ASEPTIC PROCESSING AND PACKAGING OF FOOD PRODUCTS

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DEDICATION

This book is humbly dedicated to all my former colleagues who have valiantly pursued investigations into the scientific basis necessary to establish the safety of aseptic processing and packaging, to countless others at home and abroad whose warm friendship the author has enjoyed over many years and to whom grateful thanks are expressed for their valuable contributions, and to my wife Margaret and family Christopher, Martin, Giles and Sarah, for their continual support and tolerance.

PREFACE

This book is concerned with the development of a specific process used for the long-term preservation of food products which basically involves two separate sterilization operations, the one for the food product and the other for the packaging material and the filling of the container with the food under aseptic conditions. Asepsis is achieved by excluding all spoilage or food poisoning micro-organisms from the system using a variety of decontamination techniques.

It is written from the point-of-view of the food process engineer whose role is to design, construct and operate food processing equipment which will produce food of acceptable quality and free from public health hazard. The engineering approach requires a quantitative analysis of the handling and treatment of food products from the inlet to the outlet of the process and particular attention has been paid to scientific principles which are required to achieve these objectives. In particular the food process engineer will be concerned with establishing the type of equipment required and assessing its performance in accomplishing the requirement of flowrate, heat transfer, scheduled process and other requirements. Establishing the necessary production and operating conditions are of primary importance since these lead to compilation of operating manuals, codes of practice documents and good manufacturing practice guidelines. These all require careful application of the principles of hygienic design, hazard analysis, operational research and environmental protection.

The sequence of the chapters attempts to follow the course of the food product as it passes through the various pieces of equipment, hence the sterilization of the food is dealt with first followed by a consideration of packaging materials and their requirements and finally the

filling and dealing operations and the characteristics of the final packaged product.

One of the main objectives of the author has been to examine the vast amount of information which has accumulated in the published literature and to attempt to extract and classify it in such a way that the process engineer will be able to find the detail required for the various parts of the overall design. This should also be of use to those who are designing individual pieces of equipment, e.g. pumps, mixers and other devices; equipment manufacturers will find the special requirements for the application of their equipment to the needs of the food industry. Successful design of processing equipment is essentially a team effort of specialist scientists, e.g. microbiologists, chemists and material scientists, whose opinion and advice should always be sought before the design of a process for a new food product is completed. The process engineer will also be assisted by contributions from chemical, mechanical, civil, electrical and other types of engineers. The book therefore gives guidance as to where information is available and can be found; it should be useful to research workers and lecturers in developing the subject further.

It has been necessary for various reasons to limit the scope of many of the topics, e.g. the design of heat exchangers, steam raising plant and packaging machinery, since these items will be procured directly from the manufacturer to the customer's specification. The main emphasis is on the factors which must be taken into account in order to ensure the safety of the food product for the consumer; this includes the process design and operating conditions. It is hoped that this book will be a useful guide to all those concerned with the opportunities that aseptic processing and packaging present for the retailer and consumer alike.

S. D. HOLDSWORTH

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Chapter 1

INTRODUCTION

1.1 DERIVATION

The work *aseptic* is derived from the Greek language: the verb sepo –σηπο means to rot and the adjective septicos–σηπτικος means putrefactive, the initial α rendering the word 'not liable to putrefy'. The exclusion of putrefying bacteria gives rise to *asepsis* or *aseptic* conditions.

1.2 BASIC DESCRIPTION OF THE PROCESS

Aseptic packaging, from the above derivation, implies that a product free from putrefying bacteria is packaged under aseptic conditions into a pre-sterilized container. The complete process is often referred to as *aseptic processing* or *aseptic technology*. It is a long term method of preserving food products and is an alternative to conventional canning in which containers filled with the product are sterilized and cooled. It has wide applicability to pharmaceutical, biochemical and medical products as well as food products.

The most typical form of the process is outlined schematically in Fig. 1.1, the various stages being as follows:

1. The sterilization or pasteurization of the food product; this is mainly carried out by heat, e.g. direct heating by steam injection or indirect heating using a heat exchanger — tubular, plate, scraped surface, electrical or other type. Alternatively for some liquid food products microfiltration is possible.

