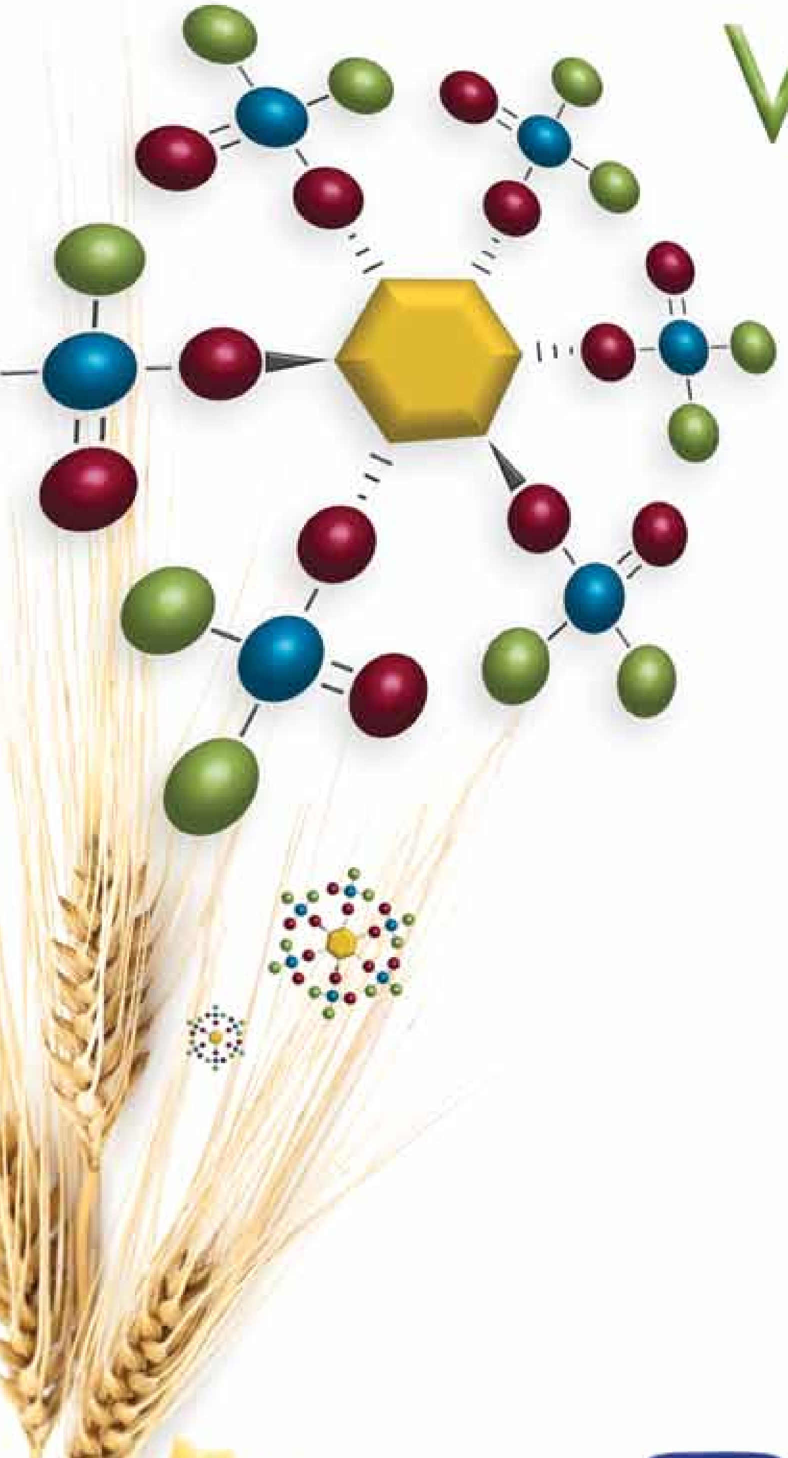


What's Cooking?

By Julie C. Lund

Engineers test techniques for making food fresher, safer and more nutritious

American consumers are tough customers. Not only do we want our food healthy and safe but we want it to be minimally processed as well as long-lasting. It can be difficult to achieve the twin goals of food stability and freshness but faculty members in the Department of Bioproducts and Biosystems Engineering are engaged in several projects to make food safer and more nutritious.

