Essentials of Thermal Processing

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Preface

Essentials of Thermal Processing is written by two authors with many years' experience of thermal processing practice, one gained in the northern hemisphere and one in the southern hemisphere. This gives the book a unique appeal. It covers all aspects of thermal processing from its beginnings in 1795 with Nicolas Appert through to modern day computer controlled processing systems and electronic data capture. The intention was to write a book of practical use to students studying food science and technology as well as for their lecturers, but also for individuals in companies and research centres that have a need to understand thermal processing principles.

The book starts with the basic microbiological principles that govern microorganism growth and death, including the use of hurdles to control their growth. When a combination of two or more food preservation factors is used, generally each factor can be used at a slightly lower level. Using more than one food preservation factor or hurdle is termed hurdle technology.

The next chapters take the reader through the different food categories that present their unique challenges for thermal processing. This includes the traditional sector of low acid foods in which the familiar $F_0 3$ concept was derived from heat resistance studies originally undertaken by Esty and Meyer in 1922. Low acid foods are a group of foods that do not contain any preservation hurdles to microorganism growth and rely on the heat process to control microorganism numbers in the food and a hermetically sealed package to prevent recontamination.

The two chapters that follow, on acid and high acid foods and on acidified foods, were considered to be sufficiently different that separate chapters were required to describe the categories and the types of thermal processes that are applied. The last of the chapters that deals with a specific food group is on heat preserved chilled foods, which is one of the most rapidly growing sectors in Europe. This includes the ready meal concept and ready-to-eat meat, fish and poultry products. Shelf-life requires refrigerated

storage and is typically up to 10 days when a very mild process is used or it can be extended beyond this with more severe treatments.

The next chapter describes the processing methods that can be used for manufacturing heat preserved foods, which is divided into in-pack or in-line systems, often known as retorts and continuous systems. It does not go into the detail of each commercial system, of which there are many, but describes the operating principles. The main types of retort are described, for example steam, steam-air, water immersion, raining and sprayed water, also included are the in-pack continuous retorts such as hydrostatic and reel & spiral cooker-cooler systems. Equipment choice for a continuous or in-line system depends mostly on the food viscosity and whether the flow behaviour is laminar or turbulent.

Thermal processing of foods has a dual purpose, which is to commercially sterilise the product and to cook it to an acceptable level. The chapter on cooking and process optimisation addresses the challenges of maximising a specific quality attribute without damaging the thermal processing effect on microbial reduction. Examples are given on the different quality parameters appropriate to heat preserved foods and how these can be mathematically analysed with the aim of adjusting processes so that maximum quantities of a nutrient, such as a vitamin, are retained.

Techniques for measuring thermal processes are described in the next chapter together with the process calculation methods used to establish safe times and temperatures. Measurement techniques for in-pack processes include temperature sensors of various types and log reduction methods that can be either microbiological or biochemical. Process calculation techniques are introduced, which allow process conditions to be calculated from the temperature measurements and analysis of deviations to be carried out. Differences in the techniques required for batch (in-pack) and continuous (in-flow) heat processes are described.

Cooling of packs is discussed in the chapter on cooling water. Almost all types of microorganisms can be found in water, and water is most often the vehicle of transmission for these organisms. Inadequate cooling is arguably the single most significant cause of public health issues of the last century from canned foods. Examples of spoilage incidents caused by cooling issues are dealt with in several chapters and so this chapter solely describes the different methods of disinfecting cooling water.

Despite the best efforts to control all aspects of a thermal processing operation, all factories will experience process deviations from time to time. A chapter is dedicated to process deviations and describes methods to assess whether a process deviation has made a critical impact on the commercial sterility or safety of a product. Methods to assess a deviation are many and include calculation methods as well as experimentally recreating the deviation using retort simulators.

Packaging of the product also demanded its own chapter. Understanding packaging options and the way they work together with the product is critical to the success of any food packaging system. The functions of packaging are to contain, protect, preserve, portion, inform, promote and make foods portable. Packaging options for thermally processed foods are many and include metal (mainly tinplate, but some aluminium), glass, cartons and specific plastics (laminates and composites). Primary packaging must be able to hold a hermetic seal, withstand the process temperature, provide a physical barrier, withstand the physical stresses during processing, transport, storage and distribution, and must not react adversely with the food.

Incubation of processed packs is commonplace in the food industry; however, a variety of incubation practices occur, which suggests that there is no standardised approach. The chapter on incubation describes the objectives of incubation together with some recommendations for times and temperatures that different types of microorganism require. It includes suggestions for sample size and methods for interpretation of results.

The penultimate chapter is about the HACCP (Hazard Analysis Critical Control Points) system. HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing. Examples are given of CCPs of relevance to thermal processing.