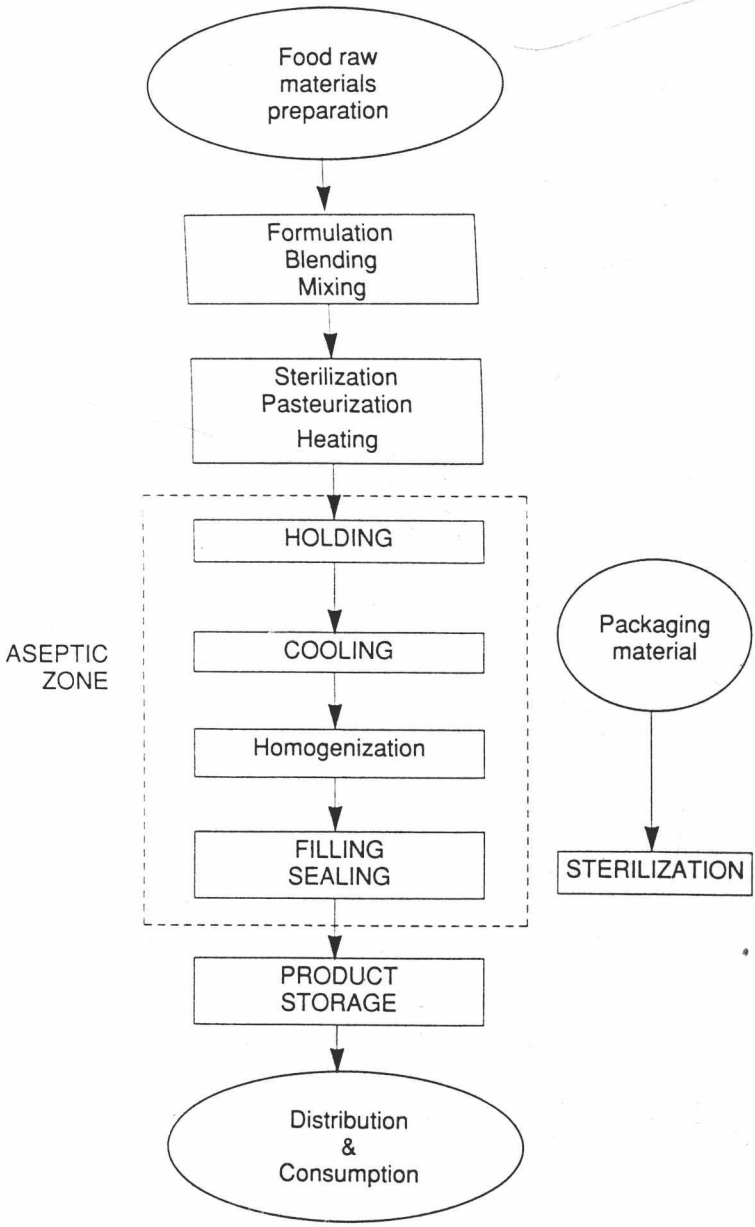

FIG. 1.1. General flow diagram for aseptic processing and packaging Heat–Hold–Cool–Fill.

2. The sterilization of the packaging material, e.g. for metallic containers using superheated steam, or for plastic based materials using chemical sterilants such as hydrogen peroxide, or irradiation treatments.

3. The filling of the pre-sterilized container with the product under aseptic conditions and finally sealing.

The range of packaging materials and container shapes is very extensive and includes metallic containers and tanks, paper board cartons — webfed, preformed or partially preformed, plastic cups and pots — preformed or thermoformed, plastic bottles thermoformed or blow-moulded, and bag-in-box.

1.3 HEAT–FILL–COOL PROCESS

An alternative method of container sterilization is to use the heat in the sterilized product to sterilize the container (see Fig. 1.2). It is necessary with this method to sterilize the lid by inverting the container after filling and holding the can for a specific length of time before cooling. This technique is ideally suited to fruit juices and soft drinks based on acidic products. It has also been applied to low-acid products with pH>4·5, e.g. meat stews, by enclosing the filling machinery in a chamber in which a sufficient over-pressure of air could be applied to prevent the product from boiling. This method is known as 'Flash 18' and has the advantage that conventional canning equipment could be used.

