Packaging for Nonthermal Processing of Food

EDITED BY

Jung H. Han, Ph.D.

Department of Food Science

University of Manitoba

Winnipeg, Manitoba

Blackwell Publishing

IFT PRESS

Packaging for Nonthermal Processing of Food

The *IFT Press* series reflects the mission of the Institute of Food Technologists—advancing the science and technology of food through the exchange of knowledge. Developed in partnership with Blackwell Publishing, *IFT Press* books serve as leading-edge handbooks for industrial application and reference and as essential texts for academic programs. Crafted through rigorous peer review and meticulous research, *IFT Press* publications represent the latest, most significant resources available to food scientists and related agriculture professionals worldwide.

Blackwell Publishing

Packaging for Nonthermal Processing of Food

EDITED BY

Jung H. Han, Ph.D.

Department of Food Science

University of Manitoba

Winnipeg, Manitoba

Blackwell Publishing

IFT Press

Dr. Jung H. Han is an assistant professor of dairy/food processing and packaging at the University of Manitoba, Canada. He is a professional member of the Institute of Food Technologists (IFT). He is an associate editor of *Journal of Food Science* and an editorial board member of *Food Research International*. Dr. Han has served as secretary, chair-elect, and chair of the Food Packaging Division of IFT. He is editor of *Innovations in Food Packaging*.

Blackwell Publishing Professional
2121 State Avenue, Ames, Iowa 50014, USA

Orders: 1-800-862-6657
Office: 1-515-292-0140
Fax: 1-515-292-3348
Web site: www.blackwellprofessional.com

Blackwell Publishing Ltd
9600 Garsington Road, Oxford OX4 2DQ, UK
Tel.: +44 (0)1865 776868

Blackwell Publishing Asia
550 Swanston Street, Carlton, Victoria 3053, Australia
Tel.: +61 (0)3 8359 1011

Cover image: E-beam unit for packaged frozen meats (*left*) and pulsed UV/light emission for liquid foods (*right*).

First edition, 2007

Library of Congress Cataloging-in-Publication Data

Packaging for nonthermal processing of food / edited by Jung H. Han.—1st ed.
p. cm.—(IFT Press series)
Includes bibliographical references and index.
ISBN-13: 978-0-8138-1944-0 (alk. paper)
ISBN-10: 0-8138-1944-X (alk. paper)
1. Food—Packaging. I. Han, Jung H.

TP374.P328 2007
664′.09—dc22

2006036529

The last digit is the print number: 9 8 7 6 5 4 3 2 1

Titles in the *IFT Press* series

- *Accelerating New Food Product Design and Development* (Jacqueline H.P. Beckley, Elizabeth J. Topp, M. Michele Foley, J. C. Huang, and Witoon Prinyawiwatkul)
- *Biofilms in the Food Environment* (Hans P. Blaschek, Hua Wang, and Meredith E. Agle)
- *Food Irradiation Research and Technology* (Christopher H. Sommers and Xuetong Fan)
- *Food Risk and Crisis Communication* (Anthony O. Flood and Christine M. Bruhn)
- *Foodborne Pathogens in the Food Processing Environment: Sources, Detection and Control* (Sadhana Ravishankar and Vijay K. Juneja)
- *High Pressure Processing of Foods* (Christopher J. Doona, C. Patrick Dunne, and Florence E. Feeherry)
- *Hydrocolloids in Food Processing* (Thomas R. Laaman)
- *Microbiology and Technology of Fermented Foods* (Robert W. Hutkins)
- *Multivariate and Probabilistic Analyses of Sensory Science Problems* (Jean-Francois Meullenet, Rui Xiong, and Chris Findlay)
- *Nondestructive Testing of Food Quality* (Joseph Irudayaraj and Christoph Reh)
- *Nonthermal Processing Technologies for Food* (Howard Q. Zhang, Gustavo V. Barbosa-Canovas, V. M. Balasubramaniam, Editors; C. Patrick Dunne, Daniel F. Farkas, and James T. C. Yuan, Associate Editors)
- *Nutraceuticals, Glycemic Health and Diabetes* (Vijai K. Pasupuleti and James W. Anderson)
- *Packaging for Nonthermal Processing of Food* (J. H. Han)
- *Preharvest and Postharvest Food Safety: Contemporary Issues and Future Directions* (Ross C. Beier, Suresh D. Pillai, and Timothy D. Phillips, Editors; Richard L. Ziprin, Associate Editor)
- *Processing and Nutrition of Fats and Oils* (Ernesto Hernandez, Monjur Hossen, and Afaf Kamal-Eldin)
- *Regulation of Functional Foods and Nutraceuticals: A Global Perspective* (Clare M. Hasler)
- *Sensory and Consumer Research in Food Product Design and Development* (Howard R. Moskowitz, Jacqueline H. Beckley, and Anna V. A. Resurreccion)
- *Thermal Processing of Foods: Control and Automation* (K. P. Sandeep)
- *Water Activity in Foods: Fundamentals and Applications* (Gustavo V. Barbosa-Canovas, Anthony J. Fontana Jr., Shelly J. Schmidt, and Theodore P. Labuza)
- *Whey Processing, Functionality and Health Benefits* (Charles Onwulata and Peter Huth)

