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Editor

## High-Temperature, Short-Time Processing

High-temperature, short-time processes, as the name implies, use higher temperatures and shorter times than conventional thermal processes to achieve pasteurization and sterilization of foods and beverages. Because the products are exposed to high temperatures for short times, there is minimal degradation of the products.

In general, temperatures and times for HTST range from 161°F for 15 sec used for pasteurization of milk to higher temperatures for shorter times. Use of temperatures above 280°F is generally referred to as ultra-high-temperature (UHT) processing.

HTST processing has been used successfully for many years. To find out what's new in this area, I spoke with various thermal processing experts. Here's what they told me.

Kenneth R. Swartzel (phone 919-515-2951), Head of the Dept. of Food Science at North Carolina State University, Raleigh, and Managing Director of the Center for Advanced Processing and Packaging Studies (CAPPS) there, said that although alternative processes have been developed over the years, thermally processed food products maintain a clear dominance in the marketplace, primarily as a result of the wealth of theoretical and empirical knowledge that has been developed regarding thermal inactivation of pathogenic microorganisms and their spores. Considerable efforts have been devoted to capitalizing on the unique kinetic advantages of HTST processes. He will be discussing advances in thermal processing over the past 25 years, with an eye to the future, in a presentation during the IFT Annual Meeting in New Orleans this month.

In any thermal process, there are heating, holding, and cooling steps. In deter-

mining the lethality of the process, the heating and holding steps are the most important. Swartzel said that efforts are being made to get the heatup time shorter. There are lots of different approaches, including a variety of new innovative microwave techniques in the United States and overseas. The real problem with using microwaves, he said, is that there have been hot spots and cold spots, which affect product quality, and innovations have been quite expensive. However, efforts have been made to minimize these effects.

Another approach is to use ohmic heating. Nestlé Carnation's Flash 18 system—which uses a pressure chamber under increased pressure, 18 psi above ambient, to process particulate-containing foodservice products packaged in No. 10 cans—has replaced its traditional heater

with ohmic heaters. This has shortened the heating curve dramatically.

There are lots of innovations in aseptic processing, he said, but traditional equipment is still being used, including scraped-surface heat exchangers and tubular heat exchangers. But tubular heat exchangers have changed dramatically. For example, helical heat exchangers provide a lot of turbulence, which improves heat transfer. Dimpled tubular heat exchangers change the flow pattern and provide quicker, more uniform heating.

Steam injection and steam infusion systems are also being used. They're an old technology, he said, but some innovative injectors and infusers are being developed.

Josip Simunovic (919-513-3190), Senior Researcher in the Dept. of Food Science and Assistant Director of CAPPS at NCSU, said he and his coworkers Tunc Koray Palazoglu and Pablo Coronel are using a flow-through cylindrical microwave reactor manufactured by Industrial Microwave Systems, Inc., Morrisville, N.C., to develop processes for liquids such as milk and very viscous food products such as spaghetti sauces and salsa. These processes also integrate novel methods for single- and multiphase continuous thermal process monitoring and evaluation developed by CAPPS researchers. Low-acid products containing particulates, such as soups and stews are also being considered. Advanced applications of rapid continuous heating in the cylindrical reactors are also being developed by NCSU researchers Brian Farkas for dairy products and Tyre Lanier for seafoods.

In the cylindrical reactor, microwaves are focused in such a way as to provide uniform exposure of product to energy within the reactor cavity. The uniform energy exposure region of the reactor is



High-capacity (60-kW) cylindrical microwave heater with two consecutive in-line reactors, manufactured by Industrial Microwave Systems and installed in the CAPPS pilot plant at North Carolina State University

approx 1.5 in diameter and 6 in long. This also allows for integration with existing continuous processing lines. Simunovic said that the basic philosophy behind this effort is to practically eliminate the heat-up time.

Using the cylindrical reactors, he said, brings us very close to instantaneous heating, but in some cases the process must be modified to extend the time allowed for the product to reach the final process temperature. For nonhomogeneous products, the rate of heating within a single reactor may be too high for some of the components, so they are considering using two or more consecutive reactors in line and allowing for equalization time in between. This allows the energy to be distributed more evenly and also targets desired temperature ranges for each reactor. As products are heated, physical and chemical changes occur, such as lipid melting, coagulation of proteins, gelling of starches, and fluid exchange between components of complex multiphase materials. We also want to target specific energy delivery to the process stages that can

result in a change of dielectric properties, he said.

Simunovic will discuss the results of continuous microwave heating of fluids at the IFT Annual Meeting. The 5-kW reactor used in his studies was installed at CAPPs in April 2000, and a 60-kW continuous microwave heater consisting of two consecutive reactors is being installed there in a collaborative effort by IMS and CAPPs and will be on line by the end of this year.

