

FOOD PROCESSING

Retort Processing Technology for Shelf-Stable Food Manufacturing

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Introduction

A food preservation technique of some kind or another has been used in almost every culture and historical period. People needed to preserve food for survival. Since food spoils in a short period after leaving the farm, different food preservation techniques were able to utilize seasonal and local food sources, thereby enhancing the quality of life. However, processing of highly perishable foods is relatively “new.” The invention of canning dates back to 1809, when Nicholas Appert of France invented the method of canning. However, the Farmers’ Bulletin 359 (Breazeale 1909) published in 1909 by the Bureau of Chemistry, was in fact one of the early United States Department of Agriculture publications providing specific directions for home canning.

The COVID-19 epidemic created a fresh set of problems that have impacted every industry in the world. Rigorous lockdowns and physical distance have had a significant impact on the food supply chain, putting additional focus and stress on food preservation techniques able to

safeguard the interests of farmers and food processors as well as ensure nutritious food to consumers.

One of the most important objectives for the food industry today is to guarantee biosecure and nutritious food for human consumption. In the market for manufacturing shelf-stable products that do not require refrigeration, sterilization technologies, such as retort processing, are seen as effective and desirable.

Basic food preservation methods involve either destroying spoilage and disease-causing microorganisms or inhibiting their growth. Even though microbes are present in almost all raw food ingredients, they cannot survive under unfavorable or unsuitable conditions, which either inactivate or inhibit their growth.

Heat is the primary method of food preservation in canned foods. The process uses a combination of time and temperatures to destroy microorganisms and create commercially sterile foods.

Thermal processing terminology and important concepts as per US regulations

- **Commercial sterility:** Commercial sterility indicates that the product is expected to be free from viable microorganisms of public health significance, including their spores. The product is also expected to be free from microorganisms that are capable of reproducing in food under normal, nonrefrigerated conditions of storage and distribution. To attain commercial sterility in canned foods, generally the product must be heated. However, application of heat while regulating water activity may also be carried out.
- **Foods in which water activity (a_w) is controlled:** Water activity is a measure of the amount of free water in foods. This is a critical factor for the growth of microorganisms. By controlling the a_w , the growth of microorganisms can be prevented. Therefore, foods with a controlled water activity would require a milder heat treatment to inactivate microorganisms.
- **Low-acid canned food (LACF):** LACF as per regulatory information is a food having a finished equilibrium pH greater than 4.6 and a water activity greater than 0.85 packaged in a hermetically sealed container. However, it is worth mentioning that tomato and tomato products having a finished equilibrium pH of less than 4.7 are not classified as LACF. LACF includes canned tuna, canned mushrooms, shelf-stable milk packed in pouches, etc.
- **Acidified foods:** Low-acid foods in which either acid or acid food is added to ensure a final equilibrium pH of 4.6 or less, with water activity greater than 0.85. Typical acids added are acetic acid and citric acid or phosphoric acid in beverages. Examples may include beans, cucumbers, puddings, fish, etc.
- **Acid foods:** Foods having a natural pH of 4.6 or less. Examples include lemon juice, blue plums, pomegranates, grapefruit, pineapples, etc.
- **Hermetic seals:** Special type of air-tight closures used for sealing packages that can prevent the entry of microorganisms, filth, and other contaminants that can impair the quality of the product and render it unfit for consumption.
- **Heating medium:** Heat is transferred to products and packaging through a heating medium, also known as a "processing medium." The most commonly used heating medium for thermal processing systems is steam. Steam is also used to heat water if the latter is used as a heating medium. Common heating media used for processing containers in retorts include steam, water, or a steam/air mixture.

- **Scheduled process:** Process parameters along with the critical factors established to produce a commercially sterile product by the controlled application of heat is termed a scheduled process or, alternatively, a process schedule.
- **Processing authority:** A person or organization with expert knowledge of thermal processing requirements for foods packed in hermetically sealed containers, and having adequate facilities to make process determinations. As per regulations, the scheduled process is required to be established by a processing authority.

Problem statement and proposed solution

- a) Underprocessing of low acid canned foods and/or container leakage may lead to microbial growth of food-borne pathogens and, in some cases, to the production of toxins, such as the deadly *Clostridium botulinum* toxin, in the container. An inadequate thermal treatment may be able to inactivate the vegetative cells but may fail to kill the more heat-resistant spores of the bacterium. The illness caused by ingestion of *C. botulinum* toxin is known as botulism; even very small amounts can cause paralysis and death. Thus, thermal processing should primarily aim to destroy the spores of *C. botulinum* to prevent the production of *botulinum* toxin.
- b) *Staphylococcus aureus* is another pathogenic microorganism that can produce heat-stable toxins in low-acid canned foods (LACF) and can survive inadequate thermal process. Contamination by this microorganism can occur during batching of food products before the thermal process. Thus, time and temperature controls need to be implemented before thermal processing.
- c) Bacteria are generally the type of microorganism of greatest concern for food processors. From a processing perspective, bacteria can be grouped into pathogenic or into spoilage groups, depending on whether they can cause disease. Furthermore, certain types of bacteria, the spore-formers, when exposed to unfavorable environmental conditions, can go into a dormant state by forming a spore, whereas some other types cannot form spores, even under unfavorable conditions, existing only as vegetative cells. With respect to heat-resistance, vegetative cells are easier to destroy by heat, whereas spores tend to be more heat-resistant. Some non-pathogenic bacteria may excrete enzymes and produce spoilage in foods. Application of adequate mild heat treatments can destroy cells of non-spore formers in low-acid and acid foods, including the vegetative cells of *C. botulinum*.