The final chapter presents a different focus for thermal processing in that it deals with environmental aspects and presents a positive case for thermal processing. As a technology for preserving food it can be environmentally beneficial because the goods are stored ambient, thus avoiding the need for refrigeration, and allows agricultural products to be processed close to where they are grown, thus avoiding transportation emissions and forcing crops to grow out of season. An example of a carbon footprint assessment is given in this chapter for a bottled apple juice.

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The authors during a practical training course session in Cape Town.

Glossary of Terms

Acid Food	A food that has a natural pH of 4.6 or below (in Europe it is common to use pH 4.5 as the upper limit).
Acidified Low-Acid Food	A food that has been treated so as to attain an equilibrium pH of 4.6 (or 4.5 in Europe) or lower after heat processing.
Adverse Conditions	Those conditions that may result in physical damage to and/or contamination of a container or its contents, rendering the food unsuitable for human consumption.
Aerobic	Presence of oxygen.
Anaerobic	Absence of oxygen.
Annealing	Heating process used in tinplate manufacture to soften the steel strip after cold rolling and to impart the required hardness; the process can either be continuous (continuous annealing or CA) or in batches (batch annealing or BA).
Aseptic Processing and Packaging	The filling of a commercially sterile product into sterilised containers followed by hermetical sealing with a sterilised closure in an atmosphere free from microorganisms.
Beads, Beading	Corrugations rolled into can walls to give added strength to the can body.
Bleeders	Small orifices through which steam and other gases escape from the retort throughout the entire heat process.
Broken Heating Curve	A heating curve that shows a distinct change in the rate of heat transfer, such that the curve may be represented by two or more distinct straight lines.

Canned Food	Commercially sterile food in hermetically sealed containers.
Cleaning	The removal of soil, food residues, dirt, grease or other objectionable matter from the external surface of the container and for the purposes of this code may be extended to the removal of rust and other products of corrosion.
Come-up Time	The time, including venting time, which elapses between the introduction of the heating medium into the closed retort and the time when the temperature in the retort reaches the required sterilisation temperatures.
Commercial Sterility	The condition achieved by application of heat, sufficient, alone or in combination with other appropriate treatments, to render the food free from microorganisms capable of growing in the food at normal non-refrigerated conditions at which the food is likely to be held during distribution and storage.
Contamination	The presence of any objectionable material on the surface of a container, or in a food.
Corrosion	Chemical action of dissolving the surface of a metal (e.g. tin in food medium).
Corrosion Accelerator	Chemical species with the ability to accept electrons, which will increase the rate of a corrosion reaction.
Critical Factor	Any property, characteristic, condition, aspect or other parameter, variation of which may affect the scheduled process delivered and thus the commercial sterility of the product. This does **not** include factors that are controlled by the processor **solely** for purposes of product appearance, quality and other reasons that are not of public health significance.
Detinning	The process of corrosion, where the internally plain tin coating is slowly dissolved by the food medium; rapid detinning refers to abnormally fast tin dissolution, caused by the presence of corrosion accelerators.

Disinfection The reduction, without adversely affecting the food, by means of hygienically satisfactory chemical agents and/or physical methods, of the number of microorganisms to a level that will not lead to harmful contamination of food.

Disposal An action (e.g. incineration, burial, conversion to animal feed, etc.), which will prevent a contaminated product from being sold or distributed for human consumption.

Dr Tinplate 'Double Reduced' tinplate where a second rolling is used to reduce steel thickness in order to produce a thinner but stronger product.

Electrolyte A substance that dissociates into ions when dissolved in a suitable medium; hence a tin-rich electrolyte is used in tinplate manufacture.

Embossing Use of a die to stamp a product code or manufacturing date into a can end.

Equilibrium pH The pH of the macerated heat processed food product.

Fermented Food A food preserved by the growth of acid-producing microorganisms in the food, which lowers the pH to 4.6 (4.5 in Europe) or less.

Fill Temperature Temperature at which the food is filled into the container.

Fill Weight The weight of the product particulates before processing, excluding the weight of the container or covering liquid.

Filler Machine used to automatically fill a container with the desired weight or volume of food.

Flexible Container A container where the shape or contours of the filled, sealed container are affected by the enclosed product.

Food Acids Organic acids, naturally occurring in foods, especially in fruits and vegetables; also used to impart flavour and to modify the pH of foods.

Headspace Space left in the top of the container after filling and end sealing, in order to allow for product expansion during thermal processing/the volume in a container not occupied by the food.

Heating Curve A graphical representation of the rate of temperature change in the food throughout the heat process; this is usually plotted on semi-log graph paper so that the temperature on an inverted log scale is plotted against time on a linear scale.

Hermetically Sealed Container A container that is designed and intended to be secure against the entry of microorganisms and to maintain the commercial sterility of its contents during and after processing (e.g. tinplate or aluminium can, glass jar, or pouch).

