon be astronomical.

Modern American food is defined as "a dietary pattern that is generally characterized by high intakes of red meat, processed meat, prepackaged foods, butter, fried foods, high-fat dairy products, eggs, refined grains, potatoes, corn (and high-fructose corn syrup), and high-sugar drinks." No wonder our diet makes us sick (just reading the previous sentence does it for me), and the statistics bear this out. Back in the 1980s, a massive study was conducted in China in which incidences of cancer were recorded across the country. Comparison with countries that were more developed revealed a simple conclusion: all forms of cancer were much less common when diets were based on plant protein, rather than animal protein. To put it bluntly, meat is killing us, while plants can keep us alive. Since the 1980s, China has become developed, and the Chinese people have started to eat more like Americans. As a result, they are starting to see the same diet-related health problems that we face.

Our poor diet got a big boost in the 1950s, when McDonald's (among others) offered quick and convenient meals for our increasingly fast-paced lifestyles. High-calorie, low-cost, tasty (meaning high fat) food could be served in seconds. By 2018, consumer spending in the quick service restaurant (QSR) industry was almost $300 billion. Dividing that figure by the current U.S. population suggests that we spend more than $900 per person (including infants and the elderly) per year in QSRs. If the average fast-food meal costs about $6, then the average American visits a QSR every other day or so. That's a lot of bad food! At the same time, our culture has also produced exercise fads, food fads, weight-loss scams, and a long list of special-interest diets, ranging from Atkins, keto, paleo, and South Beach to veganism and vegetarianism, so at least some of us recognize a connection between lifestyle and health.

So what are we going to do about it? The obesity epidemic is a difficult problem because we are all free to eat whatever diet we wish. However, policy can still have a big effect. When the link between smoking and cancer became irrefutable, tobacco advertising was banned, and now smoking is banned virtually everywhere except in private homes. Vaping may go the same way.

Food is different from tobacco because food is essential for life. Banning ads for "bad" food would lead to legal challenges from producers, and consumers would resent the imposition of a nanny state. Education must be part of the solution, but as long as bad food is cheap and tasty, while good food is expensive and requires shopping, storing, and cooking skills, many of us, especially the most vulnerable, will choose the simplest, cheapest solution.

As a free society, we really can't control what people prefer to eat. However, we can make food healthier overall by reducing excess sugar (especially high-fructose corn syrup), by not claiming that pizza is a vegetable, by providing healthy meals in schools, and by including some moderate exercise in our daily routine (skip the elevator, take the stairs). We owe that to our old age and to the next generation.

My sincere thanks to managing editor Sue Mitrovich for all that she has done for *Resource* over the years. We cranked out some great issues together. I wish her all the happiness in the world, and I look forward to working with her very capable successor Melissa Miller.

Instrumentation for Grain Quality Control

Paul Armstrong and Elizabeth Maghirang

Every year, U.S. farmers grow more than 77 million metric tons of corn, wheat, soybeans, rice, and other grains, worth more than $115 billion annually, to supply the nation and the world with food, animal feed, and biofuels. Our work at the USDA-ARS Stored Product Insect and Engineering Research Unit in Manhattan, Kansas, involves maintaining the quality and quantity of grain by applying engineering principles to cultivar development and grain handling, storage, and processing. Our mission is to ensure that U.S. farmers and processors can meet the growing demand and supply abundant, high-quality grain to the global market.

Since the early 1990s, our research unit has focused on developing instruments and techniques for rapid measurement of grain quality parameters. This effort has included significant work by other USDA engineers, including **ASABE member Daniel Brabec, ASABE member Floyd Dowell** (retired) and Tom Pearson (retired). As these instruments were being developed, collaboration with a diverse group of researchers and stakeholders provided guidance on the specific requirements for grain quality measurement. It was important that these technologies were relevant to the end users and adaptable to future applications.

Paul Armstrong carefully installs the lighted tube of the SKNIR instrument.

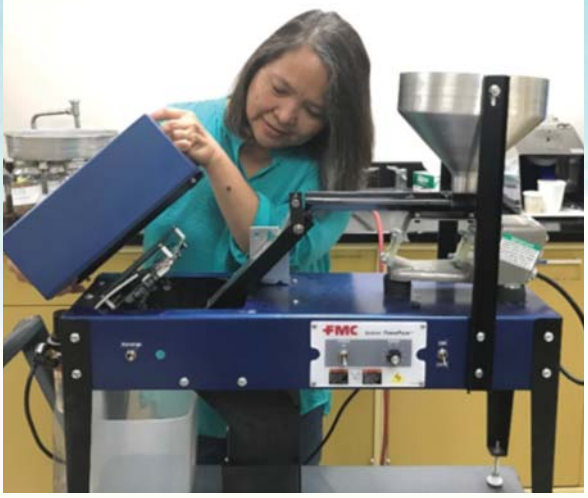
There is a critical need for instruments that can measure and sort individual kernels by specific quality attributes (such as hardness index, protein content, grain color, and defects) in an automated and non-destructive manner. Recognizing this need for single-kernel measurement, most of our work has been dedicated to developing single-kernel instruments using detection techniques such as visible and NIR spectroscopy, light-emitting diodes, lasers, and imaging. The first practical single-kernel near-infrared reflectance spectroscopy (SKNIR) instrument developed in our lab, and later produced commercially by Perten Instruments, had the ability to "singulate" small kernels (such as wheat, sorghum, and rice grains) into a viewing area for spectral data collection (950-1650 nm) and quality attribute measurement, followed by four-way sorting using solenoid-driven gates based on pre-selected thresholds (~0.5 kernels per second).

To address kernel positioning, accommodate medium-sized kernels, and achieve higher throughput (~3 kernels per second), another SKNIR instrument was developed that collected single-kernel spectra from kernels as they tumbled along the length of a glass tube while being illuminated by multiple lamps. This instrument can make simultaneous measurements of multiple quality attributes using NIR spectra from small to medium-sized types of grain (e.g., wheat, sorghum, rice, soybeans, and corn). Sorting capabilities can be added, and a visible wavelength spectrometer can be substituted for NIR.

A high-speed system (20 kernel per second) has also been developed using discrete wavelength LEDs and low-cost electronic hardware. This instrument can perform two-way sorting based on a specific quality attribute and is easily calibrated by the user. In operation, the LEDs are rapidly pulsed while a photodiode sensor collects reflectance measurements from free-falling kernels. The kernels are gravity-fed from a vibratory feeder chute and then fall past the sensor. Kernel classification is performed instantly, and the kernels are sorted using an air valve that diverts individual kernels based on their classification. The instrument has been commercialized by National Manufacturing Co. (Lincoln, Nebraska) and has been widely distributed to U.S. and international customers. Other variations of this sorter use a specially designed camera linked to a processor and configured to perform color image processing in real-time.

These instruments have allowed plant breeders to select specific traits when developing new lines, and they have allowed farmers and processors to evaluate the quality of grain and related products prior to buying and processing, thereby helping to ensure the availability of high-quality products for consumers. Some of the instrument applications reported in various publications or currently being evaluated include:

- Sorting haploid and hybrid maize seeds based on oil content.
- Rapid phenotyping to detect barley yellow dwarf virus infection and resistance.
- Sorting blue-eye damage in corn.
- Detecting the presence or level of internal insects, black tip, and sprouted kernels in wheat.



Elizabeth Maghirang sets up the LED-based high-speed sorter.

- Detecting damage levels in wheat kernels caused by sunn pest.
- Single-kernel deoxynivalenol analysis to aid breeders in studying Fusarium head blight resistance in wheat.
- An integrated measurement system for phenotyping of sorghum seeds.
- Sorting various grains and oilseeds for protein content, oil content, grain hardness index, and color.
- Detecting non-oat grains in oat streams for gluten-free products.

Agricultural technology continues to expand, requiring expertise from diverse educational backgrounds and thus providing more employment opportunities than ever before. On the forefront of this development, for the future generation of engineers, is the use of artificial intelligence, big data analytics, and advanced sensors and autonomous systems, all with the goal of providing efficient and abundant food with a smaller environmental footprint. The future of agriculture provides a great opportunity for a fulfilling career for future engineers and for those in many other disciplines.

ASABE member Paul Armstrong, Research Agricultural Engineer, USDA-ARS Stored Product Insect and Engineering Research Unit, Manhattan, Kansas, paul.armstrong@usda.gov.

ASABE member Elizabeth Maghirang, Agricultural Engineer, USDA-ARS Stored Product Insect and Engineering Research Unit, Manhattan, Kansas, elizabeth.maghirang@usda.gov.

Rediscovering Indigenous Crops

Laurencia Govender, Kirthee Pillay, Muthulisi Siwela, Albert Modi, and Tafadzwanashe Mabhaudhi

The Centre for Transformative Agricultural and Food Systems (CTAFS) at the University of KwaZulu-Natal (UKZN) in South Africa was established to contribute to building resilient, sustainable, and healthy food systems through transdisciplinary research. This mission derives from the realization that food and nutrition security is a complex and multi-faceted challenge, and tackling it calls for collaborative and transdisciplinary approaches. Through programs such as the Sustainable and Healthy Food Systems (SHEFS) and funding from the Water Research Commission (WRC) of South Africa, we conduct transdisciplinary research for informing policy.

Sub-Saharan Africa faces a double burden of malnutrition, as both undernutrition and overnutrition, which poses a serious public health concern. People in rural and peri-urban areas are most affected. A major factor contributing to malnutrition is household food insecurity. Compared to other regions, sub-Saharan Africa has the highest incidence of moderate (30%) and severe (20%) food insecurity. In South Africa, although there has been a decline in the number of people with inadequate access to food, malnutrition remains problematic, with 21.3% of households lacking access to nutritious food. Many households cannot afford healthy diets; instead, their diets are predominately starch-based and lack essential nutrients. A food basket comprising 28 basic nutritious items costs approximately USD $50 per month, which is unaffordable to many.

> “Traditional crops have been neglected despite their nutrient contents.”

If nutritious foods are unaffordable, how can we provide a diversified diet, and what alternatives exist? A possible answer lies in underused indigenous crops, which historically underpinned dietary diversity. Such crops have potential to improve nutrition by providing affordable alternatives to monotonous diets. However, due to westernization, these traditional crops have been neglected, despite their nutrient contents. Communities now see them as poor people’s food and shun them.

Bambara groundnuts (*Vigna subterranea*), an indigenous crop of African origin, could make a big difference in many people's lives by providing a nutrient-dense alternative to animal-sourced foods.

Bambara groundnut (*Vigna subterranea*) is an indigenous crop of African origin. It is not produced commercially but is grown for subsistence in the South African provinces of KwaZulu-Natal, Gauteng, Northwest, Mpumalanga, and Limpopo. Bambara groundnut is an annual crop and exhibits huge variability, including black, red, cream/black eye, cream/brown eye, cream/no eye, speckled/flecked/spotted, and brown varieties. It is drought-tolerant and produces reasonable yields in marginal areas that receive 400 to 600 mm of annual rainfall. It can be grown on its own or as an intercrop with cereal staples.