1.4 DEVELOPMENT OF ASEPTIC PROCESSING

The basic process — heat–hold–cool–fill — was originally developed for milk products to extend their shelf-life; it required the rapid pasteurization of the product in a continuous flow system by heating either directly in a steam injector or indirectly in a heat exchanger. The advantage of this method is that it was necessary to use a high temperature, e.g. 130°C, for only a few seconds to achieve an adequate *process*.† These conditions, as opposed to the lower-temperature longer-time sterilization processes, enabled the flavour of the product and the retention

†In canning technology the *process* specifically refers to temperature/time combination and is often referred to as the scheduled process.

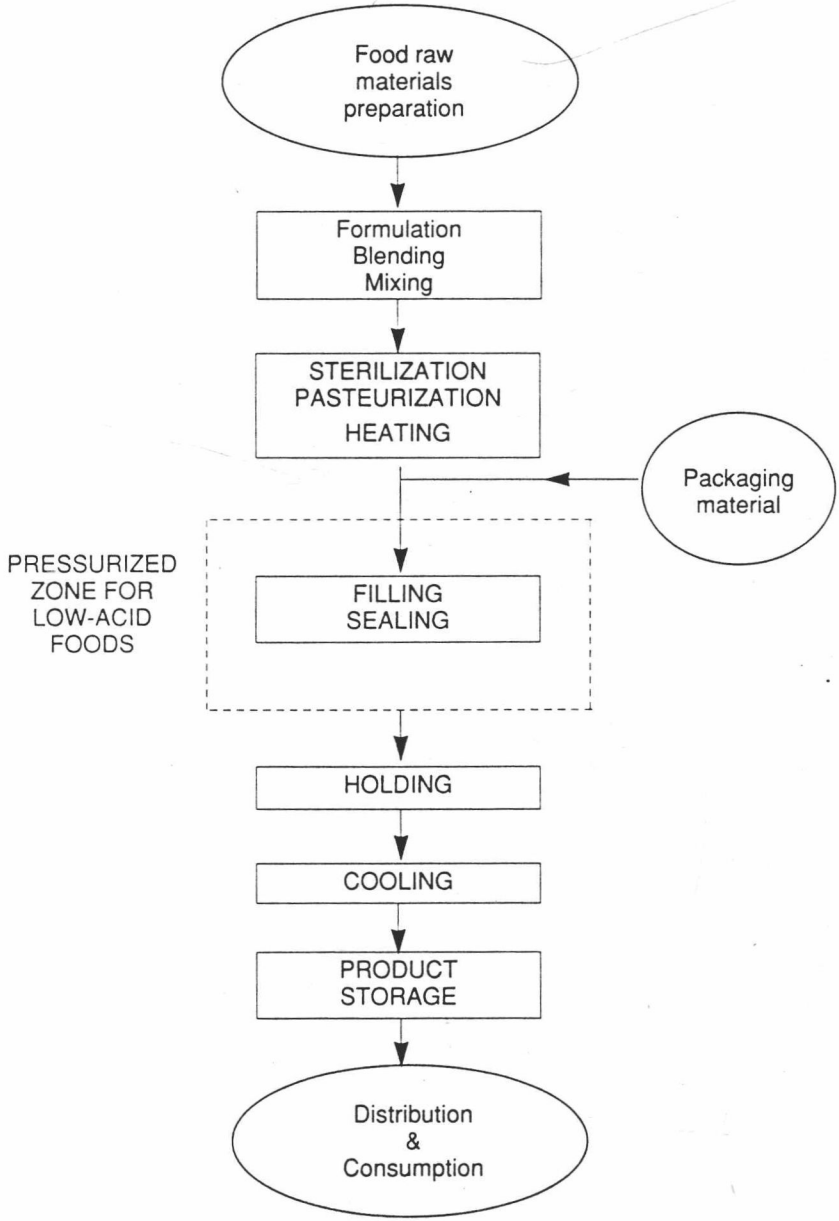

FIG. 1.2. Flow diagram for Heat–Fill–Hold–Cool method of aseptic packaging.

of nutrients to be maintained. The *process* as applied to milk is known as the UHT process (Ultra High Temperature) whereas for other products it is more generally known as the HTST process, i.e. High Temperature Short Time Process. Although the development of aseptic technology was closely associated with this concept, later developments with particulate foods, especially meat and poultry, have shown that with lower temperatures longer time processes are more suitable.

