

## Electromagnetic Energy in Food Processing

**M**icrowave and radio frequency energy are portions of the electromagnetic spectrum that can deliver heat to foods selectively and efficiently. Specifically, microwaves interact with water in foods to heat predominantly those portions that are wet. Consumers are familiar with microwave ovens as household appliances used to warm and cook foods, thaw frozen foods, and pop popcorn. On an industrial scale, microwaves have been

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used to temper frozen ingredients and have been considered for drying applications, without great success.

The Food and Drug Administration (FDA) has approved two frequencies of microwaves for application to foods: 915 megaHertz (MHz) and 2450 MHz. Most home microwave ovens use 2450 MHz. By act of Congress, defying common sense, ionizing radiation has been declared a food additive, requiring petitions and FDA approval for use. Ionizing

radiation for certain specific applications and the two microwave frequencies have been previously approved.

The parameters important in energy absorption from microwaves are the following: frequency, Hz; dielectric loss factor,  $e''$ ; dielectric constant,  $e'$ ; electric field strength, V/cm; and material volume,  $\text{cm}^3$ .

The penetration depth depends on wave length;  $e'$  and  $e''$  wave length is inversely proportional to frequency, and energy is directly proportional to the frequency. The dielectric constant and dielectric loss factor both increase with moisture content and decrease with frequency. As a result of the complex interactions among parameters, applications of microwaves are not always straightforward. For example, applying too much power in microwave assisted vacuum drying can lead to arcing and scorching of product. There appears to be an upper limit to field strength above which arcing can occur even at atmospheric pressure.

Microwaves cannot penetrate metal so cans or pouches with aluminum laminates cannot be heated in microwaves, but glass and plastic containers can be used. There are non-metallic barrier films used in some packaging materials specifically so that they can be heated in home microwave ovens.

### Radio Frequencies

Radio frequencies assigned by the Federal Communications Commission for industrial use are 13.56 MHz +/- 6.68 kHz; 27.12 MHz +/- 160 kHz; and 40.68 MHz +/- 20 kHz. Radio frequencies at the two higher frequencies have been used for final drying of certain low-moisture baked products such as cookies and crackers because energy can be delivered without overheating and discoloring the outside of the product. In practice, this has not been widely applied, with many existing drying units being turned off.

Goji Food solutions, Glenview, Ill. ([www.gojisolutions.com](http://www.gojisolutions.com)), is an affiliate of an Israeli company that has applied radio frequencies initially to the gentle thawing of blood and human tissue. Goji took advantage of the ability to detect energy absorption



*The MATS® -B device from Food Chain Safety uses microwave energy to efficiently heat and sterilize packaged foods.*  
Photo courtesy of Food Chain Safety

from radio frequencies and carefully tune the supply. Applying radio frequency to foods, Goji is developing cooking devices that can thaw and warm different foods at the same time.

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#### **In-Package Sterilization**

Patrick Dunne (c.patrickdunne@gmail.com), recently retired from the U.S. Dept. of Defense Laboratories in Natick, Mass., and Tom Yang (tom.c.yang.civ@mail.mil), still a researcher at Natick, were involved in a consortium project with Washington State University (WSU) to develop in-package sterilization using microwaves. The specific target was improved military rations in flexible pouches. The pouches are heated by microwaves while submerged in water. Some of the energy is absorbed by the water, leading to more uniform heating. The water also prevents the pouches from expanding too much. Yang and Dunne provided the following history.

From 2001 to 2009 the Microwave Processing Consortium under the Dept. of Defense Dual Use Science and Technology (DUST) program with lead contractor WSU with Professor Juming Tang as principal investigator developed a semi-continuous 40-unit in-package microwave sterilization system with a 915 MHz source and had the first filing of a microwave sterilization of a low-acid food (mashed potatoes in a retort pouch) accepted by the U.S. Food and Drug Administration (FDA) in November 2009. Five members of the microwave sterilization team from WSU and industrial partners won the IFT Research & Development Award in 2010. This process is termed Microwave-Assisted Thermal Sterilization (MATS®). The industrial partners that participated in the DUST microwave sterilization included Kraft, Hormel, Rexam Containers, Ocean Beauty Seafoods, Mars Master Foods, Graphic Packaging, and Ferrite Components (the provider of the microwave sterilization system, which replaced a four-position unit built at WSU for this project). The five awardees of the IFT R&D award were Tang of WSU, Layne Martin of Hormel, the late Evan Turek of Kraft, Kenny Lum, the Process Authority of



Seafood Products Inc., and Dunne, DUST project leader of the U.S. Army Natick Soldier Center.

