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Ultra High Pressure Treatments of Foods

Edited by
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and
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Dedicated to Rutger, Anna, Fanny, and Hannah

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Preface

During the past decade, consumer demand for convenient, fresh-like, safe, high-quality food products has grown. The food industry has responded by applying a number of new technologies including high hydrostatic pressure for food processing and preservation. In addition, food scientists have demonstrated the feasibility of industrial-scale high pressure processing. This technology is of specific interest to the food industry because it provides an attractive alternative to conventional methods of thermal processing, which often produce undesirable changes in foods and hamper the balance between high quality (color, flavor, and functionality) and safety. In addition, it offers opportunities for creating new ingredients and products because of the specific actions of high pressure on biological materials and food constituents. It allows food scientists to redesign existing processes and to create entirely new ones using high pressure technology alone or in combination with conventional processes (e.g., pressure-temperature combinations).

Researchers have investigated high pressure processing for the past century. Scientists such as Hite and Bridgman did pioneering work at the turn of the 20th century. Then during the 1980s and 1990s, there was a large effort to investigate the effects of high pressure on biological materials, particularly foods. The initial research activities in the late 1980s and early 1990s focused on exploratory activities in the food area. However, researchers recognized the need for a more scientific approach to understand the benefits of high pressure and the interaction of high pressure with biological materials. To do this, they initiated a true food engineering approach that allowed design, validation, and optimization of these processes. This approach has led to research activities that focus on the mechanistic and kinetic effects of high pressure on biological materials and the synergistic and antagonistic effects when high pressure is applied in combination with other extrinsic and intrinsic variables. Research areas have included aspects of food safety and food quality, food structure engineering, phase transitions in foods, and predictive modeling. This research has attracted extensive funding from both private and public sources and has resulted in approximately 750 scientific publications and industrial applications in Japan, France, The United

States, and Spain. Commercially available products that are processed using high pressure include fruit- and vegetable-based products, fruit juices, meat products, seafood products, and rice-based products. Today, high pressure processing is available for use on an industrial scale by the food industry.

The exciting developments sketched above have provided us with the incentive to write this book. We have brought together key players involved in research on high pressure treatment of foods to explain state-of-the-art research and technologies, recent issues, and future challenges in a manner that is accessible to everyone in the field. The book has been organized into three parts: the fundamental aspects of treating foods with high pressure, the effects of high pressure on different food attributes, and the current status of industrial-scale high pressure applications.

From this book it should become clear that tremendous advances have been achieved over the past years. This compilation of knowledge now even allows food scientists to share knowledge and transfer technologies from the area of food science to other fields in applied biological sciences. At the same time, researchers still face a number of challenges ahead. For example, researchers hope to develop more insight into the effect of high pressure processing on nutrients and nutritional aspects of foods (such as toxins and allergens), to identify indicator organisms that can be used in a standard way to assess the impact of high pressure processing, and to create unique or improved functionality by using scientific insight to combine raw materials and processing technologies within the constraints of food safety, environmental impact, and other social and economic factors. Expected benefits for the consumer include the availability of gently processed, fresh-like, safe products with high sensory and nutritional quality and optimum physicochemical properties. We sincerely hope that this book contributes to further research on the development of safe and healthy foods that comply with consumer demands, industrial needs, and the concerns of authorities.

M. Hendrickx and D. Knorr

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We would like to use this opportunity to thank a number of people who have made high-quality research on high pressure treatment of foods possible in the last decade. We hereby acknowledge the European Commission (EC) for its support of these research efforts since 1992. All contributions to this book are based on and made by key scientists who were involved in EC-funded projects—particularly Project FAIR-CT96-1113 ("High Pressure Treatment of Liquid Foods and Derived Products") and Project FAIR-CT96-1175 ("Combined High Pressure Thermal Treatments of Foods: A Kinetic Approach to Safety and Quality Evaluation"). The cooperation of many colleagues in the field, especially scientists from different laboratories and EC–funded projects who contributed to individual chapters of this book, and the cooperation of EC Scientific Officers, L. Breslin and X. Goenaga, have been an exciting and rewarding experience. The young scientists who are involved in these projects and conducting doctoral work on issues related to high pressure treatment of food as well as the scientists involved in European mobility programs should receive specific attention. We also wish to acknowledge the cooperation of Mary Anne Langdon, Senior Developmental Editor of Aspen Publishers, Inc.; our scientific colleagues for their contributions; and finally our young, highly professional coworkers involved in high pressure research who create the attraction and reward for working in our academic profession.