The early development of aseptic canning took place with milk and milk based desserts with delicate flavours and it was assumed that the HTST principle would promote the process. In fact, much of the early success of the process was due to the acceptance of this principle; however, this was not sufficient to ensure its continued success and many products had relatively short commercial success. The most dramatic success was in 1969 when ready-to-eat puddings in easy-open two-piece cans were made available.

A second advantage of aseptic technology has, however, made a large impact on bulk handling of products. The continuous flow sterilization process allowed large containers, drums, tanks and tankers to be filled and closed under aseptic conditions. Conventional canning could not be used for containers of these sizes because of the problems of heat transfer into the large mass of product; even if the temperatures necessary for sterilization could be achieved, the products would have been inedible due to the degree of overcooking.

Aseptic processing had a third advantage and that was the use of plastic/paper laminated materials in the form of semi-rigid packages, pouches, pots and bottles. The continuous sterilization process delivers a cool product and consequently the packaging materials do not have to withstand the high temperatures of conventional thermal processing. The process has even been extended to the use of relatively thin plastic membranes which are in a box to support the contents; these are known as bag-in-box packages.

The major current activity at the time of writing, and indeed the one which the author has been associated with for more than two decades, is the extension of aseptic technology to packaging a wide range of low-acid food products (pH > 4·5) containing particles often described as particulates up to 3+ cm in dimension.

Aseptic technology is therefore a highly effective method of producing shelf-stable preserved products, which have quality advantages over their conventionally canned counterparts, and can be packed in a range of packaging materials without limitations on the container size.

1.5 STRUCTURE OF ASEPTIC TECHNOLOGY

The design and operation of an aseptic processing and packaging plant requires a knowledge of several branches of science viz. microbiology, chemistry, food science and technology, physics, mathematics and engineering. An understanding of the design procedure greatly enhances the operation of the plant in such a way as to ensure the ultimate safety of the food product.

The basic structure of the subject is established by considering the progress of the food product through the process plant to the consumer. In the first part of the process, the sterilization of the food, the main concern is the destruction of microbial species; this requires a study of the kinetics of microbial death and the establishment of a scheduled process. It is during this process that consideration has to be given to the degradation processes which cause the destruction of nutrients and enzymes and the softening of the texture. The kinetics of these processes should be known in order to achieve an optimum process which removes the public health hazard of food poisoning but permits the best possible quality to be obtained. This topic has to be completed by a study of the flow characteristics of the product in the heat exchangers, the residence time distribution and the heat transfer characteristics of the processing equipment. The combination of the flow–heat transfer characteristics and the kinetics of destruction of microbial and other attributes provides the key to attaining a safe product. A number of ancillary topics have to be considered at this stage and these include plant hygiene, materials of construction and process control. The elements of food preparation are also essential and these are enshrined in the corpus of knowledge known as food technology.

In the second part of the process the sterile product has to be handled and filled under aseptic conditions; this introduces all aspects of the art of maintaining the necessary sterility in the filling and sealing machine. It also requires a knowledge of the sterilization of containers and container surfaces by heat, chemicals or electromagnetic radiation. The flow properties of the food are also important in designing the nozzles for the filling equipment in order to avoid splashing and facilitate the important cleaning operations. The properties of the plastic materials are important for the forming and sealing operations and also in relation to storage characteristics of the product. Consequently there are chapters dealing with the sterilization of the packaging material, the maintenance of sterility in the filling and closing operations, the principal

features of packaging machinery, and characteristics of some aseptically packaged food products.

