FOOD FOR THOUGHT
Topical Insights from our Subject Matter Experts

HIGH PRESSURE PROCESSING: INSIGHTS ON TECHNOLOGY AND REGULATORY REQUIREMENTS

THE NATIONAL FOOD LAB

The NFL White Paper Series
Volume 10, July 2013

Introduction and Background

The use of high hydrostatic pressure as a method to preserve food products has gained commercial importance in recent years. 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 to both extend the shelf life of foods by killing spoilage organisms, including yeasts and lactic acid bacteria, and improve the safety of foods by killing vegetative pathogenic microorganisms like *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes*. However, unlike thermal processing, HPP is less destructive to key food quality components such as vitamins, flavor compounds, and pigments, which helps products processed in this manner keep qualities associated with fresh, unprocessed foods. Thus, HPP not only improves the safety of foods, but also extends the shelf life of foods while maintaining food attributes normally associated with "minimally processed" foods.

As consumer demand for minimally processed fresh foods which also meet the ever increasing food safety standards enacted by the FDA and USDA grows, food manufacturers are under increasing pressure to find alternate processes which provide a safe product, but utilize less destructive methods to achieve this goal. Foods which meet these standards are not only in higher demand, but consumers are willing to pay a higher price for these higher quality products. HPP provides an interesting alternative processing method to meet these requirements. Even though this processing method requires a greater initial financial investment, it pays off in higher quality, higher value (premium) products. Additional details regarding some of the technical food science aspects of HPP are provided in the following paragraphs.

HPP – Understanding the Technology

The Process and Equipment: HPP of foods involves a standard processing profile. Pressure is increased at a certain rate until the target pressure is reached, the target pressure is held for a specific amount of time, and then pressure is 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. It is important to 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 like fats, resulting in a greater temperature increase during pressurization for foods with higher fat content. A schematic representation of the pressure and temperature profile of a typical HPP treatment is provided in Figure 1.

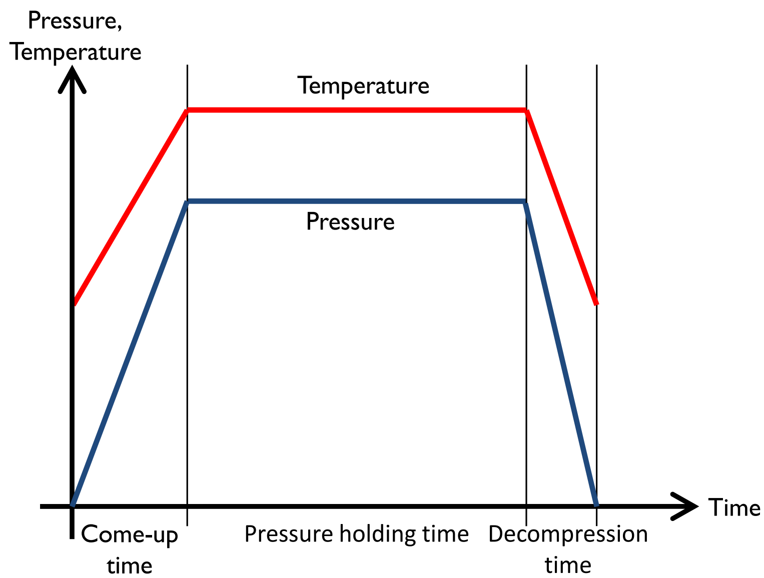

Figure 1. *Pressure and temperature profile during a typical HPP treatment applied to food.*

Although both batch process and semi-continuous HPP systems are available on the market, the majority of 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 additionally be designed as a pressure intensifier. The pressure vessel is built to withstand a certain amount of pressure and temperature, and contains the packaged food product and pressurization fluid. Pressure vessel sizes are defined by the volume of fluid that the vessel can hold, and can range from several milliliters for research units to several hundred liters for commercial units. The pressurization fluid is typically water, and is 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 are used to 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.

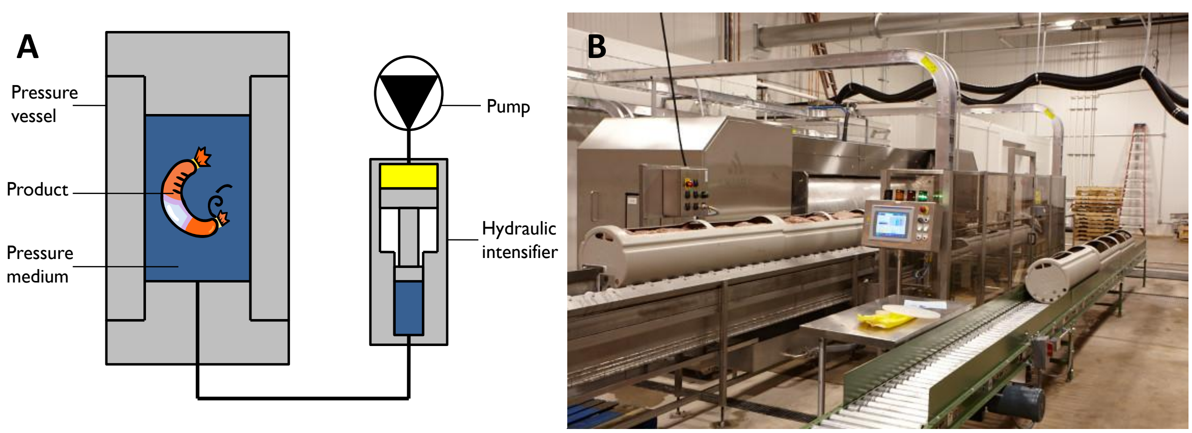

Figure 2. *Schematic of an HPP system (A) and actual photograph of a batch HPP system owned and operated by American Pasteurization Company (B).*

The Package: In order to achieve the best pressure transmission within the food product, the ideal food for HPP processing has no gas inclusions, no head space in the package, and high moisture content. Additionally, the type of material used to package the food product also has to be suitable. The packaging material has to be flexible enough to transmit the pressure without structural damage. Due to pressurization, the food is compressed and the package has to allow this reversible deformation. Rigid materials like metal and glass are not recommended, as they will not be able to withstand the HPP treatment. Vacuum packed products in flexible packages appear ideal for HPP, particularly if the package can be compressed by about 15 percent without suffering structural damage and it is able to return to its original shape upon pressure release. Currently, flexible packs, jars, trays and bottles are 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, thus preserving the nutritional value and quality of the food.