CONTENTS

CONTRIBUTORS

Aaron L. Brody
Packaging/Brody, Inc., P.O. Box 956187, Duluth, GA 30096, USA

Jung H. Han
Department of Food Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T2N2

A. R. de Jong
TNO Quality of Life, Utrechtseweg 48, P.O. Box 360, Zeist, The Netherlands

Arnold W. Hydamaka
Department of Food Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T2N2

Joan C. Junkus
Department of Finance, DePaul University, 1 East Jackson Boulevard, Chicago, IL 60604, USA

Vanee Komolprasert
Office of Food Additive Safety, Center for Food Safety and Applied Nutrition, US Food and Drug Administration, 5100 Paint Branch Parkway, College Park, MD 20740, USA

John M. Krochta
Department of Food Science and Technology, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA

Seacheol Min
Department of Food Science and Technology, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA

M. A. H. Rijk
TNO Quality of Life, Utrechtseweg 48, P.O. Box 360, Zeist, The Netherlands

Kevin C. Spencer
Spencer Consulting, 424 Selborne Road, Riverside, IL 60546, USA

W. D. van Dongen
TNO Quality of Life, Utrechtseweg 48, P.O. Box 360, Zeist, The Netherlands

James T. C. Yuan
Food Safety and Healthcare Applications, American Air Liquide, Inc., 5230 S. East Avenue, Countryside, IL 60525, USA

Q. Howard Zhang
Food Safety Intervention Technologies Research Unit, United State Department of Agriculture, Eastern Regional Research Center, 600 East Mermaid Lane, Wyndmoor, PA 19038, USA

Yicheng Zong
Department of Food Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T2N2

PREFACE

During 2005 IFT (Institute of Food Technologists) Annual Meeting (July 15–20, 2005, New Orleans, Louisiana, USA), Food Packaging Division and Nonthermal Processing Division co-sponsored two symposia under the titles of "Advances in Packaging Technology Required for Implementation on Novel Food Processes" and "Active Packaging for Nonthermal Processing." I was privileged to host these symposia as a Chair-elect of Food Packaging Division with Dr. James Yuan who was the Chair of Nonthermal Processing Division. Both symposia were successful as they provided valuable opportunities for general participants and invited speakers to share their scientific interests and practical experiences. I recognized instantly that the papers of these symposia were valuable and should be published to provide current information in a stable and concrete form. I thank IFT for accepting my proposal to contribute a book to the IFT Press Series.

Nonthermally processed food products have unique quality parameters compared to conventional food products processed by thermal treatment. Some of these new quality parameters might not be essential for the thermal processes because they were new parameters which used not to be considered for conventional thermal processes. Therefore, nonthermal processes have new requirements of processing and packaging to protect the quality of nonthermally processed foods. The conventional packaging design and materials should be changed accordingly for nonthermally processed foods. Critical protective barrier properties of packaging materials must remain to prevent chemical, physical, or microbial degradation of the contents after nonthermal processing. This book discusses the need to understand the details of process, product, and packaging material interactively for the selection of commercial products that are ready for extended shelf life and consumer testing. In addition, the critical role of information carried by packaging materials is discussed to make a new product produced by a novel process attractive to consumers.

This book could not be possible without the contribution of the chapter authors. My special thanks goes to IFT staff and Blackwell Publishing staff for initiating and completing the publication processes.

