by Aaron L. Brody

Advances in Microwave **Pasteurization and Sterilization**

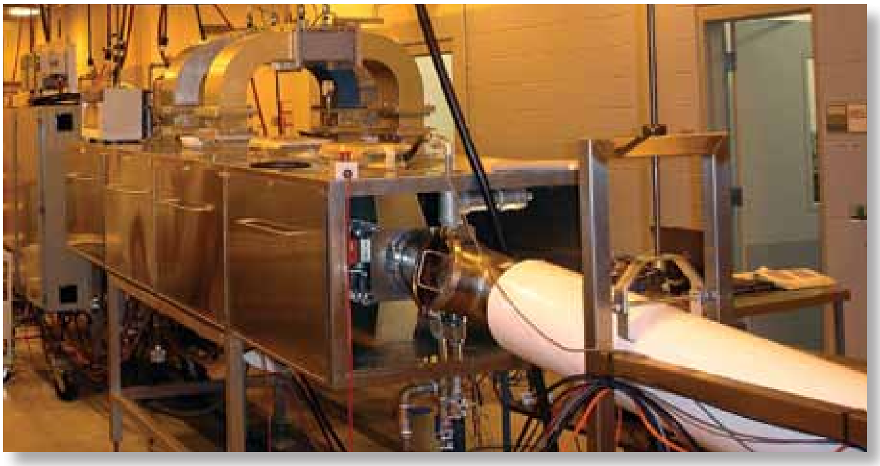
The history of microwave food heating is sprinkled with wonderfully intertwined tales of serendipity and genius that enrich and educate us to a deeper appreciation of the bearing of the past upon us tomorrow. In the beginning was Raytheon's legendary wizard Percy Spencer, whose chocolate bar melted as he wandered by a radar antenna in his laboratory, a development that led him to the invention of the microwave oven. Apocryphal or not, the water-cooled white *Radarange*®, the first commercial microwave oven, made its debut before 1950.

Perhaps the pop dreams were fueled by the amusing newspaper cartoons depicting the exploding eggs in microwave oven cavities or the popcorn popping in paper bags (which much later led to the microwave popcorn package) or the odd coupling of microwave energy with ionizing radiation that would sterilize foods with infinite ambient-temperature shelf lives. Massachusetts Institute of Technology's Team Goldblith (Sam) blitzed the notion with a carefully contrived and conducted study that demonstrated that the microbiological effects of microwaves were wholly thermal, a message that remains unheard by many through this day. Recognizing the power from the electromagnetic spectrum, Raytheon's Dave Copson engaged me to test the thesis that the quick transfer of microwave energy could destroy enzymes in orange juice within seconds. Thermodynamics proved the point, which lay latent for decades.

Multitherm Processing

During the 1960s, the brilliant Swedish scientist Lennart Stenström probed deeply into the geometry of microwaves in and out of cavities and developed several alternative solutions, one of which he dubbed Multitherm and had patented while being commercialized. Multitherm was derived from the concept that microwave radiation does not necessarily have to function alone to generate the desired uniform heating patterns that could simultaneously destroy enzymes and microorganisms with minimum heat and maximum quality retention.

Stenström noted in his Multitherm thesis that solid foods could receive energy from all surfaces, but not uniformly. This known deficiency of microwave heating challenged its ability to sterilize the food content because some of the food—just the portion containing microorganisms—would invariably not be heated to sterilization conditions. He therefore proposed combination (hence, "multi") with water and steam on the exterior to moderate the several energy sources to deliver uniform heat throughout the food mass. Thus, to spread the heat, the product (in its shallow, brick-shaped microwave-transparent barrier plastic package) is immersed in hot water, which removes heat from the corners that would otherwise overheat, and



***Second-generation microwave sterilization system** at Washington State University.*
Photo courtesy of Washington State University

***Microwave radiation does not necessarily have to function alone to generate the desired uniform heating patterns** that could simultaneously destroy enzymes and microorganisms with minimum heat and maximum quality retention.*

Advances in Microwave Pasteurization and Sterilization continued...

Segment of the UltrAseptics continuous flow microwave *sterilization installation at North Carolina State University pilot plant.*
Photo courtesy of Josip Simunovic

energy is distributed more uniformly throughout the food mass. The basic notion was reduced to practice in a single-cavity unit and later, during the 1980s, in a continuous motion commercial unit that produced a variety of high quality seafoods and vegetables marketed in Sweden.

This great physicist comprehended thermodynamics in both solids and liquids and earnestly drove a continuous flow fluid microwave sterilization process, which he called Achilles for the speed element.

Throughout this series of developments from the 1940s through to the beginning of the new millennium, only 2,450 MHz frequency microwave energy was applied, even though 915 MHz, which had greater depth of penetration, was available from regulatory authorities. Although many in the United States may not have knowledge of the processes sparked by Stenström's research, microwave heat sterilization processing has experienced a comfortable commercial success in Europe.

Microwave Pasteurized Foods

Capturing the multiple heating ideas, several companies manufactured about 100 multiphase microwave plus hot air chambers that were initially applied for pasteurization combined with chilled distribution for safe delivery of products such as wet pastas. In such applications, the high quality product in microwave-transparent barrier trays heat sealed with barrier flexible lidding entered a microwave tunnel and was exposed to 10–200 kw of 2,450 MHz energy. Microwave generators are situated near the entry to heat the interiors, and steam/hot air is present following the microwave radiation to temper the total food mass temperature.

