HIGH PRESSURE PROCESSING: INSIGHTS ON TECHNOLOGY AND REGULATORY REQUIREMENTS

Introduction

High Pressure Processing (HPP) is a pasteurization method that uses pressure rather than the traditional method of heat to kill microorganisms in foods. This process, like thermal processing, helps extend the shelf life of foods by killing spoilage organisms including yeasts and lactic acid bacteria. It also helps improve the safety of foods by killing vegetative pathogenic microorganisms including Escherichia coli O157:H7, Salmonella and Listeria monocytogenes. However, compared to thermal processing, HPP is less destructive to key food quality components such as vitamins, flavor compounds and pigments, helping to maintain food attributes associated with fresh, unprocessed foods.

Consumer demand for minimally processed fresh foods that meet increasing US Food and Drug Administration (FDA) and United States Department of Agriculture (USDA) safety standards is growing. Food manufacturers are under increasing pressure to find processes that provide a safe product while using less destructive methods to achieve this goal. Foods meeting these standards are in demand, and consumers are willing to pay a higher price for these higher-quality products. HPP provides an attractive alternative processing method; even though it requires a greater initial financial investment, the result is higher-quality, higher-value (premium) products. Let’s explore some of the technical food science aspects of HPP.

HPP – Understanding the Technology

The Process and Equipment: HPP involves a standard processing profile. Pressure is increased at a certain rate until the target pressure is reached, held for a specific amount of time, and then released at a specific rate. Typical pressures applied to foods range from 300–800 MPa (43,500–116,000 psi). Heat may also be applied; however, the majority of high-pressure processes are conducted at refrigerated temperatures, relying mainly on pressure to process the food. Note that some temperature increase does occur naturally during a typical HPP treatment due to adiabatic heating, which is dependent on the target pressure and food composition. While the temperature increase of water is approximately 3°C per 100 MPa, this can be significantly higher for more compressible food ingredients such as fats, resulting in a greater temperature increase during pressurization for foods with higher fat content. See a schematic representation of the pressure and temperature profile of a typical HPP treatment in Figure 1.

Both batch process and semi-continuous HPP systems are available on the market. Most food products are processed using batch process systems. A typical HPP batch system (Figure 2) consists of four key components: the pressure vessel, pressurization fluid, intensifier and pump. Alternatively, the pressure vessel can be designed as a pressure intensifier. The pressure vessel is built to withstand a certain amount of pressure and temperature, and it contains the packaged food product and pressurization fluid. The volume of fluid they can hold, ranging from several milliliters for research units to several hundred liters for commercial units, defines pressure vessel sizes. The pressurization fluid is typically water, added to the pressure vessel to eliminate air pockets between the packages of food. Once the pressurization fluid is added, the hydraulic pressure intensifier and pump increase the pressure inside the cell, and the pressure is transmitted through the pressurization fluid, through the packaging material to the food itself. As the pressure is applied uniformly over the whole surface of the food product, the shape of the food is maintained.
Packaging: To achieve the best pressure transmission within the food product, the ideal food for HPP processing has no gas inclusions, no headspace in the package and high moisture content. The material used to package the product must be flexible enough to transmit the pressure without structural damage. When the food is compressed due to pressurization, the package has to allow this reversible deformation. We do not recommend rigid materials such as metal and glass, as they are not able to withstand the HPP treatment. Vacuum-packed products in flexible packages are ideal for HPP, particularly if the package can be compressed by about 15 percent without suffering structural damage and can return to its original shape upon pressure release. Flexible packs, jars, trays and bottles are commonly used as HPP packaging.

Effects of HPP on Food Compounds: The effect of HPP on molecules with a low molecular weight is minimal. Therefore, vitamins, flavor compounds and pigments survive HPP processing relatively unharmed compared to thermal processing, preserving the nutritional value and quality of the food.

Other compounds are irreversibly changed with HPP. Gelatinization of carbohydrates can be achieved through pressure increase rather than through temperature increase, and proteins can be denatured at elevated pressures without increasing the temperature. Figure 3 illustrates this pressure-temperature relationship. Although the egg depicted in Figure 3 has visual similarities to a thermally processed hardboiled egg, the taste of the pressure-treated egg is closer to that of a raw egg, as temperature-induced flavor changes (chemical reactions) did not occur during HPP. This presents interesting possibilities from a product development standpoint.