Now you see it

Although neither magnetic resonance imaging (MRI) nor nuclear magnetic resonance (NMR) technology were developed for food applications, they have great potential for the food industry, says Professor Roger Ruan. "What makes these methods unique is that they are non-destructive, non-invasive and fast, compared with conventional methods of determining food stability."

As a Ph.D. student at the University of Illinois at Urbana–Champaign, Ruan studied with Paul C. Lauterbur, who was recognized with the Nobel Prize in Physiology or Medicine in 2003 for developing magnetic resonance imaging as a diagnostic tool. Just as MRI scanners can be used to "see" inside the body, they can reveal the internal composition of food, such as temperature and water distribution and the presence of microbes or other foreign materials.

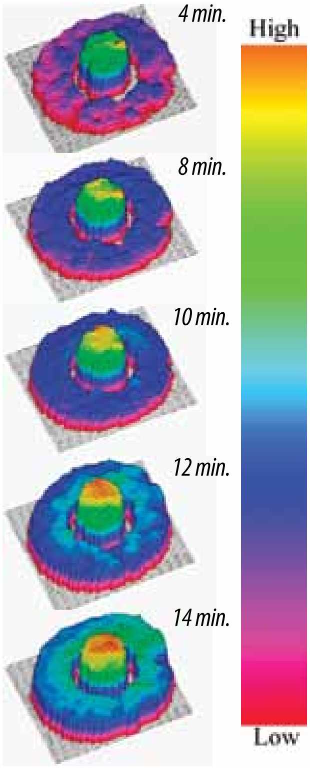
For example, MRI and NMR technologies can be used to measure and monitor water mobility in food products to determine how stable they are, explains Associate Research Professor Paul Chen. If the water molecules are mobile within the food product, they are vulnerable to chemical and biological reactions that can affect stability and shelf life.

The process is non-destructive and non-invasive. "You don't need to take samples or cut into the food. You just put it in the [MRI] chamber. And the measurements are very quick—they take just a fraction of a second," says Chen.

To model what happens during food processing requires making many assumptions, says Ruan, and modeling is not easy because many foods have complex chemical structures. "With this technology, you can use data to test the assumptions. I actually can map out the temperature distribution, the movement of moisture, the internal composition. And I can monitor it during the whole production process."

In fact, the MRI and NMR technologies can be used at several points in the production process. A producer of nutrition bars screens ingredients to see which best hold water to prevent the bars from hardening. A dry soup company uses the technique to see which components of the recipe are cake-resistant and less likely to cause lumps. The technique also can be used for quality assurance on the production line or during storage to assure that there are no foreign materials in the product or packaging.

Chen and Ruan have conducted several research projects for the U.S. Army to help create MREs (Meals, Ready to Eat) that have a long shelf life. Although not yet widely used by commercial food manufacturers, as the cost for the MRI and NMR technologies come down, Chen and Ruan anticipate broader adoption by the food processing industry.