Most of the food product mass in its hermetically sealed barrier plastic trays has been heated to near 100°C when it leaves the proximity of the microwave energy (meaning that there is some level of microwave radiation in the cavity throughout). The external hot environment heats by conduction to ensure that the entire interior food mass is tempered (heated uniformly) to a pasteurization level. The final section of the cavity does not contain any injected steam/hot air to arrest the active heating and begin the cooling process. In this system, the nebulous reduction in vegetative (but not necessarily all microbial) cells occurs at the post-packaging stage with a finite probability of the presence of pathogenic microorganisms so that the product must be distributed under refrigeration. Shelf life of such products depends on the product and the oxygen concentration in and entering the package. Thus, under present commercial practice, shelf life is probably in the range of six weeks.

Microwave Sterilized Foods in Europe

Related to microwave pasteurized foods are microwave sterilized foods, which initially took a different pathway than the Swedish Multitherm. The European Omac systems used by Belgium's Tops Foods on prepared refrigerated ready meals was effectively a blast—a pressurized chamber into which microwave energy was input for a short distance plus pressurized hot air applied for an extended period of time in order to elevate the product temperature to sterilization levels of about 130°C. The last section of the system was another pressurized section in which the product temperature was cooled to ambient. Packaging was, in effect, the same as that for retort trays but always requiring microwave transparency: shallow barrier plastic trays with hermetically heat-sealed barrier closures. Total thermal time was in the vicinity of 10 minutes, still much less than that dictated for canning or even retort tray, but with much less thermal input. The system applying 2,450 MHz was marketed in the United States under the *Classica* trade name about five years ago with no notable success.

Microwave Sterilized Foods in the United States

• **Post-packaging sterilization.** In addition to the more than 100 million microwave ovens operating in American homes and foodservice outlets, hundreds of larger-size units are finishing bacon, tempering frozen meat, and precooking foods for industrial and institutional applications using both 2,450 and 915 MHz frequencies. The three most important applications in 2011 are the Yamco continuous flow machine for sweet potato puree, the continuous flow particulate sterilizer at North Carolina State University, and the post-packaging unit at Washington State University.

Winner of a major IFT award, the in-package sterilization system is one outcome of the enhancement of the Swedish Multitherm system over an eight-year period by a consortium of industrial and academic organizations (www.microwaveheating.wsu.edu) under the direction of Washington State University's Jimmy Tang. Among the foods whose quality retention is so improved by the reduced (one-quarter to one-tenth the time of conventional canning to achieve sterility) thermal input resulting from exposure to Ferrite's single mode 915 MHz microwave energy (www.ferrite.com) are macaroni and cheese, mashed potatoes and beef (think Shepherds' pie), and solid-pack salmon and rice.

Packaging for the pilot operations is multilayer plastic trays sandwiching ethylene vinyl alcohol for oxygen barrier between layers of polypropylene for structure, moisture barrier, and microwave transparent heat resistance plus a hermetically heat-sealed, peelable flexible barrier closure. To assist in the sterilization heat transfer, the trays are relatively thin, which, not coincidentally, aids in rethermalization of the ambient-temperature-distributed product.

Although the group projects an ambient temperature shelf life of more than two years, the postulation from this perspective is that absent the removal of almost all of the oxygen from the system, shelf life would not be extended nearly that much. Chilled distribution would prolong the shelf life, but the cost/benefit return is debatable: We believe that extended-shelf-life considerations would warrant the controlled distribution, but that would have to be demonstrable in commercial practice.

• **Prepackaging sterilization.** In today's expanding spectrum of technology, low-acid sweet potato puree is sterilized at Yamco (www.yamco.net), also with 915 MHz frequency microwave energy and packaged applying aseptic technology. In the process, which has been recognized with an IFT Industrial Achievement Award, product is preheated to 170°F in a screw heater and brought up to sterilization temperatures of 290°F in 10 seconds in a double-tube continuous flow microwave unit supplied by Industrial Microwave Corp. (www.industrial-microwave.com/industries). In commercial operation, the cooled product is aseptically filled into industrial/institutional-sized bag-in-box packages on a *LiquiBox* system (www.liquibox.com).

Meanwhile, again extending the reach of microwave heating in pumpables, particulates up to ¾ inch in size are being moved applying progressive-cavity Marlen Research (www.marlen.com) pumps and microwave sterilized in the North Carolina State University pilot plant managed by Josip Simunovic (josip.simunovic@ncsu.edu).

Envisioning the Future

After too many years of fits and starts on the American market, a technological giant is stirring. Based on the integration of numerous single disciplines, holistic hurdles are driving microwave heating, pasteurization, and sterilization into the mainstream of processing, preservation, and distribution. By radically reducing the input heat required to achieve microbiological control in combination with other heat sources, oxygen reduction, gas barrier packaging, and aseptic packaging and the ever-crucial distribution system, microwave processing and its related radio frequency sources have emerged from their shroud to offer powerful new means to satisfy consumer desires for safe prepared food products that are high in quality. Once again in the chronology of all food science and technology, a multiplicity of food disciplines are weaving into an intricate web that promises to figuratively explode on the commercial scene—finally. **FT**

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