Incubation Tests Tests in which the heat processed product is kept at a specific temperature for a specified period of time in order to determine if outgrowth of microorganisms occurs under these conditions.

Initial Temperature The temperature of the contents of the coldest container to be processed at the time the sterilising cycle begins, as specified in the scheduled process.

Inject Coding Use of an ink jet to print a product code or manufacturing date on the package.

K_w K_w is an equilibrium constant for the chemical reaction that describes the ionisation of water. It is referred to as the ionisation constant or the ionic product. It has the units $mol^2\ dm^{-6}$.

Lacquers Inert organic coatings used to give additional protection to tinplate; usually applied in liquid form and 'cured' at high temperatures.

Low-Acid Food Any food (other than alcoholic beverages) with a finished equilibrium pH greater than 4.6 (4.5 in Europe) and a water activity greater than 0.85, excluding tomatoes and tomato products having a finished equilibrium pH less than 4.7.

Nesting	Containers that fit within one another when stacked.
Pack Testing	Storage and regular sampling of canned foods under controlled temperature conditions to determine internal corrosion characteristics and potential shelf-life.
Packing Medium	The liquid or other medium in which the low-acid or acidified product is packed.
pH	A measure of acidity.
Plain Cans	Cans made from tinplate without any additional lacquer coating.
Potable Water	Water fit for human consumption.
Process Authority	The person or organisation that scientifically establishes thermal processes for low acid canned foods or processing requirements for acidified foods. The processes are based on scientifically obtained data relating to heat or acid resistance of public health and spoilage bacteria and/or upon data pertaining to heat penetration in canned foods. The process authority must have expert scientific knowledge of thermal and/or acidification processing requirements and have adequate experience and facilities for making such determinations.
Process Temperature	The calculated temperature at a particular time (process time) for which a specific container size and food product need to be heated in order to achieve commercial sterility.
Process Time	The calculated time at a particular temperature (process temperature) for which a specific container size and food product need to be heated in order to achieve commercial sterility.
Recanning	The transfer and sealing of a product into a new hermetically sealable container followed by a scheduled process.
Reconditioning	The cleaning of sound containers and may include disinfection.

Reducing Environment	Conditions expected inside a plain processed food container, whereby the contents are protected from oxidative reactions such as colour change.
Reprocessing	The treatment of a canned food in its original container recovered in a salvage operation followed by a scheduled process.
Retort	A pressure vessel designed for thermal processing of food packed in hermetically sealed containers.
Rigid Container	A container whereby the shape or contours of the filled and sealed container are neither affected by the enclosed product nor deformed by an external mechanical pressure of up to 0.7 kg/cm^2 (10 psig) (i.e. normal firm finger pressure).
Sacrificial Anode	A metal that slowly dissolves in a corrosion reaction and, in so doing, protects a second metal from corrosion (e.g. tin behaving as the sacrificial anode to protect the coupled steel base).
Salvage	Any appropriate process or procedure by which food is recovered from a suspect lot of canned food and by which its safety and fitness for consumption is ensured.
Scheduled Process	The thermal process chosen by the processor for a given product and container size to achieve at least commercial sterility.
Seals	Those parts (of a semi-rigid container and lid or flexible container) that are fused together in order to close the container.
Semi-Rigid Container	A container whereby the shape or contours of the filled, sealed container are not affected by the enclosed product under normal atmospheric temperature and pressure but can be deformed by an external mechanical pressure of less than 0.7 kg/cm^2 (10 psig) (i.e. normal firm finger pressure).
Shelf-Life	The expected acceptable commercial life of any canned food.

Sidestripe	A thin band of lacquer designed to protect the weld of a can body from corrosion.
Steam Exhausting	Passing filled containers through a tunnel of steam, prior to sealing, to assist in oxygen removal from the product and headspace.
Sterilisation Temperature	The temperature maintained throughout the thermal process as specified in the scheduled process.
Sterilisation Time	The time between the moment when sterilisation temperature is achieved and the moment when cooling started.
Sterilising Value (F_0)	The number of minutes at a reference temperature of 250°F Fahrenheit (121.1°C) required to kill a known population of micro-organisms with a z value of 18°F (10°C).
Sulphide Staining	Where naturally occurring sulphur compounds in foods react with the tinplate surface to form a purple-black stain of tin sulphide or black iron sulphide.
Suspect Lot	A group of containers that is suspected of being contaminated as a result of exposure to adverse conditions and may include a part of, the whole of, or a number of code lots.
Thermal Process	The application of heat to food, either before or after sealing in a hermetically sealed container, for a period of time and at a temperature scientifically determined to achieve a condition of commercial sterility.
Venting	The thorough removal of the air from steam retorts by steam prior to a scheduled process.
Water Activity (a_w)	A measure of the free moisture in a product. It is the quotient of the water vapour pressure of the substance divided by the vapour pressure of pure water at the same temperature.

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