Bambara groundnut is a nutritious alternative to animal-sourced foods. It contains the essential amino acid methionine as well as high levels of essential fatty acids, vitamins, and minerals. Despite being nutrient dense, it remains underused for several reasons: it has a strong beany flavor, it is hard to mill and hard to cook, and it has some anti-nutritional properties. An additional factor in South Africa is that many potential consumers are unaccustomed to this crop.

However, there is hope for promoting bambara groundnut as a food crop. Studies have shown a positive acceptance of bambara groundnut depending on the way in which it is prepared. Consumer panels showed an encouraging acceptance of biscuits prepared with different substitution levels, as well as puree and snacks made with bambara groundnut. This shows that the processing method has an impact on consumer acceptance. Roasting has been shown to improve the flavor of bambara groundnut and increase the protein concentration.

Thus, the key to promoting consumption of bambara groundnut as a food product may be informing the consumer and developing recipes. For example, we investigated consumer acceptance of a composite dish comprising *phutu* (crumbly porridge) made with either white or yellow provitamin A-biofortified maize and bambara groundnut curry (see Further Reading). Participants rated the food samples as good for most of the sensory attributes evaluated.

When promoting bambara groundnut and other indigenous crops, it is important to consider the socio-economic status, geographic location, and culture of the target consumers, because these factors significantly affect food choice.

So far, the evidence shows that there is a case for promoting indigenous crops such as bambara groundnut, especially for vulnerable populations. Indigenous crops could be introduced into school feeding programs to provide affordable, healthy alternatives. That approach would increase people's exposure to indigenous crops at a young age, and hence improve the acceptability of these crops in the future. Local farmers could be educated on indigenous crops and incentivized to produce them. That approach would improve the visibility and use of indigenous crops, promote job creation, and improve food security.

Indigenous crops like bambara groundnut have the potential to make a difference in the lives of vulnerable people by providing them with nutrient-dense alternatives.

Laurencia Govender, Lecturer, Centre for Transformative Agricultural and Food Systems, University of KwaZulu-Natal, Pietermaritzburg, South Africa, govenderl3@ukzn.ac.za.

Kirthee Pillay, Lecturer, Dietetics and Human Nutrition, School of Agricultural, Earth, and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa, pillayk@ukzn.ac.za.

Muthulisi Siwela, Associate Professor, Dietetics and Human Nutrition, School of Agricultural, Earth, and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa, siwelam@ukzn.ac.za.

Albert Thembinkosi Modi, Deputy Vice-Chancellor, College of Agriculture, Engineering, and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa, modiat@ukzn.ac.za.

Tafadzwanashe Mabhaudhi, Honorary Research Fellow, Centre for Transformative Agricultural and Food Systems, University of KwaZulu-Natal, Pietermaritzburg, South Africa, mabhaudhi@ukzn.ac.za.

Further reading

Govender, L., Pillay, K., Siwela, M., Modi, A.T., & Mabhaudhi, T. (2019). Consumer perceptions and acceptability of traditional dishes prepared with provitamin A-biofortified maize and sweet potato. *Nutrients, 11*(7), 1577. http://doi.org/10.3390/nu11071577.

The Role of Precision Agriculture

Yu Zhang

My work in food science involves developing technologies that can improve food quality and human nutrition. One of the most important aspects of human nutrition is quality control, including constant inspection to evaluate and grade food products. Computer vision, as a replacement for human vision, can provide faster and more objective inspections of external and internal quality attributes. Computer vision also plays an important role in nutrient analysis. For example, many researchers use hyperspectral imaging to analyze the nitrogen content of wheat. Near-infrared imaging is widely used to detect nutrients in milk. The technologies developed in my research can help people enjoy higher-quality food, and that is my biggest motivation.

Technologies play an important role in food quality control and nutrient analysis, and that can help people make better food choices. However, we need to provide better control at the beginning of the value chain, that is, at food production. We need to reduce harmful inputs when we grow plants and raise livestock, while increasing the nutrient content at the same time. For example, excessive use of herbicides and pesticides in the field can destroy the nutrient contents of the crop and introduce harmful components as well.

To control food quality at the source, food scientists and engineers must collaborate with precision agricultural engineers. Precision agriculture is no longer a new idea. It has become the third wave of the modern agricultural revolution, after the first wave based on mechanization and the second wave based on genetic modification. To feed the projected global population of 9.6 billion by 2050, new technologies have extended the agricultural revolution with precision agriculture.

Precision agriculture optimizes crop management by providing producers with abundant information. Advanced sensing technologies (including thermal, multispectral, and hyperspectral imaging) provide detailed information on crop status, soil status, and environmental conditions to allow accurate control of inputs to prevent weeds, diseases, and losses due to climate change. Precision agriculture in crop production includes variable-rate applications (planting, spraying, fertilization, irrigation, etc.), autonomous guidance of machinery, agricultural robots, and unmanned aerial vehicles as sensing and spraying platforms. The result is reduced use of herbicides and pesticides, improved water use efficiency, improved energy efficiency, and increased crop yield and quality.

Precision agriculture also improves animal production, particularly animal welfare. A healthy environment and appropriate treatment affect the quality of animal products. Good animal welfare prevents diseases and improves the nutrient content of meat, milk, and eggs. Precision agriculture provides continuous monitoring of animal management using different sensors. It can detect diseases based on animal behavior analysis using machine learning methods, and it can improve product quality by precisely controlling the animal environment and production inputs. Precision control of plant and animal production provides accurate information for post-production food processing, and it ultimately contributes to better human nutrition.

> “Precision agriculture is no longer a new idea It has become the third wave of the modern agricultural revolution.”

Food science and engineering includes multiple disciplines—chemistry, microbiology, bioinformatics, engineering, etc. No matter what area you focus on, collaboration with others will benefit your work, and it will maximize the benefits of food science and technology.

ASABE member Yu Zhang, Research Assistant Professor, Department of Agricultural and Biosystems Engineering, North Dakota State University, Fargo, yu.zhang.7@ndsu.edu.

Food Needs Packaging

Scott A. Morris

Ask anyone about packaging and their first response is usually about an annoying package that can't be opened (or closed), while their second response might be about litter, recycling, or ecological impact. This is unfortunate, because the benefits that packaging provides often go unnoticed.

The fact that there is simultaneously a global calorie surplus as well as localized food shortages often gets lost in discussions of feeding the planet. Many factors are involved, from food waste and economics, to political upheaval, infrastructure problems, and market inefficiencies. What role does packaging play in improving food distribution? Simply put, you have to move food from wherever it is to where the people are. More than that, food has to be safe, culturally acceptable, nutritious, and affordable. When it's done well, packaging makes all that happen. To break down a complex global system, let's consider that packaging provides four basic functions: protection, communication, utilization, and integration. These four functions can help nourish the world.

Protection

Keeping a food product in marketable and edible condition has been a primary function of packaging ever since the Sumerians and the Chinese stored their beer in earthenware casks. Later, wine and olive oil were shipped in sealed amphorae around the Mediterranean and beyond. Modern technology ensures that today's material-efficient food packaging provides safe, affordable, nutritious products with a shelf-life measured in years. In the future, packaging will use active materials that prevent spoilage or even modify the product, such as milk packaging that lyses lactose to provide a lactose-free product.

Communication

Communication, typically in the form labeling, has been part of packaging from the beginning. With the advent of machine-readable UPC and QR coding, packages now inform the consumer and connect the consumer to the production, distribution, and retail infrastructure.

Traceable labeling is an essential but often invisible part of the value chain. It allows tracking of products in real-time, monitoring of inventory, identification of end users, and forecasting of demand weeks in advance. Other benefits include security, such as anti-counterfeiting codes that can be texted to the producer, giving the user an immediate confirmation of authenticity. The reverse flow of data in such systems also provides geographic data about the user's approximate location, which can help identify outbreaks of contamination.

Inexpensive wireless communication is driving global internet use past the 50% mark. As living standards rise, particularly in developing countries, demand for discretionary purchases increases, and packaging can accommodate that demand. Challenges remain, particularly in infrastructure. Delivering an online order to suburban Toronto is relatively simple, but what systems will we use for deliveries in Addis Ababa, Bishkek, Cuiabá, or Dimako?

Utilization

Clever designs capture attention, and some packages have become iconic. With less fanfare, we have improved packaging utility in other ways, from pre-sterilized medical supplies to shelf-stable microwaveable foods. In developing countries, small-quantity packages of familiar foods and consumer items have soared in popularity. As living standards rise, consumers will demand convenience, which applies to small-quantity packages from a sari-sari in the Philippines as well as large-quantity packages from a grocer in Chicago. Flexible man-

A handmade, tinned-steel soup can from the 1884 Greeley Polar Rescue Expedition contrasted with modern, lightweight food packages, including a plastic jar that can withstand thermal treatment, a retort pouch that allows thermal processing of products ranging from seafood to military rations, and a laminated box that preserves an ultra-high temperature (UHT) preprocessed product. These new packages keep their products safe and nutritious for several years. They also carry price coding and batch data in machine-readable form, information on nutrition and use for the consumer, and many other features.

ufacturing, which is evolving toward mass customization, creates the ability to adapt the same product to different regional, local, and personal needs. The packaging industry, which is driven to provide a better customer experience, is learning that good design is not expensive when spread across many units.

Integration

If a product cannot be made, or if it cannot be distributed, then it cannot be used by the people who need it. Packaging must integrate with production at all scales, from takeout food stands to regional bottling plants. The packaged product must then integrate with distribution systems at all scales. Finally, after the product is consumed, the used packaging must integrate with the disposal or recycling systems, if any.

Oceanic gyres of polymer particles are traceable to riverine outflows from regions that have experienced recent economic growth and have enthusiastically embraced packaged goods, but have not yet developed the necessary collection or recycling infrastructure. This is similar to the waste disposal problems experienced in industrialized countries a few decades ago, so solutions will evolve, assisted by the economic benefit of reclaiming waste and the social benefit of removing contamination.

The future

Future packaging will have to respond to the usual challenges, such as evolving tastes, fad marketing, and social, political, and economic shifts. Packaging must also respond to more profound challenges, such as the movement of the global economy toward Asia, or even far-fetched ideas, such as altering the human biome to allow digestion of cellulosic materials, rather than depending on herbivores.

Whatever the challenges, and there will always be challenges, there must be packaging systems that protect food, efficiently and reliably, while it gets to where it's needed. Agricultural and biological engineers have the best qualifications to address these issues. As engineers who understand food, we are particularly well positioned to make positive contributions to food packaging.

