High Pressure Processing of Foods

EDITORS

Christopher J. Doona • Florence E. Feeherry

FOREWORD BY

C. Patrick Dunne

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IFT Press

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Christopher J. Doona, PhD, serves with distinction as Research Chemist of the Department of Defense (DoD) Combat Feeding Directorate at the US Army Natick Soldier Research, Development, & Engineering Center, with responsibilities for independently and in collaboration with other research scientists conducting, coordinating, and executing new areas of basic and applied research with potential benefits to the military. Dr. Doona's research investigations specialize in novel chemical heating and disinfection technologies, and novel food processing technologies such as ohmic heating, microwaves, and high pressure processing (HPP) for the safety and stability of foods.

Florence E. Feeherry, MS, serves with distinction as Research Microbiologist for the DoD Combat Feeding Directorate at NSRDEC, with responsibilities for independently and in collaboration with other researchers carrying out basic and applied research investigations specializing in the principles of food microbiology to establish the safety of foods stabilized by hurdles or processed with novel technologies such as HPP.

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We also remember an old friend,
who reminds us to always forge ahead;
Persistence & integrity are key,
with challenge comes opportunity.

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FOREWORD

It was with extreme pleasure and appreciation that I accepted the invitation of editors Christopher Doona and Florence "Chickie" Feeherry to write a foreword for *High Pressure Processing of Foods*. All scientists and engineers interested in nonthermal processing technologies will certainly find *High Pressure Processing of Foods* useful and timely, and I am grateful to Chris and Chickie for their dedication in bringing this book to life as an outstanding resource of lasting value, and for their accomplishments in HPP research at the Department of Defense (DoD) Combat Feeding Directorate at the US Army Natick Soldier Research, Development, & Engineering Center (NSRDEC), which also include a collaborative chapter in this impressive volume.

The modern inception of HPP for food processing began in the late 1980s at the University of Delaware with a meeting of great minds: the visionary (Professor and Food Engineer Dan Farkas), the microbiologist (Professor Dallas Hoover), and the well-rounded expert (Professor Dietrich Knorr). Dan Farkas presented a seminar at NSRDEC in 1988 in relation to the use of high pressure for undersea depots for the DeepSea Forward program. The idea of HPP as a food processing technology immediately caught my attention as a biochemist. In 1991, NSRDEC provided funding to begin an important research initiative to concomitantly improve military rations and commercial foods by HPP. This initiative involved Dan Farkas (who had moved to Oregon State University) and Dallas Hoover and led to their landmark paper entitled simply "High Pressure Processing," which appeared in the 2000 supplement to the *Journal of Food Science* (pp. 47–64).

With successful research advances in this program leading the way, NSRDEC assumed greater interest in the development of HPP and provided funding for follow-on projects with my stewardship. Under a Broad Agency Announcement, Professor Bibek Ray (University of

Wyoming) carried out fundamental work on the synergies of HPP and bacteriocins (anti-microbial peptides used as food additives) for the preservation of meats that led to several related publications. Professor Hoover, Dr. Cindy Stewart, myself, and Dr. Anthony Sikes (NSRDEC) collaborated to produce US Patent 6,110,516, entitled "Process for treating foods using saccharide esters and superatmospheric hydrostatic pressure."

I am thankful to the DoD Combat Feeding Directorate – NSRDEC for the uniquely rich opportunity of becoming involved with HPP of foods that has given me the privilege and good fortune of working with a large assembly of talented people from many disciplines for the past 16 years, people whose dedicated efforts have helped move this technology forward from its nascent stages to commercialization. I am especially thankful to the many distinguished scientists and engineers in nonthermal processing for their recognition of my contributions as co-founder (along with Huub Lelieveld of Unilever) of the Institute of Food Technologists' (IFT's) Nonthermal Processing Division and for choosing me to serve as its first chair in 2000. My appreciation extends to a wide network of colleagues who supported the 2005 IFT Myron Solberg Award I received, honoring an IFT member for providing leadership and excellence in the establishment, successful development, and continuation of an industry/government/academia cooperative organization. In 2005, Dr. Edmund Ting of Avure Technologies (formerly part of Flow International) and I received a Federal Laboratory Consortium Award for Excellence in Technology Transfer for High-Pressure Food Processing to Provide Increased Safety and Quality. The basis for this award was the commercialization of HPP that was carried out under the auspices of the Army's Dual-Use Science and Technology program dedicated to simultaneously meeting the demands of the consumer marketplace and the military for expanding variety and improving the quality of shelf-stable combat rations for food products containing whole muscle meats, eggs, potato, and pasta products. I am thankful to the Army for their appreciation bestowed through numerous awards and citations for my involvement in efforts striving to improve the variety, quality, and nutritive value of operational military rations through the uses of HPP.

While the possible applications of HPP are only just beginning to be realized, nonthermal processing of foods in general, and HPP in particular, will remain an exciting and inspiring field of food science research that will surely be emphasized in finding solutions to new

challenges in food preservation and safety in the increasingly global, complex supply chain and marketplace for the twenty-first century and in the production of fresher, safe foods for all consumers to enjoy.