Figure 3: Schematic representation of the elliptic phase diagram of proteins illustrating pressure, heat and cold denaturation (A, Adapted from Smeller, L 2002) and picture of denatured eggs (B).
Effects of HPP on Microorganisms: High pressure impacts microorganisms similar to that of the different food chemistry components. Denaturation of proteins, which are essential to many of the functions of the bacterial cell, has a major impact on the survival of microorganisms, and can eventually result in cell death if a sufficient amount of pressure is applied—which makes repair/recovery impossible for the bacterial cell. For vegetative organisms including yeasts and lactic acid bacteria (spoilage organisms), as well as *Escherichia coli* O157:H7, *Salmonella* and *Listeria monocytogenes* (pathogenic organisms), this is especially true. Numerous scientific studies conducted with these organisms in a variety of different food products have demonstrated the applicability of HPP as a kill step for these organisms. Major benefits of HPP from a microbial perspective include extended product shelf life and improved food safety.

On the other hand, HPP is not effective as a kill step against all microbial forms. Spore-forming organisms are highly resistant to HPP when they are in their spore form, and a combination of pressure and heat, or some other antibacterial intervention, is required to achieve any reduction of bacterial spores in foods. Of particular concern are spores of the organism *Clostridium botulinum*, which can germinate, grow and produce a highly potent paralytic neurological toxin in low-acid foods.

The composition of the food product plays an important role in the effectiveness of HPP against microorganisms, as well as the type of organisms that may be able to grow or survive in the product. Carefully consider composition when evaluating the use of HPP as a kill step for a food product (see The Covance white paper titled “Validating My High Pressure Process Treatment” for more information).

Regulatory Requirements: The FDA and USDA each have regulatory requirements addressing food safety issues. These regulations target specific categories of food based on the composition of the food and storage conditions for the food, which influence the microorganisms that could be present or survive in the food. Regulations include:

- Hazard Analysis and Critical Control Point Systems (Juice HACCP; 21 CFR 120)
- Thermally Processed Low-Acid Foods Packaged in Hermetically Sealed Containers (21 CFR 113)
- Acidified Foods (21 CFR 114)
- Control of *Listeria monocytogenes* in Post-Lethality Exposed Ready-To-Eat Products (9 CFR 430.4)

We recommend consultation with a Process Authority to help navigate the regulatory requirements for specific food products. With more stringent food safety legislation initiated by the Food Safety Modernization Act (FSMA), validation of HPP as a kill step is required to ensure effectiveness for food safety. In the case of HPP, a specific pressure and hold time is tied to a specific level of reduction of vegetative cells of pathogenic organisms. Regulatory agencies’ specified “critical processing parameters” for HPP treatment of foods include:

- Target pressure
- Time at target pressure
- Time to achieve target pressure
- Decompression time
- Initial temperature of the product
- Initial temperature of pressurization fluid
- Product pH
- Product water activity

HPP has been validated as a kill step for:

- Vegetables & fruits—juices, salsa, dressing, guacamole
- Meats—ready-to-eat meats and poultry
- Seafood—shellfish and fish products
What Covance Offers

Covance is a recognized Process Authority with experience in process validations. We routinely conduct validations for conventional thermal processing (retorted canned foods, acidified foods, juice pasteurization), aseptic processing and packaging equipment. We have also validated roasting, convection oven, high temperature short time (HTST) and extrusion processes for food products ranging from low-moisture cereals, crackers, cookies and nuts to dried fruits, fruit purees, pet food and infant formula. With the addition of our 2-liter laboratory HPP machine, we now offer high pressure processing as well. We provide a complete consulting package to help determine appropriate HPP processes for bringing foods to market safely.

The Covance Partnership

We recognize your need for solutions across the lifecycle continuum, from product development to safe food processing and testing. Covance offers a wide breadth and depth of services and is committed to your success. Make us your partner for integrated consulting, development, and testing solutions.

Learn more about our food solutions at www.covance.com/foodsolutions