Scott A. Morris, Associate Professor, Department of Agricultural and Biological Engineering and Department of Food Science and Human Nutrition, University of Illinois at Urbana-Champaign, smorris@illinois.edu.

Food Engineering for Minimal Processing

V. M. Balasubramaniam

In the 21st century, globalization and urbanization have increased the population of health-conscious consumers, who consider diet a key part of a healthy lifestyle. These consumers prefer processed foods that have fresh-like quality attributes, and few or no chemical preservatives. As the global population continues to increase, the demand for minimally processed, microbiologically safe foods with health-promoting nutrients will also increase.

This consumer demand has shifted the attention of food engineers toward developing minimal processing technologies using alternative treatments, such as pressure, electric fields, UV, gases, and ultrasound, to inactivate pathogens with little or no impact on the nutrients in food products. Foods that are prepared with such technologies may help reduce the risk of various lifestyle-related diseases without compromising the safety of the product.

Bala and his students evaluate a continuous high-pressure process for beverages in the emerging food processing pilot plant at Ohio State's Center for Clean Food Process Technology Development.

The study of these minimal processing technologies is multidisciplinary and integrates advances in food process engineering, nutrition, product formulation engineering, microbiology, and medical science. We are just beginning to understand the unique advantages and limitations of these novel technologies for preserving the health-promoting properties of foods. More research is needed to understand how such foods are digested and the bioavailability of nutrients.

Industrial implementation of minimal processing technologies can also reduce energy and water use. To verify this benefit, life cycle assessments are needed of the various technologies. Effective solutions are also needed for reducing or reusing food packaging, and reducing packaging waste. Similarly, efforts are needed to develop sensors for improving the efficiency of various food manufacturing operations, as well as for product handling, tracking, and distribution.

Tips for food engineering students

Food engineers work in a multidisciplinary, global, and collaborative environment. Thus, food engineering students need a broad education and a variety of soft skills, including the following:

- *Mastering the fundamentals:* Develop a solid foundation in process engineering (heat transfer, fluid mechanics, and mass transfer) and food science (food chemistry, microbiology, and nutrition).
- *Critical thinking and problem solving:* A solid technical foundation is not enough. Develop critical thinking and problem skills to make logical and informed decisions.
- *Listening skills:* Food engineers need to develop listening skills to work effectively and communicate in multidisciplinary teams with people from different backgrounds.
- *Digital technology and data analytics:* With the ongoing advances in digital technology, food engineers collect and analyze increasingly large volumes of data. Thus, data management skills are essential.
- *Scientific communication to a diverse audience:* In this era of social media, all engineers must hone their communication skills, so they can share their work with the general public as well as their professional peers.

ASABE member V. M. (Bala) Balasubramaniam, Professor of Food Engineering, Department of Food Science and Technology and Department of Food Agricultural and Biological Engineering, The Ohio State University, Columbus, balasubramaniam.1@osu.edu.

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From Making Enough Food to Making Healthier Food: The Evolution of Food Security

Robert Zeigler

My fascination with agriculture can be traced to my earliest days on my family's western Pennsylvania dairy farms. Later, as a Peace Corps volunteer in the early 1970s, witnessing the terrible consequences of a famine in the Democratic Republic of the Congo (then Zaïre) set me on a life-long career in global food security. My reading at the time included *The Population Bomb* by Paul Ehrlich and *Famine 1975* by William and Paul Paddock, in which global famines were considered inevitable. As a contrarian, and entranced by the cultural diversity that I was just beginning to appreciate, falsifying that grim prediction looked like a pretty good way to spend my time. Coupled with my interest in plant ecology, working to develop sustainable increases in food production was a natural fit.

> "While my generation took up the challenge to feed the world's hungry, the new generation of agricultural scientists must determine how to nourish our people while preserving our environment. And the magnitude of this new challenge should not be underestimated."

In the early 1980s, the primary problem confronting large segments of the world's population was simply getting enough calories to prevent starvation. At that time, there was a critical need to improve the total production of energy-dense staple crops such as rice, maize, and wheat. As the Green Revolution translated large international investments in science, education, and infrastructure into abundant food supplies, the threat of global famine receded.

In the 1990s, following the emblematic Rio de Janeiro Earth Summit, global attention shifted from food security to the environment. As a consequence, agriculture was relegated to a relationship of near-enmity to the environment. Fortunately, most serious environmentalists now agree that well-managed intensive agriculture is the only way to feed our growing population while minimizing agriculture's environmental footprint.

However, the shift of attention away from food production was premature and ignored one of the founding principles of agricultural science, albeit applied to human nutrition. In the 19th century, Justus von Liebig formulated the Law of the Minimum, which stated that when a limiting factor to plant nutrition, such as nitrogen deficiency, was removed, the essential nutrient next closest in deficiency would become the limiting factor for plant growth. Unless the new limiting factor was addressed, increasing the full range of essential nutrients would have little benefit. As applied to human nutrition, once the severe caloric limitations were removed, other limitations to growth and health were revealed.

The most obvious limitations to emerge were vitamin and micronutrient shortages. Deficiencies in vitamins A and D, along with iron and zinc, were shown to have severe and long-term health consequences. Increasing other important dietary components, such as proteins, had little positive effect. These micronutrient shortages came to be known as hidden hunger, and significant international efforts to improve the nutritional composition of staple foods are beginning to show results.

Golden rice (right) is a genetically engineered rice that contains nutritionally significant levels of beta carotene, a precursor to vitamin A in human diets. It was developed to address the serious deficiency of this essential micronutrient in some of the world's poorest populations. However, its release has been hampered by those who oppose genetically modified foods. *Photo courtesy of the International Rice Research Institute.*

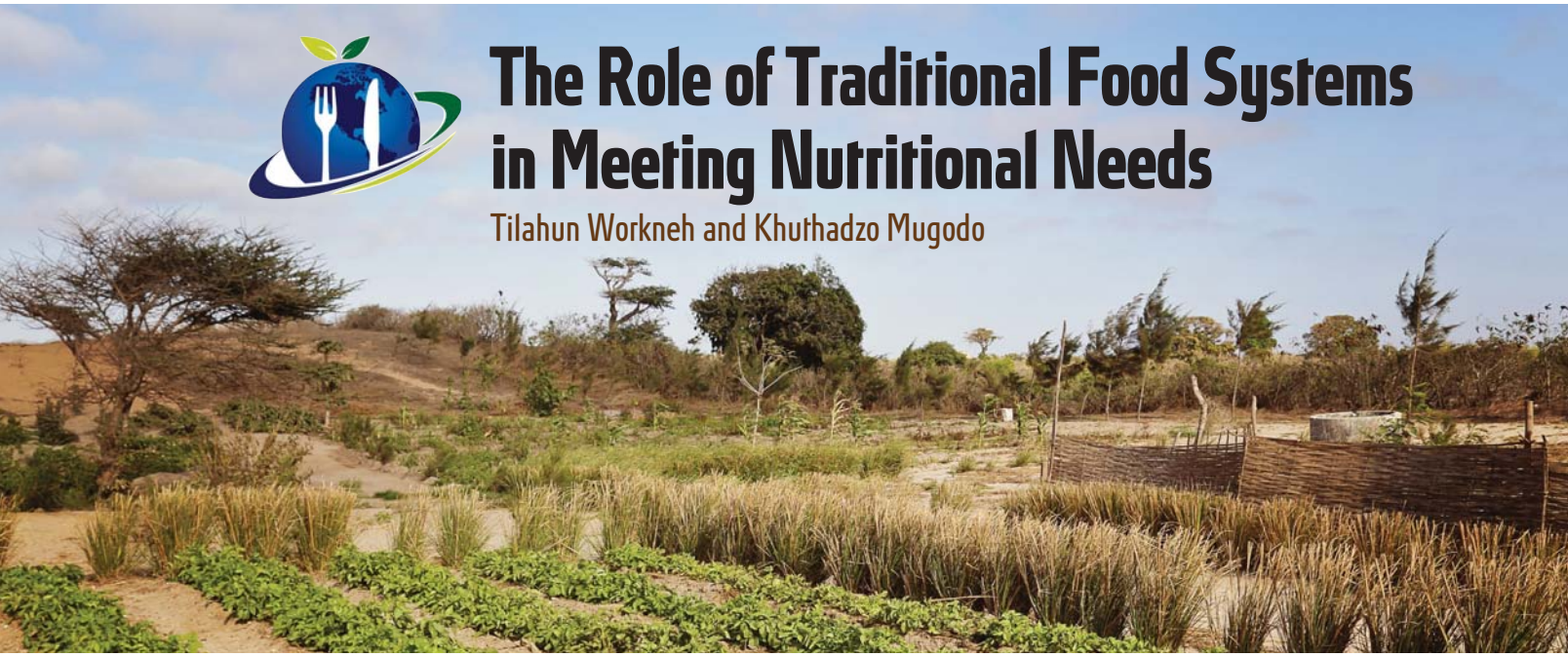
Rice and wheat varieties that are high in iron and zinc have been developed. Maize and rice varieties with high levels of beta carotene, a dietary precursor to vitamin A, are also in the late stages of development and deployment.

A parallel problem, often referred to as overnutrition, has also begun to emerge. Excessive, or unbalanced, consumption of carbohydrates is now understood to be a contributing factor to a variety of major heath problems, including type II diabetes, heart disease, and colorectal cancers. Thus, a new challenge faces the global development and research communities. Put simply, how can we continue to nourish a mostly urban, mostly sedentary population of 10 billion with crops that were domesticated 10,000 years ago, when almost all humans toiled in the fields or were otherwise engaged in physical labor?

While my generation took up the challenge to feed the world's hungry, the new generation of agricultural scientists must determine how to nourish our people while preserving our environment. And the magnitude of this new challenge should not be underestimated. It will involve fundamental redesign of some of our crops' basic metabolism and the application of sophisticated biochemistry and genetics. Research on how and why plants produce their astounding array of primary and secondary metabolites must be paired with studies of how complex carbohydrates, fatty acids, and vitamins interact within our bodies. As if further complications are needed, these interactions must be placed within the extraordinary ecosystem of our own microbiomes.

As in the days of the Green Revolution, we are witnessing another momentous convergence of global development goals with biological and ecological sciences. These are exciting times to be a young scientist with a sense of adventure.

Robert Zeigler, Director General (Emeritus), International Rice Research Institute, Los Baños, Philippines, bob@zeiglermail.net.



The Role of Traditional Food Systems in Meeting Nutritional Needs

Tilahun Workneh and Khuthadzo Mugodo

Globally, about one billion people are part of the traditional food systems that dominate the developing world, including sub-Saharan Africa. These systems are characterized by family-based farming, production of staple foods, have limited market access, and little or no contribution to the larger food supply chain.