C. Patrick Dunne
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PROLOGUE

I do not mean to say we are bound to follow implicitly in whatever our fathers did. To do so, would be to discard all the lights of current experience—to reject all progress—all improvement. What I do say is, that if we would supplant the opinions and policy of our fathers in any case, we should do so upon evidence so conclusive, and argument so clear, that even their great authority, fairly considered and weighed, cannot stand.

Abraham Lincoln
Cooper Union Address
February 27, 1860
New York

PREFACE

High pressure processing (HPP) is a leading nonthermal food processing technology that is often cited as a major technological innovation in food preservation. While it is too early to assure its place in food preservation history among breakthroughs such as Appert's discovery of canning, Pasteur and Bernard's use of heat to kill foodborne microorganisms, or Birdseye's development of frozen foods, HPP has emerged as a viable commercial alternative for the pasteurization of value-added fruits, vegetables, meat, and seafood products that are safely enjoyed by today's consumer. HPP also has the capacity to inactivate *Clostridium botulinum* and other bacterial spores, and the food industry, government agencies, and academia are intensifying their efforts to develop HPP methods for inactivating foodborne bacterial spores in foods. Such products will feature more fresh-like character and improved quality attributes for the consumer and might well be expected to significantly impact the multi-billion-dollar market for low-acid, shelf-stable canned foods. *High Pressure Processing of Foods* is intended to capture the current state of scientific knowledge regarding the use of HPP to inactivate bacterial spores as a starting point for future research that will lead to the development of commercially sterile low-acid foods.

High Pressure Processing of Foods culminates to date the scientific advances of leading experts in academia, industry, and government agencies exploring microbial inactivation for the safe preservation of foods by HPP. Patterson et al. (chapter 1) provide a historical introduction to HPP; then in a broad sense, Setlow (chapter 2), Al-Holy et al. (chapter 3), and Van Opstal et al. (chapter 4) use molecular techniques to explore various aspects of the mechanisms of spore germination and inactivation; and Gänzle et al. (chapter 5) and Chung et al. (chapter 7) cover the influence of various processing parameters (e.g., high pressure, temperature, food matrix properties, and the presence of

anti-microbial or sensitizing compounds) on microbial inactivation. Since the perspective of the consumer is critical for the commercial success of HPP-treated foods, Lau and Turek (from Kraft Global Foods; chapter 9) and Wright et al. (chapter 10) incorporate consumer analysis of HPP-treated foods in their chapters. Brul et al. (Unilever Food and Health Research Institute; chapter 8) present future models for food quality assurance systems. Doona et al. (chapter 6) use nonlinear mathematical models to characterize and predict microbial inactivation, and Ting (chapter 11) discusses controlling temperature with HPP equipment. It has been our pleasure and privilege to work with this collection of esteemed scientists.

HPP is an important avenue of present and future research at DoD Combat Feeding Directorate – US Army Natick Soldier Research, Development, & Engineering Center (NSRDEC). Our interest in HPP originated from the application of pressure in inorganic reaction kinetics, which later melded with research involving intrinsic chemical markers and pathogen modeling. Presently, our HPP research involves the application of the Quasi-chemical kinetics model for a more complete understanding of bacterial spore inactivation. From these interests, we conceived a progression of high-profile, cutting-edge symposia at IFT annual meetings (co-sponsored by the Nonthermal Processing Division and the Food Microbiology Division) that formed the foundation for *High Pressure Processing of Foods*.

What better place to have begun this journey than Chicago, with the first symposium, "Science-Based Applications of High Pressure Processing in the Food Industry," so near in proximity to the stockyards and meat packing companies that were described in Upton Sinclair's *The Jungle*? Publication of *The Jungle* led to President Theodore Roosevelt's support of the 1906 Pure Food and Drug Act and Meat Inspection Act to control the safety of the nation's food supply. The second symposium, "Inactivating Pathogens, Parasites, and Viruses Using High Pressure Processing and Other Emerging Technologies," in Las Vegas broadened the knowledge base to include other types of organisms and additional alternative food processing technologies. The third symposium, "Mechanisms and Modeling of Bacterial Spore Inactivation by High Pressure Processing," and held in pre-Katrina New Orleans, addressed the inactivation of bacterial spores and provided the primary driving force for the development of *High Pressure Processing of Foods*.

With Lincoln's rationale, as quoted above, serving as a metaphor describing scientific advancement, let us assert that *High Pressure Processing of Foods* conveys the experiences of esteemed scientists who demonstrate they were not bound simply to follow implicitly in their pursuit of scientific knowledge, but set out on bold new paths of scientific exploration and innovation, with their progress lighting the way toward the commercialization of shelf-stable foods. It is our hope that research efforts such as these shall provide a basis for future scientific evidence so conclusive and argument so clear that sometime soon—in the beginning of the second century since publication of *The Jungle* and passage of the 1906 Pure Food and Drug Act—the use of HPP will become viable for the commercial sterilization of high quality, safe, low-acid foods.

Christopher J. Doona
Florence E. Feeherry

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