Rapid cooling is the next great frontier, Simunovic said. In a continuous thermal multiphase process filing, the cooling section of the heat-hold-cool curve will get minimal lethality credit, so the logical thing is to minimize the cooldown time. More-efficient heat exchangers are being developed, including helical heat exchangers and corrugated-tube heat exchangers. Also in the future are other technologies such as magnetic cooling, which is very expensive and used only in military and some scientific applications, as well as cryogenic and Peltier (electronic) cooling. Depending on the throughput

and economics of the process, he said, all are potential technologies for rapid cooling.

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Sudhir K. Sastry (phone 614-292-3508), Professor in the Dept. of Food, Agricultural and Biological Engineering at Ohio State University, Columbus, and Co-Director of CAPPs, said that HTST processes have been used for many years to sterilize low-acid foods and beverages. An HTST process is typically considered as 270–290°F for the appropriate time required for sterility (a few seconds at 290°F), depending on the  $F_0$  value desired. Using high temperatures for short times improves the quality of liquid foods. The problem is to apply it to products that are solid or contain large solid particles. Since not all particles flow at the same rate, enough heat must be provided to sterilize the slowest-heating (i.e., fastest-moving) particle. This means that the other particles get overprocessed—they get the high temperature but not the short time—thereby affecting the quality of the product.

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# Products & Technologies

Some recent technologies have been getting better at it, Sastry said. One is microwaves. This technology is getting better at delivering a uniform dose, but it's still problematic. It's much easier to deliver a uniform dose of energy to a liquid than to a product that contains liquids and solids. A variety of microwave technologies are being looked at. Industrial Microwaves Systems manufactures a cylindrical microwave reactor that focuses energy as the microwaves penetrate into the product. If focused right, the energy is concentrated. This compensates for the loss of energy due to attenuation of the wave as it penetrates the product.

Another technology being revived is ohmic heating. Land O'Lakes used it in the early 1990s but discontinued using it in 1995. There have been a lot of developments in this technology since then, he said. One is alternative power supplies. Solid-state power supplies have improved the technology to the point where one can deliver various different frequencies of ohmic heating at much lower cost than typical radiofrequency methods.

Several equipment manufacturers are involved in ohmic heating. At least two companies in Europe are looking at lower-cost ohmic heaters, and a group in Europe is looking at use of ohmic heating for whole-fruit processing, Sastry said. There are also several developments in the United States. The 5-kW ohmic unit that had been used in the Land O'Lakes facility is now in Sastry's Food Engineering Laboratory at Ohio State University, and a custom-designed 54-kW unit has also been installed there. Both are available for testing by food companies interested in evaluating this technology for their products.

We can heat very rapidly with these technologies, he said, but cooling has historically been a problem, one that researchers are seeking to remedy. Sastry had a project with USDA's National Research Initiative, and one of the developments of the 54-kW facility will be a rapid cooling system that will be fully set up by this fall. Sastry is in the process of preparing a patent application for the system.

Another technology being developed

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Research Associate Brian Heskitt operates the ohmic pilot plant at Ohio State University. The inclined objects are ohmic heaters

is pressure-assisted thermal processing. The process starts at a high temperature (90°C), and pressurization takes the product up to sterilization temperature. Then decompression cools the product down to the initial temperature, via adiabatic decompression. Although the process is not well understood yet, he said, it appears that two rapid compressions are better than one. It is a batch process, whose economics still have to be determined, he added.

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An aseptic process for a low-acid product containing particulates (potato soup) was filed with the Food and Drug Administration in 1997 by Tetra Pak, as a result of two workshops conducted in 1995–96 by CAPPs and the National Center for Food Safety and Technology (see article in the August 1997 issue of *Food Technology*). Since then, Sastry said, no other such processes have been filed. Aseptic processing is being used for products containing particulates in Europe, but to the best of Sastry's knowledge not in the United States.

The standard equipment used for HTST processes has been plate heat exchangers, steam injection, and steam infusion, all of which are in commercial operation. But other technologies are being developed because particulates can't be processed by steam injection or infusion effectively, said Sastry, who will be presenting a paper on electrothermal processing at the IFT Annual Meeting.

Rakesh K. Singh, Professor of Food Engineering at Purdue University (765-494-8262) until June 30 and Head of the Dept. of Food Science and Technology at the University of Georgia (706-542-0994) as of July 1, said that most advances in HTST processing are in aseptic processing of low-acid particulate foods. Europeans are already doing it, but no U.S. companies are, probably because companies don't want to be the first to use it.

However, companies are using aseptic HTST processing for high-acid foods, including those containing particulates, such as diced tomatoes, pineapples, strawberry fillings, etc., since high-acid processes don't need to go through FDA filing. As long as a company believes the product will have commercial sterility in the marketplace, it will produce it, he said.