The main challenge for the people in these traditional food systems is the lack of nutritional diversity, or undernutrition, regardless of the type of production. Of the 821 million people who are undernourished globally, 257 million are in Africa and 237 million are in sub-Saharan Africa. The trend for sub-Saharan Africa, as observed in 2018, is accelerating. Consequently, this region is not on track to meet the United Nations' Sustainable Development Goal 2 (SDG 2) of ending all forms of hunger and malnutrition by 2030.

The most frequently underestimated consequence of undernutrition is its contribution to human development. The World Bank has shown that undernutrition in its various forms may be delaying Africa's transition to the fourth industrial revolution. This is because undernutrition makes it difficult for people to reach the level of cognitive ability that allows them to synthesize complex concepts, such as the principles underlying engineering and technological fields.

Another challenge facing traditional food systems is climate variability. The main limitation to accessing markets and contributing to the food supply chain is the lack of consistent production, which can be attributed to the extreme weather patterns that have been dominating the region, as well as water shortages, which have resulted in massive crop losses. Open-field conditions are not suitable for growing diverse crops. For example, in South Africa, traditional food systems have potential for growing vegetables in addition to staples. However, growing a variety of crops, which can improve a community's nutritional status, is costly because it requires environmentally controlled production systems.

As a strategy for adopting to climate variation, smallholder farmers are planting less produce, or not planting annually. As a result, the inconsistent production supply of foods leads to undernutrition, especially in rural communities. These communities must rely on what is available in the local open markets (products sold at roadsides), which are often limited to maize and wheat products.

Despite the challenges, traditional food systems are important to the culture of sub-Saharan Africa. Innovations could help these systems practice more nutrition-sensitive agriculture. Here are some of the necessary innovations:

Food system assessment

Addressing the challenges facing traditional food systems requires analysis of all the components of the system, to identify the scale and impact of the challenges. This analysis should include all the relevant food value chain and stakeholders.

Sector collaboration

An additional challenge facing traditional food systems is the dumping of foreign products, which makes imported products less expensive than local products. As a result, local producers must struggle to practice nutrition-sensitive agriculture while their profitability is threatened. Inclusive solutions from various sectors are needed to address this economic challenge.

Diverse production

The nutritional value of traditional food systems can benefit from the addition of regionally appropriate products, such as orange-fleshed sweet potato due to its high vitamin A content, and many other fruit and vegetables known to grow in sub-Saharan Africa. Several programs have been initiated to encourage production of these cultivars. Sustainable, small-scale production of a variety of crops can be accomplished through farmer cooperatives, which contribute to the local economy by providing employment and fair trade.

Nutrition education

It is essential to educate people within traditional food systems about the importance of nutrition, especially the local producers because they are the source of the community's food. The focus should be on ensuring that the local community is provided with a highly nutritious variety of foods.

Climate-smart production and food preservation

Finally, innovation in local agricultural practices, including production and preservation methods, is necessary for improving traditional food systems. Some of the needed solutions include technology to support decision making, information-based management, sustainable mechanization, and sustainable use of water, land, and soil. Postharvest processing technologies designed for the farmers in these systems is essential for sustainability in a variety of fresh and processed products.

Food security is a challenge throughout Africa. This challenge requires localized technology that is based on multidisciplinary research and development. History has shown that working in professional isolation is not fruitful. Today's global environment requires multinational partnerships that focus on sustainable innovations. There are many opportunities in this field, and there is a high demand for engineers who want to benefit the global population.

Tilahun S. Workneh, Professor, Discipline of Bioresources Engineering, School of Engineering, University of Kwazulu-Natal, Pietermaritzburg, South Africa, seyoum@ukzn.ac.za.

Khuthadzo Mugodo, New Generation of Academics Programme (nGAP) lecturer, Discipline of Bioresources Engineering, School of Engineering, University of Kwazulu-Natal, Pietermaritzburg, South Africa, mugodok@ukzn.ac.za.

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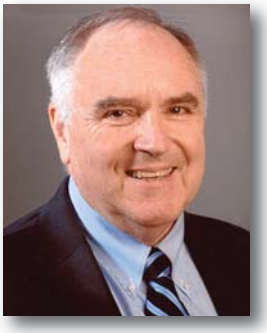
A Food Safety Success Story: Detecting Mycotoxin Contamination

Rebecca Nagy

In the early 1960s, nearly 100,000 turkeys died under suspicious circumstances in the U.K. It was soon determined that these birds were given feed that contained peanut meal that was contaminated with a fungus. The fungus produced a lethal, carcinogenic substance known as an aflatoxin. Aflatoxins are naturally occurring compounds and are a type of secondary metabolite, known as mycotoxins, produced by certain fungi.

The U.S. Food and Drug Administration (FDA) and the USDA responded to the U.K. incident with a mandate to test all shelled peanuts produced in the U.S. for aflatoxin contamination during processing. Any lot with more than 20 parts per billion was deemed unsafe.

Unfortunately, the test results were highly variable, which created uncertainty in determining which lots were safe and which were not. Some lots that were actually well below the FDA limit produced test results that were above the limit for aflatoxin contamination, and those lots were rejected. Far more troubling, some lots that were actually above the FDA limit tested below the limit, which cleared them for use in the food supply.



ASABE Fellow Thomas Whitaker.

That's where **ASABE Fellow Thomas Whitaker** enters the story. When Whitaker arrived at the Department of Biological and Agricultural Engineering (BAE) at North Carolina State University in 1967, aflatoxins had just been discovered. Whitaker joined NC State with a faculty appointment and a position with the USDA-ARS Market Quality Handling Research Unit, which was housed in BAE. Since then, he has dedicated his career to improving food safety. He is internationally known for his work in evaluating mycotoxin sampling methods for agricultural commodities.

A needle in a haystack

Working with NC State's Department of Statistics and industry partners, Whitaker's team improved the methods used to detect aflatoxin in agricultural commodities. "The first thing I had to do was learn why there was so much variability," Whitaker explained. "I looked at the sampling, the sample preparation, and the analytical steps of the aflatoxin test procedure to see where errors could arise." He determined that uncertainty was associated with all three steps of the test procedure. Uncertainty could occur during sampling, and it could occur in the lab.

The fungus *Aspergillus flavus* is a major producer of aflatoxin in crops.

The team determined that 80% of the variability in the aflatoxin testing procedure was a result of errors during sampling. Looking for contaminated peanuts in a commercial lot is like looking for a needle in a haystack. "A peanut lot has millions of kernels in it," Whitaker explained, "And maybe one kernel in a thousand is contaminated. If you find contamination, it's because you got that one contaminated kernel in your sample, or you can sample the lot and miss the contaminated kernels. That explained why we were seeing so much variability."

From those findings, the team developed a method to evaluate the risk of accepting a bad lot and the risk of rejecting a good lot for any mycotoxin sampling protocol as a function of the sample size, test portion size, and number of analyses. That method was used by the FDA and USDA to design the peanut industry's sampling protocol, which is still used today to test all shelled peanuts in the U.S. for aflatoxin.

Because of Whitaker's success in those peanut studies, he and his team have been asked by domestic and foreign food industries, regulatory agencies, and by the Codex Alimentarius to study mycotoxin contamination in other food commodities. To date, Whitaker and his team have developed methods to design and evaluate mycotoxin sampling protocols for more than 20 different mycotoxin/commodity combinations.

Established by the FAO and WHO, the Codex Alimentarius is the preeminent repository of international food standards. Its standards, guidelines, and codes of practice protect the health of consumers and ensure fair practices in the food trade. The Codex Alimentarius used the methods developed by Whitaker and his team to establish maximum limits for mycotoxin contamination, as well as sampling protocols for commodities that are traded in international markets. The method used to design and evaluate sampling protocols is available at http://tools.fstools.org/mycotoxins/.

The future of food safety

Whitaker is proud of what he and his colleagues have accomplished. His research has assisted domestic and international producers, processors, and regulatory agencies in developing mycotoxin control programs to improve international trade and ensure consumer protection. The sampling methods originally developed for mycotoxin detection have been extended to evaluate the methods used to detect genetically modified grain, TCK spores in wheat, pesticides on seeds, protein allergens in food products, and toxic compounds in fruit.

"When you see a problem that's difficult and important, you really want solve it," Whitaker said, "and we had the tools to do it. We shared our research results with other groups around the world who were also working on mycotoxins. There was an economic concern for manufacturers and a safety concern for consumers, so the stakes were extremely high, especially in developing countries. It was rewarding to find a solution to such a high-stakes problem."

As the global population continues to grow, a new generation is needed to take on these high-stakes challenges. "There are many hungry people in developing countries, so improving food security can make a huge difference," Whitaker said. At the request of the Common Market for Eastern and Southern Africa (COMESA), Whitaker and his team have recently developed aflatoxin sampling protocols for groundnuts and maize, which are traded among the COMESA countries.

As Whitaker sees it, the issue of food contamination extends from the farm to the fork, and there are many opportunities for young engineers to get involved across disciplines. "At every step along the way, there are health issues, economic issues, and regulatory issues," he said. "There are many places that young professionals can get involved in solving these problems, and there's much that can be done." In Whitaker's case, it all started with a peanut.

Rebecca Nagy, Communications Specialist, Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, renagy@ncstate.edu.

The Sustainable Intensification of Agriculture

Jules Pretty

What makes agriculture unique as an economic sector is that it directly affects many of the assets on which it relies. Agricultural systems at all levels rely on services that flow from assets that they influence. Five types of assets are particularly important: natural, social, human, physical, and financial.

The desire for agriculture to produce more food without environmental harm, or even with positive contributions to natural and social assets, has been reflected in calls for various types of sustainable agriculture, including a "doubly green revolution," "alternative agriculture," an "evergreen revolution," "agroecological intensification," "green food systems," "greener revolutions," and "evergreen agriculture." All of these terms are based on the belief that agricultural systems and uncultivated systems should no longer be considered separate.

Intensification was once synonymous with types of agriculture that resulted in environmental harm. The compatibility of sustainability with intensification was first hinted at in the 1980s and then used in conjunction with an examination of African agriculture. The combination of the two terms, sustainability and intensification, was an attempt to indicate

that different desirable outcomes, such as more food and better ecosystem services, need not be mutually exclusive. Both could be achieved by making better use of land, water, biodiversity, labor, knowledge, and technologies. Sustainable intensification (SI) was further proposed by a number of key commissions, and SI research increased from about ten papers annually before 2010 to over 100 papers per year by 2015. SI is now central to the UN's Sustainable Development Goals as well as wider efforts to improve global food security.