Jung H. Han, Ph.D.

Packaging for Nonthermal Processing of Food

Chapter 1

PACKAGING FOR NONTHERMALLY PROCESSED FOODS

Jung H. Han

Introduction

Since nonthermally processed food products have unique quality parameters when compared with food products processed by conventional thermal treatment, the packaging design and materials used for the nonthermally processed food products should be changed accordingly. Advances in packaging technology are required for implementation in novel food processes. A number of novel thermal and nonthermal processing methods are actively undergoing research and development in industrial, academic, and government laboratories. A key step that now needs addressing is finding the best packaging materials for commodities processed by nonthermal procedures such as high pressure, pulsed electric fields, ultraviolet (UV), irradiation, microfiltration, active packaging (oxygen scavenging or antimicrobial packaging), or biopreservation (antagonistic culture), which preserve the benefits of improved product quality imparted by these emerging preservation technologies. Critical protective barrier properties of packaging materials must be preserved to prevent chemical, physical, or microbial degradation of contents after nonthermal processing. This book discusses the need to understand details of process, product, and packaging material interactively for selecting commercial products that are ready for extended shelf life and consumer testing. In addition, the critical role of information carried by packaging materials in making a new product produced by a novel process attractive to consumers is discussed.

Nonthermal Processing of Foods

Food processors traditionally utilized thermal processes, that is, cooking, blanching, pasteurization, and sterilization, to inactivate microorganisms, enzymes, and other chemical reactions in food materials as well as to cook raw foods for extending the period of desirable quality and safety level. Because of numerous practical applications of heat treatments with various types of foods, from prehistoric age until today, many chemical and physical changes taking place in foods after the thermal process have been understood. Not only the changes in the nature of food products after thermal processes, but also the chemical interactions between thermally processed foods and common food packaging materials are well identified.

Characteristics of Nonthermal Processes

Nonthermal processes are food preservation methods to inactivate spoilage and pathogenic microorganisms at temperatures below those used for thermal pasteurization without significant changes to flavor, color, taste, nutrients, and functionalities (Min and Zhang 2005). They involve the use of high electric power, high pressure, high intensity of light/radiation, microfilters, chemicals, or antagonistic cultures. Electric power, pressure, light emission, radiation dose, microsieves, and/or natural chemicals have not been used traditionally for food preservation. Compared with heat treatment, these nonthermal treatments are less studied for their effects on chemical, physical, and microbiological changes in food products. The quality attributes of nonthermally treated foods are obviously different from those of thermally processed food products. Moreover, the chemical reactions involved in food quality deterioration following nonthermal treatment would be different from the reactions in heat-treated food products (Figures 1.1–1.3).

Among many alternative nonthermal pasteurization treatments, pulsed electric field and high-pressure processing are the most investigated treatments despite their short history compared with other treatments such as irradiation and chemical treatments (Butz and Tauscher 2002). Both technologies allow the inactivation of vegetable microorganisms but fail to destroy spores when they are applied alone (Devlieghere, Vermeiren, and Debevere 2004). Because of these relatively

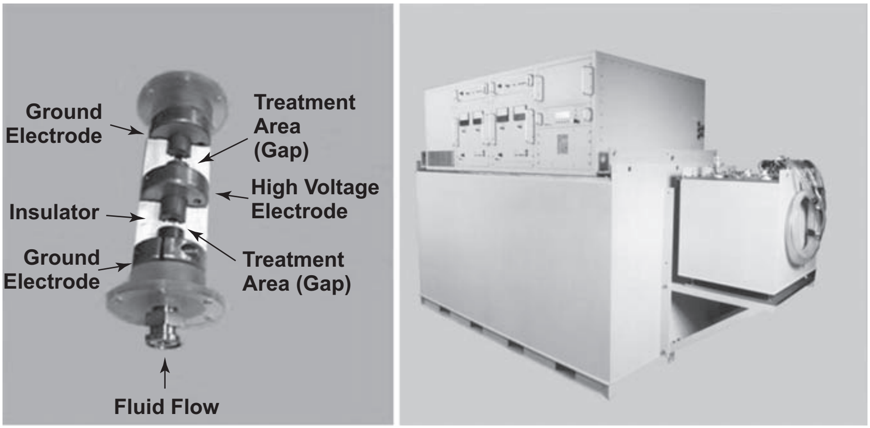

Figure 1.1. Pulsed electric field chamber structure and exterior of processing unit (courtesy of Diversified Technologies, Inc., and Ohio State University).