The same types of equipment are used for high-acid products as for low-acid products. The only requirement for low-acid products would be right kind of seal to withstand the high temperature. But that is already being done for nonparticulate products, such as puddings. It's not an equipment problem.

Microwave heating and ohmic heating are research-type approaches, Singh said. Ohmic had lot of potential in 1989–91 and went through some testing, but he doesn't see anyone using it except a liquid egg processor. Nobody is using it for particulates. Microwave and radiofrequency both are laboratory or pilot scale. Microwaves use 915 and 2,450 MHz, whereas

RF frequencies are much lower, providing better heat penetration for larger particulates. Nobody is yet using large-scale RF systems, he said.

A lot of new beverages processed by HTST aseptic-type systems are in the market. The biggest use is not-from-concentrate orange juice, which is being processed and then stored aseptically in million-gallon tanks. Combined fruit juices are also using the same HTST technology. Baby food manufacturers are getting into the same technology because of better quality and better packaging. The packaging will probably drive the market, Singh said. Baby foods traditionally come in clear glass jars through which the product can be seen. Now newer plastics can go through aseptic lines and remain clear, resulting in a convenient, see-through package.

With regard to equipment, some manufacturers are making more efficient heat exchangers. The tubes in tubular heat exchangers used to be smooth, but now they're dimpled to provide better turbulence and heat transfer. Also, channels are being used to produce a helical-type channel flow, also improving heat transfer. There are also improvements in plate heat exchangers to handle higher pressures. They used to work only with low-viscosity liquids but now can handle very high viscosities. Scraped-surface heat exchangers are used for a very limited number of products. They are not as efficient as plate and tubular heat exchangers but are used for very viscous products.

Bob Fox (757-220-3693), President of Pressure Pack, Inc., Williamsburg, Va., has taken another approach to HTST processing. The Pressure Pack system, patented by Fox and Joseph Marcy of Virginia Polytechnic Institute & State University, combines three primary processing methods—HTST processing, hot-filling, and in-container sterilization—into one. A food product is heated by conventional HTST means, then pumped through the sidewall of the pressure vessel and volumetrically filled into a container within the pressurized vessel. The container is then sealed and held long enough to achieve the desired sterilization value, the length of time depending on the fill temperature. It is then transferred into an overpressure cooler, where it is cooled to below the flash point, then is transferred to an ambient-pressure counterflow agitated cooling system for final cooling.

It's not a new process, Fox said. It's the

same basic process that has been used commercially for more than 30 years, the Flash 18 process. The limitation of Flash 18 is that it involves personnel within the pressure chamber, where the pressure is 18 psi above ambient. Fox's system differs in that the pressure vessel is too small to accommodate people, so the vessel can be designed to process and package foods at added pressures greater than 18 psi and temperatures above 255°F. The system is applicable to processing of such products as nutraceutical beverages packed in thin-walled aluminum cans. The hold time at 284°F is 15 sec, so there is minimal damage to the product quality.

The energy requirements are virtually the same as in aseptic processing, Fox said, and a lot lower than for conventional re-torting, and the product quality is virtually indistinguishable from that of aseptically processed products, for all types of products tested.

The beauty of this process, he said, is that it opens up the opportunity to process very high-quality particulate products, with no limits on particulate size.

Rich Meyer (253-539-0266), President of Washington Farms, Tacoma, Wash., will discuss HTST thermal-assisted high-pressure sterilization during the IFT Annual Meeting. He said that in the quest for better quality of shelf-stable, low-acid foods, a number of emerging technologies have been considered, including pulsed electrical fields, irradiation, pulsed light, high pressure, and oscillating magnetic fields. Of these, only high pressure has proven to be effective in eliminating all spores and enzymes while retaining a quality level equal to or better than that of freezing.

According to Meyer, an HTST process is one that provides a 12-log kill of *Clostridium botulinum* spores, e.g., 121°C for 6 min. With high pressure (690 MPa or higher), sterility can be accomplished with an end temperature of 100–105°C at each pulse peak, using two pulses (cycles). In the batch process, product is placed into the pressure chamber and heated uniformly to 90°C at 690 MPa. Adiabatic heating raises the end temperature to 119°C. The chamber is pressurized, then decompressed to ambient pressure, then repressurized and decompressed again. He said that it is necessary to pulse the system because, although high pressure protects the product from heat degradation, it also protects spores. If only one pulse is used and the product is held under pressure for even as long as 60 min, sterility is

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not achieved. It's the pulsing that kills, he said, not the time at a certain temperature, unlike conventional thermal processing.

For those of you who will be attending the 2001 IFT Annual Meeting in New Orleans on June 23–27, Meyer's presentation (paper 6-6) will be on Sunday morning, June 24; Simunovic's (paper 13-8) on Sunday morning; Swartzel's (paper 52-2) on Monday afternoon); and Sastry's (paper 65-2) on Tuesday morning. ●

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