In general, SI is defined as an agricultural system in which valued outcomes are maintained or increased, while maintaining or enhancing environmental outcomes. SI means increasing output without cultivating more land (and thus losing natural habitats). In other words, the increase in system performance incurs no environmental cost. SI is an open concept, emphasizing outcomes rather than means, it can apply to enterprises of any size, and it does not require predetermined technologies, production types, or design components. SI differs from earlier intensification efforts in its emphasis on a wide range of environmental and social outcomes. Central to SI is an acceptance that there is no perfect end point, due to the multi-objective nature of sustainability. Thus, no system is expected to succeed forever, and no single set of practices can fit the shifting dynamics of every location.

The transformative impact of SI requires cooperation, or at least individual actions that result in cumulative benefits. For farmers to adapt their production systems in the face of environmental and economic stresses, they need to have the confidence to innovate. As ecological, climatic, and economic conditions change, and as knowledge evolves, farmers and communities can drive the necessary transition based on collective learning. This transition also requires adaptability. Interventions that evolve with changing conditions are more likely to be sustainable than those that require a rigid set of conditions.

Recent research has assessed global progress toward SI for integrated pest management, conservation agriculture, integrated crop and biodiversity systems, pasture and forage systems, trees in agricultural systems, irrigation management, and intensive small systems. As shown in the accompanying graph, data from 47 large SI initiatives were collected (each with more than 10,000 farms), and the results showed that some 163 million farms (29% of all farms worldwide) are making the transition and now practice some type of SI on 453 Mha of agricultural land (9% of the global total).

At the farm and landscape scale, the need for SI is urgent. Pressure is growing on existing agricultural land. Environmental degradation reduces this asset base, expansion of urban infrastructure takes land out of production (in the European Union, the agricultural land area has decreased by 31 Mha since 1961; in the U.S. and Canada, 0.5 Mha are lost annually), and climate change and extreme weather create new stresses, testing the resilience of the global food system.

There is much to be done to increase the production of nutritious food while ensuring positive impacts on natural and social assets. This effort will require that farmers and societies invest in SI, not just for the sake of sustainability but for their livelihoods and profitability. There are also risks: technologies can be mis-adopted, advances can be lost, and competing interests can co-opt and dilute innovations.

Most important, while SI is necessary, it is not sufficient for transforming the global food system. Other positive changes are also needed, such as consuming healthier food and reducing food waste, to avoid putting more pressure on farmers to produce more food at any cost.

Jules Pretty, Professor of Environment and Society, School of Life Sciences, University of Essex, Colchester, U.K., jpretty@essex.ac.uk.

Pretty's recent book, *This Luminous Coast*, won the New Angle Prize for Literature and the East Anglian Book of the Year award.

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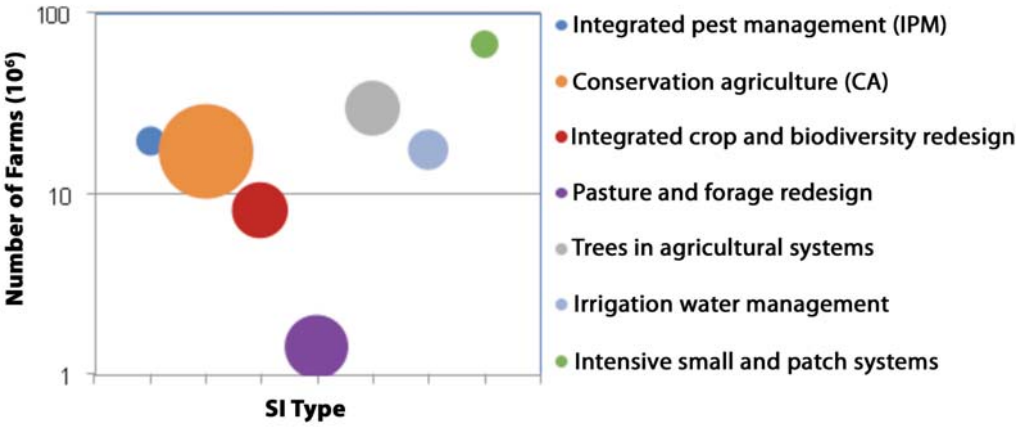

Seven types of sustainable intensification (SI) and the number of farms on which each SI type is practiced. The size of each circle represents the relative global area of each SI type.

The Need for Food Engineering

Ali Demirci

Food engineering is a discipline that combines engineering and science, especially biology and microbiology, to cover all stages of food production, from farm to table. The most important guiding principles of food engineering are ensuring the quality and safety of food, and providing affordable food.

Food engineering will become increasingly important as the global population increases from 7.7 billion currently to 9.7 billion in 2050, and possibly to 11 billion by 2100, according the United Nations. In the meantime, food safety is still a concern, even in developed countries. According to the U.S. Centers of Disease Control and Prevention (CDC), foodborne diseases affect about one in six Americans each year, including 128,000 hospitalizations and 3,000 deaths.

Providing safe, sufficient, and high-quality food to the growing population cannot be achieved just by increasing the area of farmland or by growing crops with more efficient methods. We also need new processing, storage, and transportation methods. According to a recent study by the United Nations FAO, roughly one-third of the food produced for human consumption, about 1.3 billion tons per year, is lost or wasted. This huge loss is due to a lack of resources and technology, as well as a lack of education. Therefore, we must provide food technologies that are affordable for underdeveloped and developing countries, while educating the public at the same time.

> “Providing safe, sufficient, and high-quality food to the growing population cannot be achieved just by increasing the area of farmland or by growing crops with more efficient methods.”

Enhanced food technologies start at the farm, for growing agricultural products more effectively, including genetically modified varieties, and harvesting them without reducing the nutritional quality. Storage and transportation technologies are also significant areas for improvement so that product quality and safety are ensured.

The next enhancements are needed during processing of foods by developing new technologies that maintain quality and safety while reducing costs. These novel methods include smart packaging and monitoring technologies that can provide alerts if the product quality changes during transport and storage. Education of the public is also important. People must know how to store and handle food to reduce waste and contamination. They may need to change their shopping habits to ensure timely consumption of perishable products, and they need to understand the terminology of food labeling, such as the difference between sell-by dates and use-by dates.

In addition to enhancements in conventional food production, we also need new ways to produce food using non-traditional methods. These novel production methods might involve microorganisms, insects, and cell cultures. For example, growing food products in self-contained bioreactors can decrease the need for farmland and eliminate the associated environmental risks. It can also decrease the production time. Instead of the months, or years, required to produce traditional foods, we could produce the same amount of food in just weeks or days. These controlled production environments also allow better control of product quality and safety. Of course, the definition of quality might change in the future, as we adopt new foods and new production methods.

The opportunity to help people, and the environment, by developing safer, more efficient methods of food production is what motivated me to study food and bioprocess engineering. When I began my career, I didn’t fully appreciate the importance of this field. Since then, I have realized the impact that this field has on people everywhere, every day.

And now food engineers are needed more than ever. Fortunately, young food engineers are choosing their careers in a more informed way than I did, and they understand the enormous responsibility of their work. All too soon, there will be 11 billion mouths to feed!

ASABE member Ali Demirci, Professor, Department of Agricultural and Biological Engineering, Pennsylvania State University, University Park, demirci@psu.edu.

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Portable NIR Spectroscopy: Affordable Technology for Developing Countries

Isaac Rukundo

I'm a doctoral student in the Department of Food Science and Technology at the University of Nebraska-Lincoln. My research focuses on evaluating the use of handheld near-infrared (NIR) spectrometers for food and feed quality analysis. I'm originally from Uganda, where much of the agricultural production goes to waste during bumper harvests due to the lack of adequate processing, preservation, and storage facilities. In addition, food quality testing services are either too expensive or unavailable, which limits commerce, consumer knowledge, and safety.

That is a shame because testing is a key step in the food value chain, allowing management of complex food systems and ensuring sustainability of production. Accurately detecting the nutrient content, adulteration, or microbial contamination of foods allows manufacturers to produce consistently high-quality products and gain consumer trust. In developing countries, unreliable food quality can adversely impact the ability to export valuable products and increase waste. Similarly, with limited information, livestock producers do not know when their animal feed is adequate and when it needs to be supplemented.

Dr. Shinekhuu Jugder uses a handheld NIR spectrometer to scan forage samples in her lab at the Mongolian University of Life Sciences.

So, what can be done? In the developed world, testing laboratories have long embraced NIR spectroscopy as a fast, non-destructive, and cost-effective technique for analyzing the quality and nutritional value of foods and feed. Unfortunately, the adoption of benchtop NIR spectrometers in developing countries has been slow due to the upfront costs and, at times, the lack of awareness of the technology and its advantages.

However, recent advances in optics and microelectronics have led to the development of miniaturized NIR spectrometers. These handheld devices have a narrower spectral range and lower resolution than benchtop NIR spectrometers, but they are portable and much less expensive. These devices can be calibrated for use in screening materials based on a minimum quality standard, such as crude protein content, and suspect materials can be sent to a laboratory for more thorough testing using standard reference methods, so that the amount of material that needs to be tested by rigorous chemical methods is greatly reduced. Materials that fail to meet the minimum quality standard can then be diverted for additional processing to increase their value.

Farmers, wholesalers, and even retailers can benefit from portable NIR technology because it provides a quick, objective measurement of product quality. When the seller and the buyer both have access to the same information and market price, an honest transaction ensues.

Last summer, I visited Dr. Shinekhuu Jugder, an animal nutritionist and extension specialist at the Mongolian University of Life Sciences in Ulaanbaatar. Portable NIR technology allows Dr. Jugder and her colleagues to analyze forage quality in a timely and cost-effective manner so they can recommend feed supplements to Mongolia's semi-nomadic cattle herders.

For centuries, Mongolian herders have moved their livestock and households among seasonal pastures to meet the nutritional needs of their animals and conserve pasture resources. As the climate of the Mongolian plateau becomes warmer and drier, and droughts and winter storms increase, the quality and productivity of these pastures have degraded, while livestock numbers continue to soar. Most of the animals do not reach their full potential productivity due to unbalanced feeding. Hence, portable NIR spectrometers can provide real-time, site-specific forage quality data for the seasonal pasturelands so that these limited resources are better managed and made sustainable, while giving researchers and the government a better understanding of the Mongolian steppe ecosystem.

If you're a young engineer or food scientist, you've chosen a timely profession. With the global population estimated to reach 9 billion by 2050, there will be a huge demand to find creative, sustainable solutions to increase the food supply and reduce or reuse agricultural waste. With a career in food science and engineering, you are well placed to make a contribution to this global challenge. Keep working hard, keep thinking creatively, and you can make a difference in nourishing the planet.

ASABE member Isaac Rukundo, Graduate Research Assistant, University of Nebraska-Lincoln, isaac.rukundo@huskers.unl.edu.