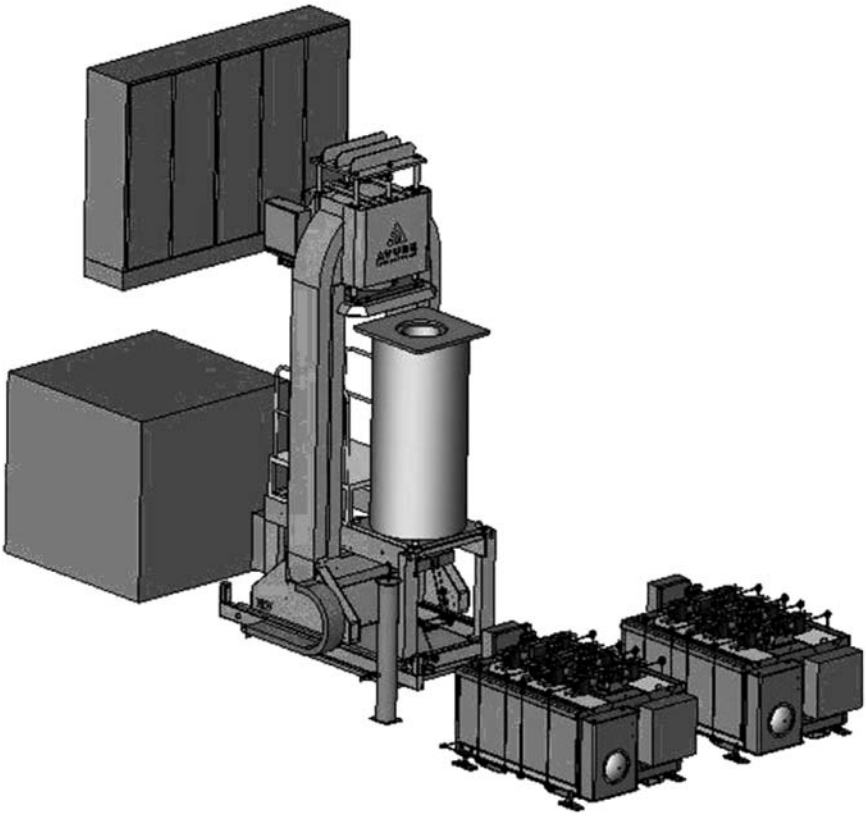

Figure 1.2. High-pressure processing system. Food will be inserted into the cylindrical pressure vessel (courtesy of Avure Technologies, Inc.).

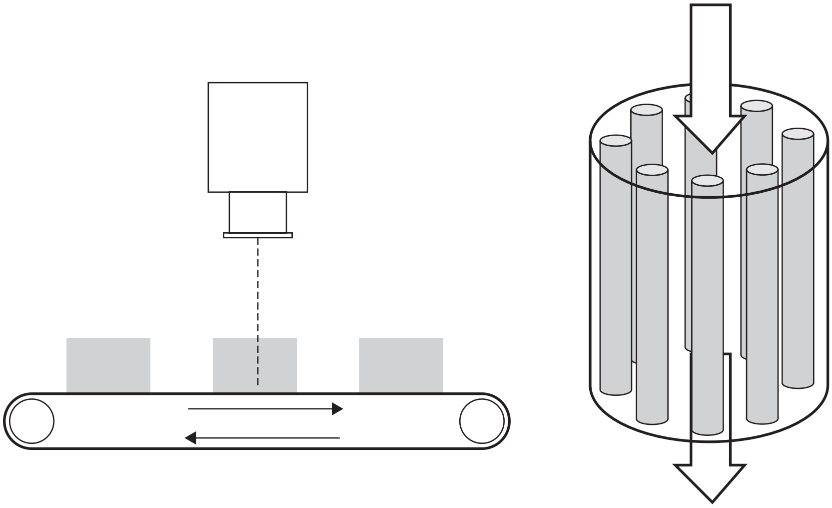

Figure 1.3. e-beam unit for packaged frozen meats (left) and pulsed UV/light emission for liquid foods (right). e-beam radiates on the packaged frozen case meats, and light illuminates from light tubes to liquid foods inside the chamber.

mild conditions of nonthermal processes compared with heat pasteurization, consumers may be easily satisfied by the more fresh-like characteristics, minimized degradation of nutrients, and the perception of high quality (Butz and Tauscher 2002; Min and Zhang 2005) (Table 1.1).