- d) Molds are another type of microorganism that can cause spoilage in foods. Molds are multiple cell organisms and much larger than bacteria and yeasts. So they are often visible in the foods they grow. Some molds produce heat-resistant spores, so a thermal process must be designed accordingly for their control. Certain molds are of concern in thermal processing of acidified products because they can consume acids in foods they grow in, thereby raising the pH of products. There are a few examples in acidified food processing where the growth of molds has removed the acidic conditions required to inhibit bacterial growth, and favoring conditions for growth of *C. botulinum*.
- e) Yeasts are the third type of microorganisms that may be present in canned foods due to underprocessing or post-process contamination. Yeasts belong to the spoilage group and are capable of adapting to adverse conditions, such as acidity and dehydration. However, they are highly susceptible to thermal treatment and most of them are easily destroyed by heating to 170°F.
- f) Viruses are another type of biological contaminant. Though viruses cannot multiply in foods, and need a host to replicate, viral outbreaks may occur due to contamination of food by infected handlers or at a single source – for example, from contaminated irrigation water. In the U.S., norovirus outbreaks occur most frequently. However, heat treatment can destroy viruses. Viruses are denatured at 212° F for a 10-minute time period, a method followed in most thermal processes for low-acid canned foods.
- g) Thermal processing may result in some unintended, undesirable outcomes, such as nutrient losses, creation of toxic substances (acrylamide, furan, or acrolein), or development of substances with mild negative impact on flavor perception, texture, or color. Therefore, optimizing the heat treatment of food is necessary to encourage beneficial effects while effectively mitigating negative consequences.

How to achieve these objectives

- a) Mild thermal process for products with low pH (pH<4.6): Since processing conditions require using temperatures lower than 212° F, atmospheric pressure is adequate. Mild thermal processes may be applied in 1) Atmospheric cookers, or 2) Hot-fill-hold process.
- b) High temperature-pressure processes: Since these processes require the use of temperatures greater than 212° F systems need to be pressurized to reach process temperature. These processes may be applied in 1) Conventional canning using retorts, or 2) Aseptic processing and packaging technology.

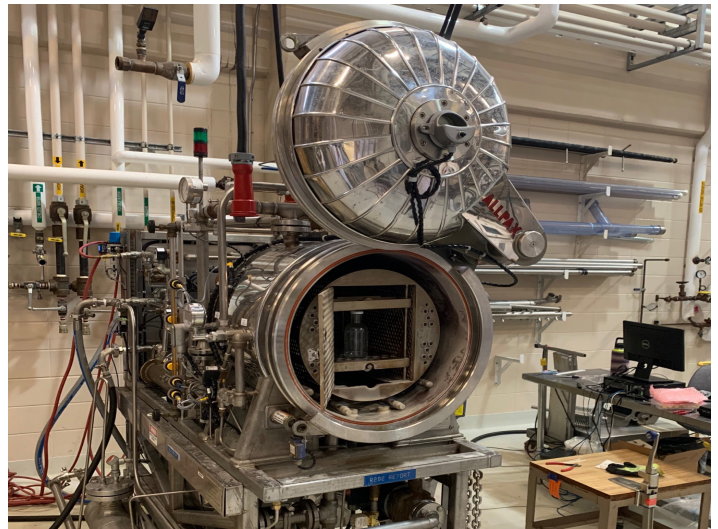


Figure 1. Multi-mode retort for acidified and low-acid canned food manufacturing.

Special note:

- 1) Low-acid canned foods (LACF) cannot be processed through a mild thermal process operated at temperature of 212° F or lower because the process will not destroy bacterial spores of pathogenic organisms such as *C. botulinum* (thus posing a public health risk) nor spores from spoilage organisms. For these reasons, all LACF products require pressure processes operated at temperatures greater than 212° F, as in conventional canning in retorts, or an aseptic process and packaging to achieve commercial sterility.
- 2) For acid and acidified foods, mild thermal processing operated at 212° F or less may be adequate because the low pH of the product (pH<4.6) inhibits the germination of the bacterial spores that would survive the thermal treatment. However, in some instances pressure processes may be applied to these products at moderate temperatures.

Conventional canning in retorts

A retort is a closed, pressurized container used to heat foods that have been hermetically sealed in containers prior to thermal treatment. Commercially sterile foods packaged in hermetically sealed containers may be produced using various retort operating conditions. The advantage of retort processing is that the product reaches commercial sterility “in the container.” Conventional canning in retorts has a few common attributes, regardless of the type of retort used:

- a) Before entering the retort, the product is filled into a container and hermetically sealed.
- b) Products across all pH ranges can be processed in retorts. A retort method, however, could be overly harsh and impair the quality of products with low pH.