Improving Nutrition for the World's Neediest People

Brian Sims

We are experiencing a concerning increase in the global population. At the same time, we have an obscene inequality in income distribution and, consequently, in access to adequate food and nutrition. Currently, there are well over 800 million undernourished people in the world, compared with the 2 billion who are obese. This skewed situation is set against a backdrop of an accelerating climate crisis and the relentless devastation of our planet's resources, both of which will have dire consequences for food production and nutrition in the near future. In response to this challenge, we must look for ways to achieve more and better food while, at the same time, preserving and even enhancing our natural resources. Here are three promising strategies for developing countries:

Urban and peri-urban agriculture

One of the features of the current population dynamics in developing countries is migration from rural areas to urban areas. By 2050, the current 50:50 balance is projected to rise to 30:70 in favor of urban areas. This migration has serious implications for housing and crime as well as nutrition in urban areas.

Urban and peri-urban agriculture improves the air quality in cities by using photosynthesis to extract CO_2 from the air and replace it with O_2, while using recycled water and solid waste to produce fresh fruits and vegetables. As a result, pollution is reduced, previously infertile environments are invigorated, people in urban neighborhoods are brought together in local cooperatives, and the community is better nourished with fresh, locally grown food and short supply chains (http://www.fao.org/urban-agriculture/en/).

Drip irrigation and greenhouse production

Improving the agriculture sector of developing countries leads directly to poverty reduction and to achieving the UN's Sustainable Development Goals, especially SDG 2 to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture." In low-rainfall, seasonally dry regions, smallholder farmers can produce out-of-season fruits and vegetables in greenhouses with drip irrigation. This provides a year-round livelihood for the farm family, and it provides fresh, nutritious food to nearby urban areas.

The necessary infrastructure is not expensive. It typically consists of a simple, manually operated pump, such as the Money Maker (http://moneymakerpumps.org), which is used to lift water to an elevated storage tank. The tank feeds water to drip irrigation lines that can be located outside for robust vegetables (such as kale, cabbage, pumpkins, and peppers) or inside a greenhouse for more delicate (and profitable) crops such as tomatoes. The greenhouse is very simple and consists of a wooden frame covered with plastic sheeting.

Smallholder incomes can be greatly increased, and nearby urban populations can be better fed, by producing fruits and vegetables in the off-season, when demand is high. For example, raising tomatoes in simple greenhouses with drip irrigation can help subsistence farmers become successful entrepreneurs.

Conservation agriculture and agroforestry

Many current agricultural practices have deplorable effects on the world's soils, water resources, and rural environments. It's not just the quantity of soil that's lost as a result of unsustainable agricultural practices; the soil quality also suffers because soil fertility is associated with the preferentially eroded smaller soil particles. Water resources, biodiversity, and ecosystem health are all negatively affected by soil degradation. Conservation agriculture and agroforestry, two

environmentally friendly practices, can provide sustainable harvests from the world's agriculture.

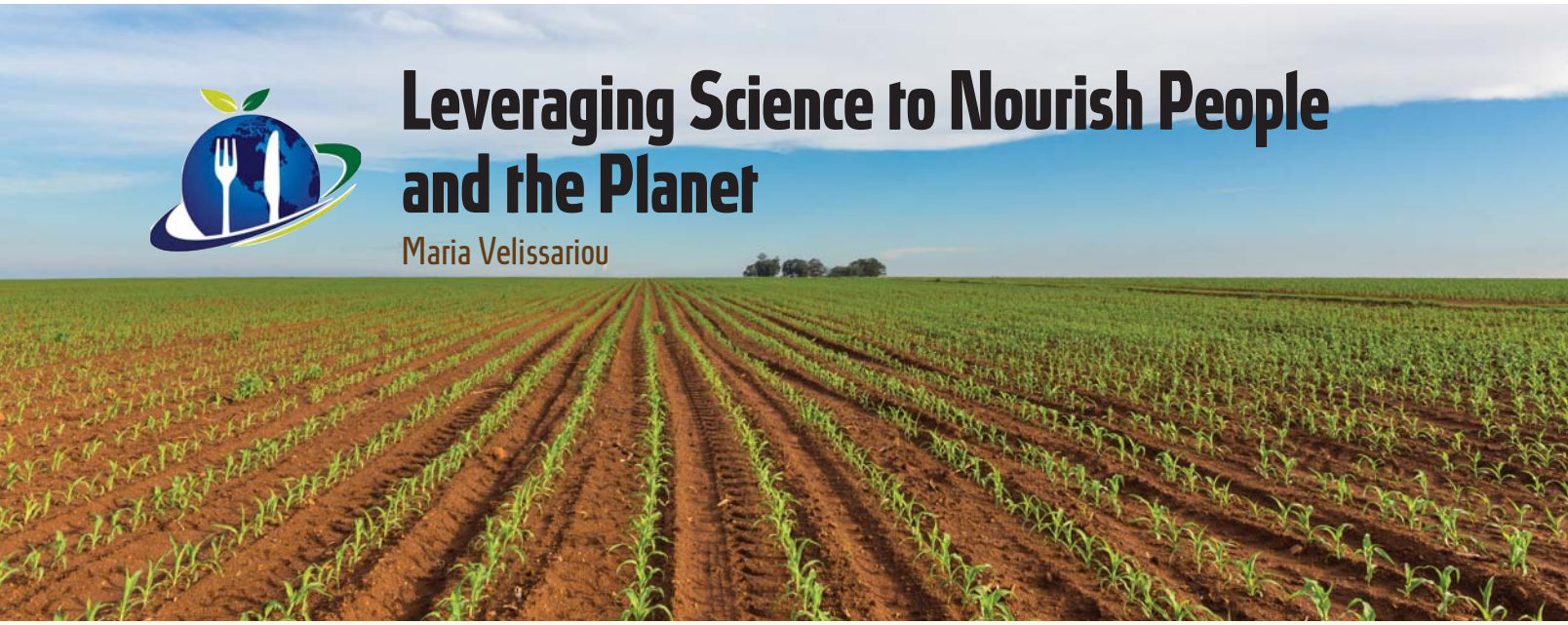
Conservation agriculture is a broad concept, but in general it means achieving acceptable profits with high-sustained production while conserving the environment (www.fao.org/conservation-agriculture/en/). Conservation agriculture is characterized by three principles:

- Minimum mechanical soil disturbance (i.e., no tillage) through direct placement of seeds and fertilizer. In practice, this requires the development of appropriate machinery.
- Permanent organic soil cover from crop residue or cover crops.
- Species diversification, including diversified rotations for annual crops and plant associations for perennial crops, such as trees in agroforestry.

Ideally, conservation agriculture mimics a natural ecosystem. For example, in a forest, nutrients are recycled through decomposition of fallen leaves, which creates a rich soil biota. Removing this ground cover, as in conventional crop production, removes nutrients and destroys natural channels for water infiltration and gas exchange, which means that the natural sustainable system must be replaced with expensive and damaging tillage. Organic cover also provides other important benefits to the soil, such as control of the soil temperature and moisture content.

Above all, organic soil cover protects the soil from the degrading effects of wind and water erosion. Erosion rates with conservation agriculture, agroforestry, and forest systems can be reduced to practically zero, ensuring long-term productivity.

ASABE member Brian Sims, Consultant, Engineering for Development, Bedford, U.K., sims.brian2@gmail.com.



Leveraging Science to Nourish People and the Planet

Maria Velissariou

Since 1939, the Institute of Food Technologists (IFT) has worked to advance the science of food and its application across the global food system. Our vision is a world where science and innovation are universally accepted as essential to a safe, nutritious, and sustainable food supply for everyone. As the Chief Science and Technology Officer at IFT, I am responsible for setting the strategic agenda and overseeing IFT's science, technology, and policy initiatives (including our Global Food Traceability Center), advocating for the science of food, and partnering with stakeholders to ensure that IFT's education and content are relevant to our members and customers.

The motivation for my work is the impact that food has on consumers' lives and on society at large. Food is a basic human need, an indispensable part of culture, and essential for healthy lives. As individuals, we identify with certain foods, and we follow certain eating habits and rituals based on our lifestyle, culture, and beliefs. Those values often include a deep desire and a sense of responsibility to feed

others, especially our own families. As a food scientist, I recognize the significance of nourishing all families, especially those that are underserved.

The global food industry has a responsibility to feed billions of people every day, and that number continues to grow. According to the United Nations, the current population of 7.7 billion is expected to reach 9.8 billion in 2050. At the same time, we see an alarming rise in diet-related disease and malnutrition, including both underfeeding and overfeeding.

Food security and sustainability are critical to nourishing the global population across all socio-economic strata. Staggeringly, 51 countries are already facing crisis levels of food insecurity, and approximately 1 billion people lack sufficient access to food. Meanwhile, the growing population will require a nearly 60% increase in food production by 2050, putting even greater strain on the global food industry.

To improve global food quality, availability, and affordability, we must approach food as a system that requires interdisciplinary collaborations across a variety of fields, including agronomy, food science and engineering, packaging, nutrition, digital technologies, environmental sciences, social sciences, and more. Academia and industry cannot work in isolation, and neither can policymakers and regulators.

First, we must increase food production with environmental sustainability.

Although year-on-year food production is increasing, there are hot spots where record productivity, food insecurity, and environmental degradation co-exist. A recent report by the World Resources Institute (WRI) indicated that agriculture generates an estimated 25% of annual greenhouse gas emissions due to the combination of production activities and the land use changes associated with farming, such as clearing vegetation and plowing. If current trends continue, but agricultural productivity does not increase beyond 2010 levels, the WRI concludes that most of the world's remaining forests will need to be cleared in order to feed the world.

By revamping our current production processes with regenerative agriculture, biodiversity, new crop varieties, and managing the water supply, we will be better equipped to withstand climate strain and manage the growing food demand.

"By revamping our current production processes with regenerative agriculture, biodiversity, new crop varieties, and managing the water supply, we will be better equipped to withstand climate strain and manage the growing food demand."

Second, the food industry must expand its focus to include human health.

According to the World Health Organization, as of 2016, more than 1.9 billion adults were overweight, and a third of them were obese. As of 2018, the American Diabetes Association estimated that there are more than 500 million cases of type 2 diabetes worldwide. The prevalence of these diet-related diseases is comparable between high-income and low-income countries. At the same time, the UN's Food and Agriculture Organization estimates that about 800 million people, mostly in developing countries, are undernourished.

Biofortification, which means enhancing the nutrient content of common food crops (such cereals, pulses, and fruits and vegetables), offers a solution to providing sufficient levels of bioavailable micronutrients to general and targeted populations. Combining taste and nutrition is also imperative, because people eat what they like.

Third, we need to tackle packaging pollution head on.

The report from the 2017 World Economic Forum indicated that only 14% of packaging materials are recyclable. In particular, discarded plastic is permeating the planet. According to a recent study from the University of South Florida at St. Petersburg and Eckerd College, the waters of Tampa Bay contain an estimated four billion particles of microplastics. Other waterbodies around the world are similarly affected, including the oceans. In addition to plastic recycling and pollution remediation, there is an urgent need for ecofriendly alternatives to plastic packaging.