Concerns of Nonthermal Processing

Bacillus stearothermophilus has been used as an index microorganism for the standard evaluation of thermal processes. For other specific foods with extreme conditions of pH, water activity, and solute concentration, other spore-forming bacteria have been used to verify adequate heat treatment. There are many but standardized data tables of the values of *D* (time) and *Z* (temperature) for these standard microorganisms, and the effect of these thermal treatments is evaluated based on their *F* value. However, owing to the diverged resistance of microorganisms to various nonthermal processes such as electric field, pressure, irradiation, or chemicals, it is impossible to identify the appropriate standard microorganisms and their quantitative resistance index to the nonthermal processes. Various scientific studies have been

Table 1.1. New nonthermal food-processing methods (reprinted from Butz and Tauscher 2002, p. 280, with permission from Elsevier Ltd.).

Process	Description	Critical Factors	Mechanism of Inactivation	Status
Ultraviolet (UV) light/pulsed light	UV radiant exposure, at least 400 J/m^2	Transmissivity of the product, the geometry, the power, wavelength, and arrangement of light source(s), and the product flow profile	DNA mutations induced by DNA absorption of the UV light	Used for disinfection of water supplies and food contact surfaces
	Intense and short-duration pulses of broad spectrum (ultraviolet to the near-infrared region)			
Ultrasound	Energy generated by sound waves of 20,000 Hz or more	The heterogeneous and protective nature of food (e.g., inclusion of particulates) severely curtails the singular use of ultrasound for preservation	Intracellular cavitation (micromechanical shocks that disrupt cellular, structural, and functional components—cell lysis)	Combination with, for example, heat and pressure has certain potential
Oscillating magnetic field (OMF)	Subjecting food sealed in plastic bags to 1–100 OMF pulses (5–500 kHz, 0–50°C, 25–100 ms)	Consistent results concerning the efficacy of this method are needed	Controversial results on the effects of magnetic fields on microbial populations	Application at the moment not considered

(*continued*)

Table 1.1. New nonthermal food-processing methods (reprinted from Butz and Tauscher 2002, p. 280, with permission from Elsevier Ltd.). (*Continued*)

Process	Description	Critical Factors	Mechanism of Inactivation	Status
Pulsed electric field (PEF)	High-voltage pulses to foods between two electrodes (<1 s; 20–80 kV/cm; exponentially decaying, square wave, bipolar, or oscillatory pulses at ambient, subambient, or above-ambient temperatures)	Electric field intensity, pulse width, treatment time, temperature, pulse wave shapes, type, concentration, and growth stage of microorganism, pH, antimicrobials, conductivity, and medium ionic strength	Most theories studied are electrical breakdown and electroporation	Different laboratory- and pilot-scale treatment chambers designed and used for foods; only two industrial-scale PEF systems available
High-pressure processing	Liquid/solid foods, with or without packaging (100–800 MPa, <0°C to >100°C, from a few seconds to >20 min instantaneously and uniformly throughout a mass of food independent of size, shape, and food composition)	Pressure, time at pressure, temperature (including adiabatic heating), pH, and composition	Denaturation of enzymes and proteins, breakdown of biological membranes, and cellular mass transfer affected	In use since 1990 (Japan, United States, France, and Spain); current pressure processes include batch and semicontinuous systems

conducted to determine the resistance of significant microorganisms to nonthermally processed foods. For example, there are many studies by civil and environmental engineers on the resistance of *Escherichia coli* or other bacteria to UV radiation treatments in drinking water. These researches dealt with selected microorganisms and determined their resistance (*D* and *Z* values for time and intensity, respectively) to UV light. However, they did not suggest standard target microorganisms for UV light treatment, like the *B. stearothermophilus* for heat treatment, because their projects were oriented to inactivating coliform bacteria and parasites.