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Part I

Fundamental Aspects of Treating Foods with High Pressure

CHAPTER 1

The Evolution of High Pressure Processing of Foods

Grahame W. Gould

INTRODUCTION

With few exceptions, foods lose quality at some rate or other following harvest, slaughter, or manufacture. The nature of the quality loss is dependent on the type of food; its composition, formulation, and processing; and conditions of storage. The most important quality-loss reactions, and thus the most important targets for preservation, include microbiological, enzymatic, chemical, and physical reactions (see Table 1–1) (Gould, 1989).

When preservation fails, the consequences range broadly—from extreme hazard (e.g., when toxicogenic microorganisms are present and able to multiply), to economically important spoilage (which results in loss of valuable products), to relatively trivial loss of quality (e.g., changes in color, flavor, or texture). The most serious forms of quality loss are those that result from the survival and/or growth of infectious pathogenic bacteria (*Salmonella* species, *Campylobacter jejuni* and *coli*, enteropathogenic and verocytotoxigenic [verotoxin producing, toxic to cells] strains of *Escherichia coli*, *Listeria monocytogenes*, *Yersinia enterocolitica*, *Vibrio*

Table 1–1 Quality-Loss Reactions of Foods

Microbiological	*Enzymatic*	*Chemical*	*Physical*
• Growth of toxinogenic microorganisms	• Hydrolytic reactions catalyzed by lipases, proteases, etc.	• Oxidative rancidity	• Mass transfer, movement of low-molecular-weight compounds
• Growth or presence of infective microorganisms	• Rancidity catalyzed by lipoxygenases	• Oxidative and reductive discoloration	• Loss of crisp texture
• Growth of spoilage microorganisms	• Enzymatic browning	• Nonenzymatic browning	• Loss of flavors
	• Destruction of nutrients	• Destruction of nutrients	• Freeze damage

parahaemolyticus, *Aeromonas hydrophila*, *Plesiomonas shigelloides*, enterotoxin-producing strains of *Bacillus cereus*, *Clostridium perfringens*) or the multiplication in foods of toxinogenic bacteria (*Staphylococcus aureus*, emetic toxin-producing strains of *Bacillus cereus*, *Clostridium botulinum*) (Lund et al., 2000).

A limited range of techniques are available to combat pathogenic and spoilage microorganisms and to delay other types of quality loss. Most of the antimicrobial techniques (e.g., chill storage, frozen storage, drying, curing, conserving, vacuum packing, modified atmosphere packing, acidifying, fermenting, adding preservatives) act by inhibiting, slowing down, or preventing the growth of microorganisms. In contrast, few available techniques act primarily by inactivating microorganisms in foods (e.g., heat pasteurization; heat sterilization; and, to a much smaller extent, irradiation). Inactivation techniques are fundamentally more desirable than inhibitory ones, particularly if the aim is to reduce the risks of food poisoning. Elimination of pathogens from foods is more likely to be an effective intervention than inhibition of growth, which assumes some contamination in the first place. Thus, it is encouraging that most of the techniques that are coming into use or are under development act by inactivation (e.g., high hydrostatic pressure, electroporation, manothermosonication, high-intensity laser and noncoherent light pulses, high-strength magnetic field pulses, addition of bacteriolytic enzymes, addition of bacteriocins, and surface decontamination techniques for carcasses).

Against this background, consumers in many countries are demanding foods that are more convenient (i.e., easier to store and prepare); fresher (e.g., chill-stored); more natural; and therefore not as heavily processed (e.g., processed with less heat), less heavily preserved (e.g., preserved with less acid, salt, and sugar), and less reliant on additive preservatives (e.g., sulfite, nitrite, sorbate, propionate, benzoate, and parabens) than foods that have previously been available. A potential consequence of these trends is a reduction in the intrinsic preservation of foods and in their stability and safety. As the food industry reacts to these trends (see Exhibit 1–1), it is important that new technologies retain or improve upon the effectiveness of preservation and ensure safety that might otherwise be lost.

The application of physical techniques, including high pressure, for food preservation has the potential to produce foods that meet many of these consumer demands. Physical techniques are based on the inactivation of microorganisms rather than on their inhibition, the techniques are essentially additive-free, they are mostly nonthermal or involve reduced heat treatments, they have minimal deleterious effects on product quality, and they are usually perceived as "natural."

PRESERVATION TECHNOLOGIES

Traditional Technologies

Of the limited range of preservation technologies currently employed to preserve foods, some (such as drying) have a long history of use, while others (such as modified atmosphere packaging) are recent (see Exhibit 1–2).