As we look ahead, nourishing the planet will require a multidisciplinary approach. Regardless of their professional discipline, the young generation of scientists, including food scientists and engineers, must confront this challenge collectively. The scientific community can drive meaningful innovations in food production and distribution, especially for the world's most vulnerable populations, while reducing our impact on the environment and climate.

Maria Velissariou, Chief Science and Technology Officer, Institute of Food Technologists, Chicago, Illinois, mvelissariou@ift.org.

Microwave Drying Could Improve Head Rice Yields

Griffiths Atungulu

Head rice yields are extremely important to the rice industry. Head rice, which is the mass of milled rice kernels that are at least three-fourths of the original kernel length after milling of brown rice, is the high-value portion of processed rice. Under ideal conditions, a perfect head rice yield would be about 70% of the total rough rice produced. However, with conventional hot-air drying, not only is the drying rate low, thereby creating bottlenecks at peak harvest time, but the head rice yield can be as low as 50%, and even lower depending on pre-harvest and post-harvest factors.

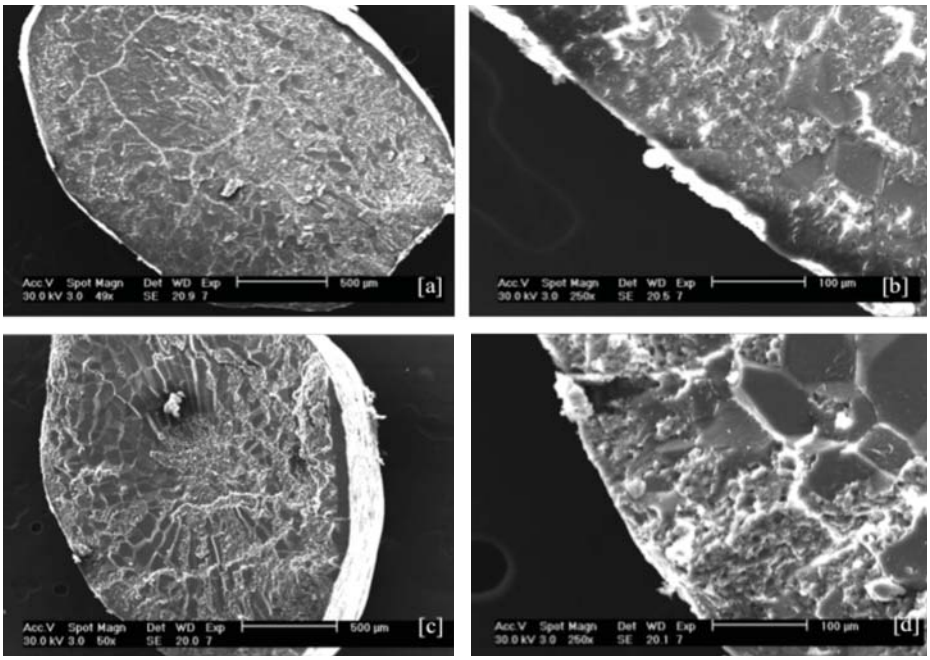
Reductions in head rice yield have significant economic consequences for rice producers. As demand for rice continues to increase, with expansion of rice production in the U.S. to meet this demand, there is a critical need to improve the rice-drying process to minimize revenue loss and ensure food quality and security.

High-temperature, cross-flow column dryers are the most common type of dryer used in industrial-scale rice processing. In these dryers, the grain flows vertically downward between two metal screens, forming a grain column. Heated air flows through the grain column perpendicular to the grain movement (hence "cross-flow"). In cross-flow dryers, the rice kernels dry at different rates across the column thickness. Kernels closer to the heated-air plenum interact with hotter air and dry faster, while kernels farther from the plenum interact with cooler, more humid air and dry more slowly. This non-uniformity of cross-flow column dryers presents two challenges: under-drying or over-drying of the kernels, and the formation of fissures inside the kernels. These fissured kernels reduce the head rice yield.

To reduce non-uniform drying, rice is typically dried in more than one pass through the dryer, with tempering stages between the passes. During tempering, the temperature and moisture gradients within the kernels are allowed to subside, and consequently fissuring and head rice yield reductions are minimized. However, these additional drying passes and tempering stages require a larger energy input and a longer drying duration, which constrains the harvesting process.

Microwave heating is distinguished from convective air heating by its volumetric effect. Because the entire kernel volume is heated at once, microwave heating can reduce the stresses caused by temperature and moisture gradients within the rice kernels and potentially improve the head rice yield, milled rice quality, and drying efficiency. However, there is no commercial use of microwave technology for rice-drying in the U.S.

Microwave power at 2.45 GHz is used almost universally for industrial and scientific applications. Lab-based experiments have explored the use of 2.45 GHz microwave systems for rice drying, with only limited success in scaling up the operation. A major drawback of 2.45 GHz microwave power



Images of milled rice kernels subjected to microwave drying at two specific energy (SE) levels as observed under a scanning electron microscope. For each SE level, the images show the kernel cross-section (images a and c) and an enlarged view of the edge (images b and d). ***Courtesy of Grain Process Engineering Laboratory, University of Arkansas.***

is the limited penetration depth of the microwave field into the product, which leads to non-uniform heating.

Our R&D team uses microwave power at 915 MHz. This frequency penetrates to a greater depth than 2.45 GHz, which makes 915 MHz suitable for large-scale rice drying. To develop 915 MHz microwave drying for rough rice, we need to determine the head rice yields associated with one-pass microwave heating of different rice cultivars. It is also important to consider the typical moisture content ranges of rough rice at harvest. Without this information, microwave drying of rough rice will remain susceptible to losses in head rice yield, with negative consequences for producers, processors, and consumers.

Researchers at the University of Arkansas Division of Agriculture are studying the use of microwave drying to prevent fissuring of dried rice kernels and maintain milled rice quality.

In the long term, we hope to develop, validate, and commercialize one-pass microwave drying technology for rough rice that maximizes head rice yield. Using microwave energy to dry freshly harvested rice, or high-moisture parboiled rice, could do more than just get the job done faster; it could also improve the end product. Microwave treatment can modify the structures of macromolecules in rice to achieve new end-use functionality and new sensory characteristics of rice and rice-based products, creating new uses for this staple food.

ASABE member Griffiths Atungulu, Associate Professor and Agricultural/Food Engineer, Department of Food Science, University of Arkansas, Fayetteville, atungulu@uark.edu.

Tackling the Food Waste Problem

Haibo Huang

Today, one in nine people globally is undernourished. On the other hand, more than one-third of the food that is produced globally is lost or wasted, generating more than one billion tons of food waste each year. In the U.S., nearly 40% of food is wasted, accounting for the single largest component of municipal solid waste and resulting in an enormous economic loss, including the food itself and the associated water, energy, and chemicals used in the food supply system. Reducing food waste would greatly improve the sustainability of our planet; however, the challenges associated with this complex issue call for innovative ideas and technologies.

The U.S. Environmental Protection Agency is aware of this challenge and has developed a "food recovery hierarchy" of preferred actions to prevent and divert food waste. The first recommended action, based on the hierarchy, is to pre-

vent the generation of surplus food. If the supply of food accurately matches the demand, then the amount of food waste due to oversupply will be reduced.

The second action is feeding surplus food to hungry people. A good example of this action is donating surplus food to a local food bank, which is a non-profit organization that collects and distributes food to hunger-relief charities.

The third action in the hierarchy is diverting food scraps to animal feed. However, this practice requires basic understanding of the regulations that restrict the use of excess food as animal feed.

Fourth on the list: industrial uses, such as anaerobic digestion of food waste to produce biogas for heat and electricity, followed by composting to create a nutrient-rich soil amendment.

The final action in the hierarchy is incinerating food waste or disposing of it in landfills. This is the last option because it potentially creates environmental pollution.

Food waste generated by a small-scale food processing center.

Agricultural and biological engineers are well-positioned to tackle the food waste challenge. Here are three areas where we are leading the way:

Appropriate and affordable mechanization

Food waste refers to food that still has good quality for consumption but is discarded by retailers or consumers due to its undesirable appearance, overstock, or other reasons. In contrast, food loss refers to food that is lost, due to spoilage or damage, before it reaches the retailer or consumer. Food loss typically occurs during the production and distribution stages. Vast quantities of produce are lost on the farm because it cannot be harvested in time due to the farm labor shortage. Advanced and affordable agricultural mechanization, from all-purpose utility vehicles to crop-specific harvesters, helps to reduce these farm-level food losses.

New food processing and storage techniques

Food is often discarded because of improper storage or expired shelf-life. Innovative food processing technologies, such as ozonation, microwave treatment, and cold plasma-mediated treatment, have potential to extend the shelf-life of perishable foods, thus reducing food loss. To further avoid losses, smart packaging and sensing technologies are being developed to better preserve food and alert processors, retailers, and consumers to food quality issues.

Converting food waste to useful products

In addition to converting food waste to biogas through anaerobic digestion, bioprocessing engineers are researching effective ways to obtain biofuels and bio-products, such as bioethanol, biobutanol, biocrude oils, and plastics, from food waste. At Virginia Tech, our lab is working with the university's student dining services to convert food waste to value-added biobutanol using anaerobic fermentation. We have found that food waste is particularly suitable for fermentation due to its high content of carbohydrates and other essential nutrients, such as proteins and minerals.

Besides the aforementioned three areas, there are many other opportunities for agricultural and biological engineers to contribute to the reduction of global food waste and food loss. The more we can save, the less we will have to grow.

Haibo Huang, Assistant Professor, Department of Food Science and Technology, Virginia Polytechnic Institute and State University, Blacksburg, huang151@vt.edu.

We Have the Technology

Xin (Rex) Sun

I was born and raised in a country where food is at the root of culture and history. More than 3,000 years ago, Chinese people learned to combine a variety of beans (called the Eight Treasures) to produce healthier food. Today, as the global population soars, along with a growing middle class, people are no longer satisfied with just a full stomach. Modern food must also be appetizing, high quality, nutritious, and most importantly, safe for consumption. How can we achieve that?

So far, there is no app that will let us take a picture of our food and then display the relevant quality and safety information on the screen. That would be great! Until then, how can we guarantee that our food is safe and of high quality? That question inspired my interest in food science and technology. I'm currently an assistant professor in the Department of Agricultural and Biosystems Engineering at North Dakota State University. My research focuses on advanced technologies in precision agriculture and food production.

Thermal mapping of beef cattle.

To produce high-quality food, we must start at the beginning. More research needs to focus on food production. We should put more attention on how we can grow better crops and healthier livestock. If our food sources grow better, they will taste better, and technology is the key. We need to apply existing technologies and develop new tools to improve our production systems.