A microwave sterilized salmon fillet in Alfredo sauce was accepted under the FDA low acid canned foods regulations in 2010. A successor consortium was formed to support further research at WSU and the development of a fully continuous microwave sterilization system by a new company, Food Chain Safety of Washington, which received a license from WSU to the key microwave sterilization patents.

Key accomplishments to date are the installation of two pilot-scale continuous-prototype microwave units of improved design at contractors to the Dept. of Defense Combat Rations Program, AmeriQual Foods in Evansville, Ind., and Wornick Foods in Cincinnati, Ohio. Consortium members will have first access to the pilot systems in the U.S. Dept. of Agriculture-approved facilities for the production of a variety of new test products as well as improved combat ration entrees. One major accomplishment at WSU under the new consortium was the broad acceptance by USDA of items containing more than 2% meat sterilized by the MATS® system; chicken and dumplings, an item in the current assort of meals ready to eat (MREs), was the lead test item. Natick has done sensory and shelf-life testing of this item as well as other microwave-processed items. >>>

*Radio frequency has a greater penetration depth than microwaves, but is used less frequently.* Photo courtesy of Juming Tang

## Electromagnetic Energy in Food Processing continued...

### Microwave Aseptic Processing

The Center for Advanced Processing and Packaging Studies (CAPPS), a consortium among North Carolina State University, Ohio State University, and the University of California-Davis, has supported both the WSU system and the North Carolina State system, and compared both systems for production of diced tomatoes in a USDA grant to CAPPS that was reported at the 2012 IFT Annual Meeting and was also the subject of an IFT short course. The North Carolina State system pumps food through a microwave cavity, replacing conventional heat exchangers in an aseptic processing system. There have been a number of good products from the continuous microwave system; these include salsa and chili con queso plus the yam puree produced by Yamco of North Carolina using Industrial Microwave Systems equipment.

### Microwave-Assisted Extraction

A recently published text is devoted to this topic (Chemat and Cravatto, 2013). During

extraction, microwave energy may be absorbed by the substrate, the extraction solvent, or both. Higher temperatures generally promote diffusion and so accelerate extraction rate. Some of the solutes that have been studied using microwave-assisted extraction include essential oils and aromas; fats and oils; antioxidants and food colors; and pharmaceutical and nutraceutical compounds.

Most microwave-assisted extractions reported are on a small scale, typically for analytical purposes, where the reduction in time is appreciated. There are some commercial applications, including recovery of polyphenols from wood during drying; recovery of pigments from plants, flowers, and algae; recovery of antioxidants; and production of vegetable oils rich in carotenoids.

In addition to the benefit of uniform heating, as distinguished from conventional heating from the outside, microwaves appear to disrupt cells of the substrate, releasing the target compounds more easily. On the other

hand, microwave-assisted extraction appears to be less selective than alternate techniques such as super critical solvent extraction (SCSE), in which super critical carbon dioxide is used as a solvent. In SCSE with carbon dioxide, the solvent power is easily controlled by adjusting pressure. Very high pressures are required, which makes for high capital investment.

Microwave solvent extraction also runs the risk of overheating volatile solvents, some of which could explode or catch fire. Precautions include using relatively low power levels and carefully monitoring temperature.

### Drying

The advantage of microwave heating in drying is that it delivers energy where it is needed, where the water is. During conventional drying, as water is removed, starting from the outside of a food piece, an insulating layer of dry, porous material is formed, which grows larger as drying proceeds. This is why drying rates reduce with time. In contrast, with microwave energy, energy transfer is not inhibited by the dry layer, but, instead, is delivered directly to the wet area.

Microwaves have been applied to conventional drying as well as freeze drying. As previously noted, in a vacuum, such as is usually applied in freeze drying, there is an increased risk of electrical arcing, but even with reduced power levels, microwave-assisted freeze drying is faster than conventional freeze drying, which uses conductive heating by direct contact with a heated platen to speed dehydration. Most microwave drying is done in batches, but continuous drying tunnels in which the energy is applied through focused horns have been constructed. Care in design is needed to prevent escape of radiation from the cavity. In a batch chamber, wave patterns are deliberately disrupted to provide more even heating. **FT**



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### REFERENCE

Chemat, F. and Cravatto, G., eds. 2013. Microwave-assisted Extraction for Bioactive Compounds, Springer, New York, N.Y.