Figure 2. A No. 10 can being prepared for heat penetration study using a thermocouple to monitor in-can temperature of kidney beans in brine.

- c) The process is carried out under pressure to reach temperatures higher than 212° F. For instance, operations are frequently carried out at temperatures of 250° F for the time needed to achieve 12 log reductions of *C. botulinum*, at the minimum.
- d) Batch or continuous processes may be carried out depending on retort design.
- e) Depending on retort design and product type, containers may be stationary or agitated, during the process.
- f) Water, steam, or steam-air mixtures are commonly used as heating media, depending on retort design.
- g) Product, package, and closure are sterilized at the same time by the external heat from the heating medium.
- h) Overpressure Processing: Overpressure by air or additional steam during processing may be required to maintain the integrity of certain food packaging containers as flexible packages and semi-rigid plastic containers that have limited resistance to internal pressure.
- i) Process authorities perform temperature distribution tests, heat distribution, and heat penetration studies to establish proper operating procedures for all retort types.

Determination of retort operating procedures

The construction and operation of a retort should ensure that finished products are commercially sterile. It is the responsibility of a processing authority or the original equipment manufacturer (OEM) to develop operating procedures to ensure that the temperature within the retort is uniform for every single operation. Usually, temperature distribution studies are carried out during the installation and commissioning of the retorts. In these tests, several thermocouples are placed along various locations inside the retort, followed by temperature monitoring. Temperatures are monitored inside the retort for two main reasons: 1) to identify the slowest heating zone, and 2) ensure that the

temperature monitoring device of the retort accurately represents the overall temperature of the retort during the process.

The specific operating steps for each retort system depend on the type of heating medium used, such as steam, hot water, or steam/air mixture. Process timing does not start until the required temperature is indicated on the temperature-indicating device and uniform temperature distribution has been achieved within the retort. FDA and USDA-FSIS require processors to retain copies of retort operating procedures and temperature distribution studies. Such documentation, along with thermal processing records, must be made available to regulators upon request.

Regulations also require that the production of LACF products be carried out under the supervision of personnel who are Better Process Control School (BPCS)-certified. As mentioned earlier, the specific steps that need to be followed and recorded when operating a retort will be determined by the processing authority and will depend on the characteristics of the product, food packaging material, and the type of retort process used. Different types of retorts may be used in the food industry. Those types usually can be classified in these general categories: 1) still steam retorts, 2) crateless retorts, 3) total water immersion retorts, 4) continuous agitating retort, 5) discontinuous agitating retort, 6) steam/air retorts, 7) water spray/cascade retorts, and 8) hydrostatic retorts.

Sections of CFR related to FDA regulations for retort equipment and operations

Topic	FDA 21 CFR Part
<i>Emergency permit control</i>	108
<i>Records</i>	113.00
<i>Critical factors</i>	113.40 113.81 113.83 113.89 113.100
<i>Retort equipment and instruments</i>	113.40 113.87
<i>Electronic controls, records maintained on computers</i>	11
<i>Product traffic control, initial temperatures, and timing devices</i>	113.87
<i>Headspace, consistency, and viscosity as critical factors</i>	113.40 (c) 113.40 (d) 113.40 (e) 113.83 11.100
<i>Current good manufacturing practices</i>	117

Importance of records and record-keeping practices

- 1) Records serve as evidence of the control of the critical factors and of the corrective actions taken if deviations of the critical factors occurred.
- 2) Records of the thermal process are “Real Time Records” – i.e., they are prepared by the processing system operator, container closure inspector, or any other designated and trained operator only at the time the specific operation or testing procedure takes place. Pre-recording information based on anticipation of pre-known real-time values, or post-recording, is not permitted.
- 3) Recording of critical process factors as a) pH, water activity, or other product measurements; b) process time and temperatures; c) container closure requirements; d) other critical factors as previously determined by the process authority must be performed by persons trained in the process.
- 4) As per regulations, copies of required records must be retained for each lot of processed product at the processing plant for one year from the date of manufacture and for an additional two years at reasonably accessible locations.
- 5) Processors producing shelf-stable acidified and low-acid foods packed in hermetically sealed containers are required to register the processing facility with the FDA. They are also required to make specific procedures, as well as procedural documents and records, available for inspection and copying upon demand by authorized FDA or USDA-FSIS staff. The links at the bottom of this review article contain information about the regulations.

Useful Links

<https://www.fda.gov/food/establishment-registration-process-filing-acidified-and-low-acid-canned-foods-lacf/establishment-registration-process-filing-acidified-and-low-acid-canned-foods-lacf-paper-submissions>

<https://www.fda.gov/food/establishment-registration-process-filing-acidified-and-low-acid-canned-foods-lacf/establishment-registration-and-process-filing-acidified-and-low-acid-canned-foods-lacf-electronic>

<https://www.ecfr.gov/current/title-21>

<https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-113>

<https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-114>

<https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-117>

<https://ag.purdue.edu/departments/foodsci/mishralab/workshops/better-process-control-school.html>

<https://consumerbrandsassociation.org/about-us/programs-initiatives/better-process-control-school/>

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