For example, I'm currently investigating the use of remote sensing and artificial intelligence to help farmers recognize different weed species and locate weeds in the field. Using robotics and variable-rate spraying, the areas with weeds can be specifically targeted for herbicide application. This technology avoids applying herbicide needlessly across the entire field.

Another research topic that I'm investigating is early diagnosis of diseases in beef cattle using thermal imaging, so ranchers can treat their sick animals earlier and thereby avoid heavy doses of vaccines or other medicines. With these technologies, we can minimize the chemical inputs that are used in production, which inevitably end up in the food on our plates. Farmers and ranchers also benefit from these technologies due to the reduced expenses for treating their crops and livestock.

To improve global food quality, we also need methods for monitoring the growth cycles of crops and livestock, so that we can identify when to intervene to improve growth and health. This long-term, system-wide monitoring requires vast data storage and processing, so technologies like the internet of things, big data, and cloud computing can help us achieve this goal. Fortunately, data storage and processing abilities are steadily increasing in size while decreasing in cost.

Finally, educating people about where their food comes from is important for improving global food quality. Long ago, most people were farmers. Today, most people are completely disconnected from agriculture. Consumers worry about the quality and safety of their food, but they have little knowledge about how their food is actually produced. If people knew more about agriculture and more about food production systems, they would appreciate food more, and they wouldn't waste so much of it! This general awareness would help increase food quality and food security.

Despite the images of technological menace that appear in our popular culture, I'm a firm believer that technology can change our lives in a good way. In the food industry, we're not creating Robocop; we're creating robots that can pick up to 1.6 billion pounds of strawberries per year, just in the U.S., and this valuable produce might otherwise go to waste due to the shortage of human labor. As agricultural and biological engineers, there are many such opportunities out there, waiting for us, to help farmers and ranchers produce high-quality food using the right kind of technology.

In 1969, the Apollo guidance computer, which had a 2 MHz CPU and 4 kB of RAM, landed a man on the Moon. Now, 50 years later, most of us carry a smartphone that typically contains a 2.2 GHz (2200 MHz) CPU and 8 GB (8,000,000 kB) of RAM. If we could land on the Moon so long ago, then surely we can feed ourselves today. The technology is ready; we just need to get to work.

ASABE member Xin (Rex) Sun, Assistant Professor, Department of Agricultural and Biosystems Engineering, North Dakota State University, Fargo, xin.sun@ndsu.edu.

YPC News & Notes

Your Future: Get It in Gear

Do phrases like "thirsty Thursdays," "all-nighters," and "coffee breaks" seem archaic when you step into industry? Do "meaningful communication," "project management," and "professional etiquette" become more realistic?

What does the future hold after your undergraduate degree—grad school, industry, or both? What do these options have to offer? How do you decide between academia and industry?

In my perspective, when something fascinates you to the extent that you want to delve into the details, that's when academia is the answer. An undergraduate degree provides broad knowledge of the subject matter, but less training in how specific requirements can affect engineering design. Grad school provides an opportunity for in-depth analysis on a topic of your choice.

On the other hand, when you step out with your completed coursework and a handful of student projects to try your hand at a real-world job, you quickly discover that industrial projects are very specific. The client's need is narrowly focused, and you must meet the desired goal with strictly limited resources, which are usually time and money. That's when you complete your engineering education—with time and cost management, quality deliverables, people skills, and group dynamics. Of course, the paycheck in industry tends to be a little better than what you make as a grad student.

You can't have the best of both worlds, but you can have the right vision. My experience includes work in both industry and academia, and what I've learned is this:

Think of your career path as a chain of gears. You need three gears—passion, enthusiasm, and subject knowledge—to pursue your career, whether in industry or academia. The way the gears rotate and transmit power may differ in different settings, but connecting these three gears will simplify your path. When the gears get stuck, options are available to get going again. Ask for help from a reliable source to help keep your career on track!

ASABE member Sushant Mehan, Water Resources Engineer (Hydrologist), Formation Environmental LLC, Sacramento, California, sushantmehan@gmail.com.

ASABE Foundation Work in Focus

Support the recognition of food engineers

Chris Butts, P.E.

A key role of the ASABE Foundation is support of the Society by raising and managing funds for awards and recognition. Some awards have endowed funds in which gifts from donors are held in perpetuity, and the interest earned provides funding for the award. An alternative to an endowed fund is a capital fund. An award with a capital fund is terminated when the fund is fully expended.

Over the last 47 years, the Processing Systems Technical Community (PRS) of ASABE and its predecessors have conferred the Outstanding Food Engineer Award, which is supported by capital funds, to 32 recipients. The award honors original engineering contributions in research, development, design, or management of food processing operations of significant economic value to the food industry. This award was sponsored by the Food Processing Suppliers Association Foundation until 2009, when FPSA members discontinued their sponsorship. Corporate sponsorship was secured to continue the award, now called the International Food Engineering Award, but that sponsorship ended after the 2016 presentation.

ASABE Past President Maury Salz presents ASABE Fellow Yanbin Li with the 2019 ASABE International Food Engineering Award. The Foundation is fundraising to fully endow this important award.

In 2016, a campaign was initiated to raise funds to endow the award in perpetuity while continuing to fund the award annually. Since then, approximately $26,000 has been raised toward the goal of $75,000. Dr. Shaojin Wang's substantial efforts raised $15,000 through the Sino-US Food and Agriculture Innovation Center in China. The remaining funds have come from individuals within the PRS Community in response to efforts by the PRS Community Roundtable and Forum at the Annual International Meeting. Many of the individual donations were contributed by past award recipients. According to the Foundation treasurer's report at the 2019 Annual International Meeting, the fund for the International Food Engineering Award has a projected balance of $14,000.

ASABE's PRS Community and its food engineers want to continue this award because it has become an international hallmark for recognizing engineering accomplishments and enhancing the distinction of the food engineering profession. Award recipients are not required to be ASABE members. The current award honors the recipient with a plaque and a cash award of $1,000, as well as assistance with travel expenses to attend ASABE's Annual International Meeting, where the award is presented. The annual cost of administering the award is estimated to be $3,000.

Therefore, the leadership of the PRS Community has asked the Foundation to assist in a fundraising effort to meet the goal of fully endowing the International Food Engineering Award, which would require approximately $60,000. We anticipate that this effort will require support from a number of partners, including corporate entities and individuals who recognize the great value of food engineering.

In her article in the September/October 2019 issue of *Resource,* ASABE Past-President Sonia Maassel Jacobsen quoted Colin Powell, who quoted Theodore Roosevelt, that as members of a volunteer organization, we have an obligation to support that organization with our time, our talent, and our financial resources.

A grassroots effort within the PRS Community and across the ASABE membership would demonstrate ASABE's support of the food engineering profession. We seek support to continue the legacy of the International Food Engineering Award and thus demonstrate our continued commitment to innovators in the food industry.

ASABE Fellow Chris Butts, P.E., Research Agricultural Engineer, USDA-ARS National Peanut Research Laboratory, Dawson, Georgia, chris.butts@usda.gov.

ASABE Foundation board member Ed Barnes, Senior Director, Cotton Incorporated, Cary, North Carolina, ebarnes@cottoninc.com.

ASABE Foundation board member Mark Riley, Associate Dean for Research, College of Engineering, University of Nebraska-Lincoln, mriley3@unl.edu.

Nourishing the Planet

Lalit Verma, P.E.

"Nourishing the planet" can mean "providing adequate nutrition for the growing global population" or "maintaining our planet's environment for the population to stay healthy." Both meanings pose a monumental challenge for the scientific community. Warnings about unsustainable food supplies and climate change have been repeated often lately, possibly to the point of making people numb to the message. But the challenge remains: we must increase food production and food security without affecting environmental quality and with minimal use of water, chemicals, and energy.

Supplying nutritious food means more than just calories. The need for high-nutrient foods is urgent, especially for children in hunger-intensive regions. A healthy diet costs more than junk food, which makes affordability a challenge. Supply chain costs are also a big part of food prices, especially for perishable fruits and vegetables.

The World Health Organization (WHO) defines food security as "when all people at all times have access to sufficient, safe, and nutritious food to maintain a healthy and active life." According to the United Nations FAO, more than enough food is produced every year to feed our entire population. Nevertheless, hunger endures, and it is most serious in developing countries. With significant shifts in economic status, population demographics, urbanization, and protein demand, the need for healthy food has increased drastically in many regions.

Providing nutritious, safe, and affordable food for all segments of the global population may seem an unachievable goal due to the numerous, intertwined factors that have been documented by the FAO, WHO, and other organizations. However, researchers are tackling this challenge from many directions, with advances in agronomy, production methods, food processing, and smart technology, and many solutions are already underway. Using limited resources wisely has led to innovations in efficiency and sustainability, such as precision agriculture and organic farming. Advances in water use efficiency and reduced use of chemicals and energy are further indicators of progress.

The trend toward urban agriculture holds promise for supplying food to growing urban centers. Locally grown produce can help with the challenge of providing affordable nutrition, and local supply chains can bring perishables to market quickly. Innovative technologies to increase the productivity of small-scale agriculture are evolving, and there is much more to accomplish, particularly with the growth in digital connectivity.

However, many technical and social problems must be overcome to ensure food security. Storage solutions are needed for regions that lack a transportation infrastructure and temperature-controlled supply chains. Water is critical because aquifers are depleting at an alarming rate, and water demand is skyrocketing. Because the food supply is greatly affected by climate change and the unpredictable availability of water, producers must become more resilient while producing more food.

As several of the articles in this issue point out, lack of nutrition is not just a lack of food. It can also mean an excess of poor nutrition. The food security spectrum extends from starvation on one end to obesity on the other. Ideally, wouldn't it be great if the excess calories of the two billion people who are overweight could somehow be diverted to the 800 million people who are hungry? Ironically, more than half of those malnourished people work in agriculture. It is estimated that about 55% of food crop calories provide human nutrition, while the remaining calories go to animal feed and biofuels. Sadly, about 25% of the calories are lost or wasted.

Delivering nutritious food to the entire population of our planet is achievable, and agricultural and biological engineers have been addressing this challenge for decades. In fact, it's our global vision (http://asabe.org/gpfgs).

Our profession works to meet essential human needs and improve the quality of life for people everywhere, so why is agricultural and biological engineering not more widely recognized? How can we raise our profile in the world and in the scientific community? Telling our story, marketing our profession, and promoting our accomplishments require considerable financing and leadership, and we have done well within our profession. Now we need a strong global identity.

ASABE and the ASABE Foundation must lead the campaign to increase our recognition. Let's tell the world that agricultural and biological engineers are working to nourish the planet and the global population, to create a healthy planet for healthy people.

ASABE Foundation President, Fellow, and Past President
Lalit Verma, P.E., Professor and Head, Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville, lverma@uark.edu.