Nonthermal processes can be applied as a part of combined processes with other nonthermal processes, heat treatments, or chemical treatments. In these combinations of multiple processes, it is harder to select the target microorganism as a standard because the other combined processes affect the resistance of the target microorganisms to the nonthermal processes. However, the effects of these nonthermal processes on microbial inactivation would be increased synergistically with other treatments by maintaining fresh-like taste and retaining color and nutrients of foods.

Besides these technical aspects of nonthermal processes, there are more significant nonscientific factors such as consumers' acceptance of the new technologies, which also govern the commercialization of nonthermal processes strongly. Since food is a critical consumer product, applying any new technology that consumers are not familiar with, regardless of the positive results of scientific risk assessment, is a very sensitive issue.

Official permission from governmental regulatory agencies to use the new technology is one of the requirements for the commercialization of new nonthermal processes, which can also be considered as a partially nonscientific parameter. Since food-related legislation process is very political, the regulatory issues of the permission to use any nonthermal process are also political. Food industry, regulatory agencies, consumer groups, and nonthermal equipment industries may have different voices to the same issue. Furthermore, there are not enough scientific data and results to provide one solution to these diverged parties of interests. Therefore, it is very important to identify the current development status of technology commercialization and for scientific societies and academic institutes to provide a fair milestone to these interest groups.

Nonthermal food processes can substitute conventional heat treatment, at least partially, depending on the nature of commodities or foods. The use of nonthermal processes for food preservation will become more popular in the near future. However, the complexity of scientific and nonscientific parameters could influence the successful utilization of these nonthermal processes. This complexity can be simplified by tight communication and collaboration between various interest groups.

Food Packaging

Roles of Food Packaging Systems

Food is packaged for storage, preservation, and protection traditionally for a long time. These three are the basic functions of food packaging that are still required today for better maintenance of quality and handling of foods. In addition to these primary functions of food packaging, more superficial functions are required for food marketing, distribution, and consumer-related issues, which are to provide required information, handling and dispensing convenience, sales promotion, and stock management. No matter what new fancy function of packaging is explored, the first priority should be serving the basic functions of food packaging.

Generally, the main goal of food packaging is to maintain the quality of packaged foods during distribution. However, following the evolution of modern society and lifestyle, the significance of several functions of packaging is also shifting from one aspect to another. There is a trend of changes in the priority of these functions with time and social circumstances. The distribution of priority of each packaging function is highly dependent on the commodities and, therefore, the properties of packaged foods. Owing to cost-saving high-quality packaging materials, the basic functions of packaging materials and systems are not considered as the most significant functions. Instead, the importance of superficial functions becomes emphasized when a new food package is designed. The major functions of food packaging have moved from containment, preservation, and protection to convenience and sales promotion, which indicates that the role of food packaging is shifting from technical functions to socioeconomic functions.

After the tragedy of September 11, 2001, a new critical function appears to be the top priority of food packaging purpose: safety and security. More functions that could secure the integrity of packaging are considered as very important roles of packaging, including tamper-evidence packaging, antimicrobial packaging, freshness indicator, time-temperature integrator, and electronic coding system.

The fast development of nonthermal processing systems is another factor that affects the changing trends in the functions of food packaging. Most food packaging materials and systems have been designed for fresh produce, fresh meats, or heat-processed (i.e., cooked) foods. The commercialization of a newly developed nonthermal processing system essentially requires deep research on the packaging material properties and the interactions between the packaging materials and nonthermally processed foods. The packaging for nonthermally processed foods may necessitate extra functions of packaging for successful commercialization.

Packaging for Nonthermal Processing

Food products and packaging materials interact with each other. These interactions include the migration of packaging ingredients into food products, absorption of hydrophobic food ingredients such as flavors and colorants into packaging structures, and the oxidative reactions of residual sanitizers used for packaging surface disinfection with contacted food surfaces.

Conventional food manufacturing processes use high temperature for pasteurization just before or after the food products are packaged. Special considerations of the effect of high temperature on the physical and chemical properties of packaging materials are essentially required. Packaging material should have strong resistance to the thermal effect. This resistance may be determined by phase-transition temperature, elastic modulus, physical strength, and barrier properties with response to the temperature of the thermal process. For thermal processing, the heat resistance of various microorganisms has been determined, and the effects of thermal process on the survival of the microorganisms have been evaluated by thermal death time, F value. Therefore, the changes in packaging material characteristics because of heat should be minimized with this F value condition. Thermal