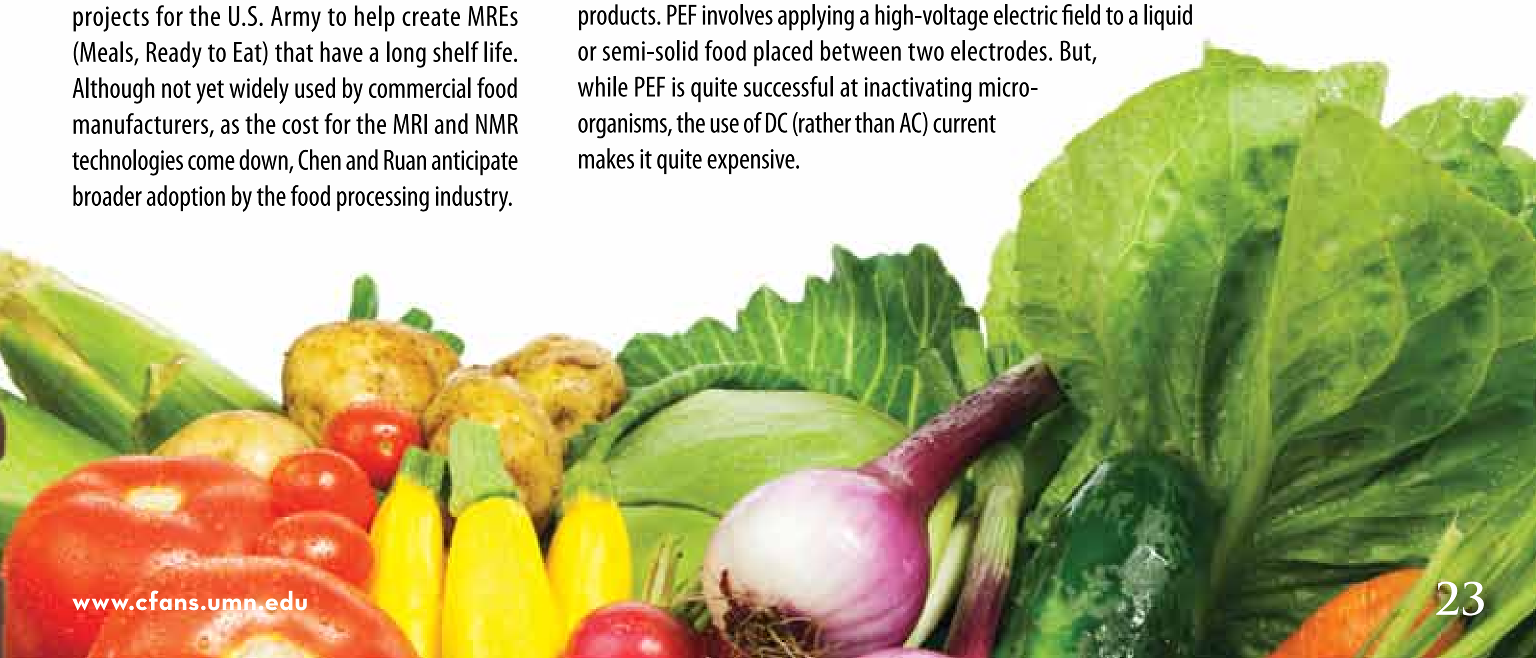


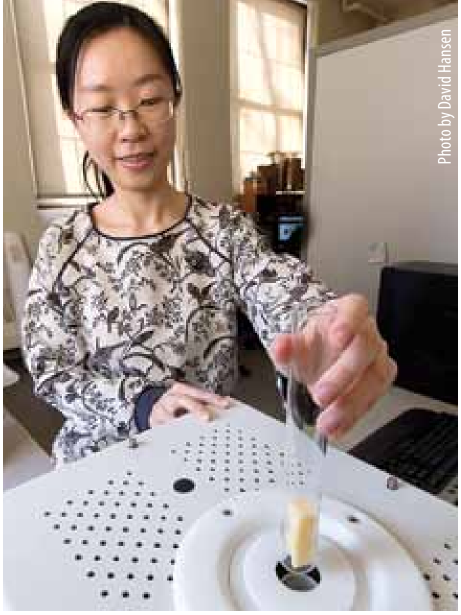
Left: A temperature map of ohmically heated whey and liquid produced by MRI imaging. Below: Roger Ruan poses with a prototype of a Concentrated High Intensity Electric Field (CHIEF) reactor that can more effectively and cost-efficiently destroy pathogens in food without altering its essential characteristics.

Less heat, more taste and nutrition

As well as products that stay fresh on the shelf, shoppers want assurance that the foods they buy are safe and free from bacteria, microbes or other unwanted micro-organisms. Irradiation, ultrafiltration, ozonation and ultra-high temperature processing are among several methods that the food industry uses to kill pathogens. Unfortunately, these technologies have limitations, as they are either extremely expensive or affect the product's flavor, color or nutrient content. Non-thermal pasteurization, on the other hand, offers the possibility of producing safe, fresh-like, minimally processed foods without degrading or damaging the food's taste or nutritional value.