On the other hand, 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 actually 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.

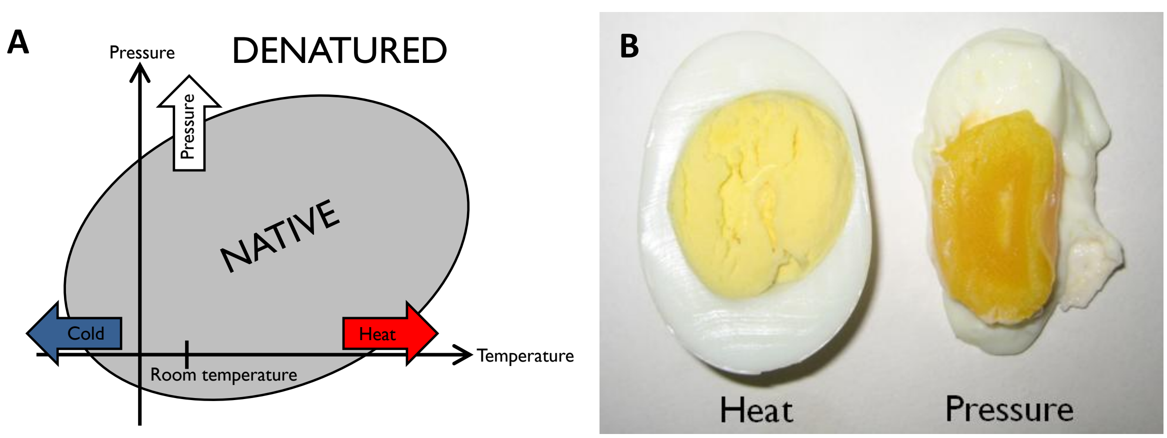

Figure 3. *Schematic representation of the elliptic phase diagram of proteins illustrating pressure, heat and cold denaturation (A, Adapted from Smeller, L. 2002) and picture of denatured eggs (B).*

Effects of HPP on Microorganisms: High pressure impacts microorganisms in a similar manner to that described for 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 applicability of HPP as a kill step for these organisms. Major benefits from the application of HPP to the different food products 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.

It is important to note that the composition of the food product plays an important role in the effectiveness of the HPP treatment against microorganisms, as well as the type of organisms which may be able to grow or survive in the product, and should be carefully considered when evaluating the use of HPP as a kill step for a specific food product (see The NFL's white paper entitled "Validating My High Pressure Process Treatment" for more information).

Regulatory Requirements: The United States Food and Drug Administration (FDA) and United States Department of Agriculture (USDA) each have a number of regulatory requirements which are specifically tailored to address food safety issues associated with foods. These regulations target specific categories of food based upon both the composition of the food and the storage conditions for the food which, as previously mentioned, impact the microorganisms which could be present or survive in the food. Some of these regulations include the following:

- 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)

Consultation with a Process Authority is recommended to help navigate the regulatory requirements for specific food products. However, with the advent of more stringent food safety legislation initiated by the Food Safety Modernization Act (FSMA), validation of HPP used as a kill-step is required in order to make sure that the HPP treatment is in fact at a level of effectiveness to ensure food safety. In the case of HPP, this means that a specific pressure and hold time can be tied to a specific level of reduction of vegetative cells of pathogenic organisms. Specified "critical processing parameters" for HPP treatment of foods by the regulatory agencies include the following:

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

Currently, commercially available HPP products for which HPP has been successfully validated as a kill step include the following:

- Vegetable & Fruits – Juices, salsa, dressing, guacamole
- Meat – Ready to eat meats and poultry
- Seafood – Shellfish and fish products

What The NFL Can Offer

The National Food Lab (The NFL) is a recognized Process Authority with years of experience in the area of process validations. Not only does The NFL routinely conduct validations for conventional thermal processing (retorted canned foods, acidified foods, juice pasteurization), aseptic processing, and packaging equipment, but we have also validated roasting, convection oven, high temperature short time (HTST), and extrusion processes for a variety of different food products, which range 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 are now able to expand our process validation services to include high pressure processing. Combined with our experience as a Process Authority, we can offer clients the complete consulting package to help them determine an appropriate HPP process for a given food product to bring it safely to market.

About The NFL

The National Food Laboratory is a food and beverage consulting and testing firm providing creative, practical and science-based solutions for the following areas: Food Safety and Quality; Product and Process Development; and Sensory and Consumer Research. We create value for our clients by enabling them to develop commercially safe, high quality and great tasting foods and beverages. For more information about The National Food Laboratory, please visit us at www.TheNFL.com.

Authored by: Carrie Ferstl, Ph.D., Manager- Food Safety / Peter Ferstl, Ph.D., Process Engineer-Aseptic

For more information, please contact:
Jena Roberts at RobertsJ@TheNFL.com, 925.551.4205