The final part of aseptic technology deals with the important aspects of quality assurance, critical point hazard analysis, codes of practice and test methods to ensure compliance with specifications.

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SOME SYMPOSIA HELD ON ASEPTIC TECHNOLOGY

Date held	*Title*	*Place*
1969	Ultra-High-Temperature Processing of Dairy Products	Agricultural Institute, Republic of Ireland
1971	Manufacture and Packaging of UHT milk	Zilina, Czechoslovakia
1972	Aseptodynamics	Food Processors Institute, Washington, DC, USA
1974	Aseptic Packaging 1st National Conference	New York University, USA
1978	Sterilized Milk and Aseptic Packaging	Ankara, Turkey

1978	Aseptic Processing and Bulk Storage and Distribution	Purdue University, USA.
1979	UHT Processing and Aseptic Packaging of Milk and Milk Products	North Carolina, State University, USA.
1981	UHT Processing	Australian Society of Dairy Technology, Melbourne, Australia
1982	Aseptic Processing and Packaging	University of Auckland, New Zealand
1983	Aseptic Packaging	Chipping Campden, CFDRA, UK.
1983	Capitalizing on Aseptic	National Food Producers Association, Washington, DC, USA.
1983	Aseptic Packaging 1st Aseptipak	Schotland Business Research Inc., Princetown, New Jersey, USA.
1984	Aseptic Packaging 2nd Aseptipak	Schotland Business Research Inc., Princetown, New Jersey, USA.
1985	Aseptic Packaging 3rd Aseptipak	Schotland Business Research Inc., Princetown, New Jersey, USA.
1985	Capitalizing on Aseptic II	National Food Producers Association, Washington, DC, USA.
1985	Aseptic Processing and Packaging of Foods	Tylösand, Sweden (IUFoST)
1985	Aseptic Processing and Packaging of Foods	Lund Institute of Technology, Lund, Sweden
1989	Sterilization and Aseptic Filling of Particulate Foods	Society of Chemical Industry, London, UK.
1989	Aseptic Packaging of Food	Behr's Seminary, Munich, Germany
1989	Recent Development in Aseptic Technology	Chipping Campden, CFDRA, UK.
1989	Aseptic Processing and Packaging — Drink Tec Interbrau '89	Fraunhofer Institute, Munich, Germany
1989	Aseptic Processing Technologies 1st International Congress	Indianapolis, USA.
1991	UHT and Heat Processed Foods	Chipping Campden, CFDRA, UK.

PROCEEDINGS OF THE WORKSHOPS OF COST 91 BIS RELATED TO ACTIVITIES OF SUB-GROUP 1: HTST PROCESSING AND SIMILAR NOVEL HEAT PROCESSING SYSTEMS

1st Workshop: Data Collection and Analysis — Development of Mathematical Kinetic Models (K. O. Paulus, Editor)

Published *Berichte der Bundesfor.* Für Ernährung BFE-R-86-03, Karlsruhe, October 1986.

2nd Workshop: Sensors and Measurement of Product Properties Instrumentation and Process Control (K. O. Paulus, Editor)

Published *Berichte der Bundesfor.* Für Ernährung BFE-R-87-01, Karlsruhe, February 1987.

3rd Workshop: Influence of HTST Treatments on Product Quality and Nutritive Value of Food and Feed (K. O. Paulus, Editor)

Published *Berichte der Bundesfor.* Für Ernährung BFE-R-87-02, Karlsruhe, September 1987.

4th Workshop: HTST Treatment: Severity of Processing and Influencing Parameters (K. O. Paulus, Editor)

Published *Bund für Lebensmittelrecht und Lebensmittelkunde*, Bonn, March 1989.

Final Workshop: The Effects of Processing and Distribution on the Quality and Nutritive Value of Foods

Published *Processing and Quality of Foods* (P. Zeuthen, J. C. Cheftel, C. Eriksson, T. R. Gormley, P. Links & K. Paulus, Editors), Vol. 1, HTST Processing, Elsevier Applied Science, London & New York, 1990.