The use of electrical fields to purify products is relatively new in the food industry. Pulsed electric field (PEF) pasteurization was first used commercially in the United States in 2005 on apple cider products. PEF involves applying a high-voltage electric field to a liquid or semi-solid food placed between two electrodes. But, while PEF is quite successful at inactivating micro-organisms, the use of DC (rather than AC) current makes it quite expensive.





Postdoctoral research associate Yun Li prepares to place a piece of cheese in an MRI scanner to look at lipid distribution.

"There also is the problem of electrode contamination," Chen says. The electrodes must make direct contact with the food. As the electrodes erode, they can contaminate the food."

Chen and Ruan's process uses novel reactors to generate high-intensity electric fields or non-thermal plasma to kill micro-organisms. Between the electrodes, they use dielectric barriers to separate and protect the food from the electrodes, eliminating possible contamination. The reactors use less expensive AC current, making them cheaper and more efficient to operate. Chen and Ruan recently built a prototype Concentrated High Intensity Electric Field (CHIEF) reactor that concentrates electrical energy, effectively destroying pathogens with very low voltage but without destroying the food or liquid's physical or chemical properties.

Plasma is the fourth state of matter, explains Chen (the others are solid, liquid and gas). It is essentially ionized gas created by applying enough voltage to release the electrons from the atoms. Positively charged nuclei swim in a "sea" of freely moving disassociated electrons, which allows the plasma state to conduct electricity. These "energetic particles" can bombard other particles they come in contact with, such as bacteria, viruses and fungi.

Thus far, most of the research has been done on milk, orange juice and whey products. "Our system is small, and there is room for improvement," Chen says. "But it holds enormous potential."

Pop goes the wheat bran

Changes in consumer attitudes and behavior have contributed to a growth in the consumption of "healthy" foods, as well as a growth in the demand for minimally processed foods. The increase in consumption of healthy food is associated with an abundance of scientific evidence regarding linkages between diet and good health.

The benefits of a diet rich in fruits, vegetables and whole grains is well documented. These foods contain many phytochemicals—beneficial chemical compounds found in plants (phyto is Greek for "plant"), such as antioxidants, that may contribute to health but are not considered essential nutrients, like vitamins and minerals. Examples include the carotene that makes carrots orange or the flavonoids that give grapes and blueberries their purple and blue pigments.

Unfortunately, many phytochemicals cannot be digested in their natural form; they simply pass through the human body unabsorbed. "A lot of good things—especially antioxidants—are hidden in cells that are very rigid and hard to break, so we don't have access to all of the nutrients in the food we eat," explains Chen.

As an example, 80 percent of the phenolic antioxidants in wheat bran—the "good stuff" in the wheat kernel—are structurally bound and insoluble. And, while wheat bran contains 43 percent dietary fiber, 40 percent is insoluble fiber, which is much less useful to the body than soluble fiber.

Chen and Ruan have explored several ways to improve the bioavailability or absorption rate of fiber and phytochemicals in whole grain foods, including enzyme and chemical treatments and a physical process called high-pressure pasteurization (HPH).

"It's relatively simple," Ruan says. "We use high pressure, and then suddenly release the pressure. The sudden change in pressure explodes the cell structure, releasing the micro-nutrients."

In an air puffing system, such as those used to make "puffed" breakfast cereals, the difference in pressure is only a few hundred pounds per square inch (psi), Ruan explains. "But we use very high pressure, with a difference in pressure of tens of thousands of psi."

Ruan and Chen's recent research showed that optimal HPH processing resulted in wheat bran ingredients with nearly 500 percent more soluble dietary fiber and a three-hundred-fold increase in free, unbound phenolics.

An added benefit is that HPH can be done with little or no change in temperature. High-temperature pasteurization can cause chemicals to oxidize, destroying some of the food's antioxidant properties.

"The sudden change in pressure also helps to deactivate some kinds of bacteria, so it's a non-thermal pasteurization technique, too," says Ruan. "In the end, you have a functional, nutritious product that is safe to eat." ■

Paul Chen uses a laser defraction particle size analyzer as part of the quality assurance process.