SHAKA: A NEW AND NOVEL PROCESSING TECHNOLOGY TO PRODUCE COMMERCIALLY STERILE CANNED FOODS

by

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Abstract

The process of canning or "commercial sterilization" has been studied for more than two centuries. The first to develop canning as a defense against spoilage was Nicholas Appert also known as the "father of canning." Appert invented a method of preservation by enclosing food in hermetically sealed containers and then heating containers to boiling temperatures for a specific period of time. The canning preservation method has changed over the years, and continues to change for the better. Technology for retorts, or processing vessels, has grown from the traditional steam heating medium to also include water and steam/water spray heating mediums. The once static vessels, now utilize rotation and shaking motions to decrease process time and in turn increase product quality. The product packaging has also evolved to include not only rigid metal containers, but semi-rigid and flexible plastic containers. The variety of packaging adds greater flexibility to the type of food products that can be produced in a shelf stable manner. Canning or "commercial sterilization" is still used today by the food industry as a method of providing safe food with extended shelf life. Today's goal of commercial sterilization is to continue to produce safe food products that are high in quality and profitable to produce.

A variety of processing equipment is available to accomplish those goals, ranging from a basic steam retort to the newest technology on the market known as Shaka. This new retort technology uses reciprocal agitation to shorten processing times and increase the quality of the final products. Studies have shown that the Shaka process reduces processing times better than 20-fold compared to a still process and better than 10-fold compared to a rotary process.

As the field of thermal processing continues to evolve, the challenge will be to consistently produce safe, commercially sterile food that exceeds current quality expectations in a shorter process time while using less energy. Shaka, and other new technologies, will help the food industry meet these challenges and expectations by expanding the current capabilities of thermal processing to meet consumer demands.

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Chapter 1 - Introduction

The field of thermal processing has been studied for more than two centuries. In 1795 Napoleon Bonapart, the leader of France offered a reward of 12,000 francs to a person who could find a solution to the malnutrition and food poisoning that plagued his soldiers (Tucker and Featherstone, 2011). Nicholas Francois Appert won the prize by developing a preservation method that involved enclosing food in containers and then boiling them in a water bath for a period of time. Because of his accomplishment, Appert was deemed the “father of canning” or “father of thermal processing.”

Since then the canning industry has grown and evolved to what it is today. Sterilization, used for food preservation, is a more recent technology to preserve foods but has been proven to be one of the most effective. Traditional canning still dominates the food industry even though new technologies are beginning to emerge (Chen and Ramaswamy, 2004). Canning is often referred to as commercial sterilization and is one method of thermal processing. Thermal processing is the application of heat to destroy (inactivate) microorganisms and enzymes, which can cause spoilage of foods and health hazards to the consumers (Saravacos and Kostaropoulos, 2004). Commercial sterilization is defined as the condition achieved by application of heat, sufficient, along or in combination with other ingredients and/or treatments, to render the product free of microorganisms capable of growing in the product at normal non-refrigerated conditions at which the product is intended to be held during distribution and storage (Weddig, et al., 2007). The canned food sterilization process is also referred to as appertization after Nicholas Appert (Ramaswamy and Chen, 2004). Traditional canning refers to in-container sterilization.

Other methods of thermal processing include: cooking, blanching, pasteurization, and aseptic processing. Cooking refers to the method of producing a palatable food through baking, broiling, roasting, boiling, stewing, frying, etc. Blanching is meant to inactivate enzymes before freezing to remove tissues gases, to wilt the tissue to facilitate packing, or to cleanse the tissue prior to canning. Pasteurization is to kill pathogenic and selected spoilage microorganisms in the food (Rizvi, 2011). Aseptic processing is the filling of a commercially sterile product into sterilized containers followed by hermetically sealing with a sterilized closure in an atmosphere free of microorganisms (Tucker and Featherstone, 2011). The development of aseptic processing allows a liquid or semi-liquid food product to be heated and then placed directly into a container. This process produces shelf stable products that are commercially sterile.

During the past two centuries, equipment, processes, and packaging material used to produce canned or commercially sterile foods that are shelf stable has changed. Much of what is known in regards to thermal processing has remained the same; however, the field is continuing to develop and advance each day. Retorts have evolved from batch to continuous systems. Some benefits achieved by these improvements are reduced processing times, improved product quality, increased product capacity and throughput, reduced costs, and increased customer satisfaction.

Ongoing advancement is important to continue to revolutionize the food industry. An essential innovation is the improvement of thermal processing equipment and techniques, more specifically the development of the Shaka process. This new retort technology uses reciprocal agitation to shorten processing times and increase product quality. Studies have shown that the Shaka process reduces process time more than 20-fold compared with a still process and more than 10-fold compared to a rotary process (Walden, 2010).

The purpose of this report is to review and understand the changing processing techniques and packaging options for shelf stable food products, more specifically in-container sterilization. This report will discuss the history of the canning process; various pieces of equipment used by the food industry to process commercially sterile food; packaging materials used for commercially sterile food products; and the aseptic processing method. The primary focus will be on the Shaka process and how this novel processing technique and retort system can reduce processing times and improve food quality.

Chapter 2 - Today's Canning Industry

The canning industry began out of necessity. People were looking for a way to help ease hunger and malnutrition caused by limited resources and food spoilage. Today, canned foods can be found almost anywhere from the local supermarket to a neighbor's pantry. Consumers rely on canned food products because they are safe, have an extended shelf life, can be stored at room temperature, and are convenient.

In 2010, 129.5 billion metal containers were shipped to a variety of industries within the United States (U.S.). Of that total number, 96.5 billion metal containers were used by the beverage industry, 28.4 billion containers were used by the food industry, and 4.6 billion containers were used by industries including but not limited to paint and automotive products (CMI, 2011). Also in 2010, the U.S. shipped 30.5 billion glass containers. Of those 18.5 billion glass containers were used in the beer industry, 10.0 billion in the food/beverage/spirits industry, and 2.0 billion in the wine industry (Glass Packaging Institute, 2011).

The retail value of the worldwide packaged food category was 1,952 billion U.S. dollars for the year 2010. That was up from 1,857.8 billion U.S. dollars in 2009 and 1,894.0 billion U.S. dollars in 2008 (Euromonitor International, 2011). The retail value of the worldwide canned food category, which includes canned/preserved food, canned/preserved beans, canned/preserved fish/seafood, canned/preserved fruit, canned/preserved meat and meat products, canned/preserved pasta, canned/preserved ready meals, canned/preserved soup, canned/preserved tomatoes, canned/preserved vegetables, and other canned/preserved food, was 173.0 billion U.S. dollars in 2010 compared to 166.6 billion U.S. dollars in 2009 and 167.6 billion U.S. dollars in 2008. The retail value of the U.S. canned food category accounted for 38.5 billion U.S. dollars in 2010 compared to a retail value of 38.0 billion U.S. dollars in 2009 and 36.5 billion U.S. dollars in 2008 (Euromonitor International, 2011).

The canning industry accounted for 8.86% of the packaged foods category in 2010 (Euromonitor International, 2011). However, it is still a vital part of the worldwide food industry and it continues to grow year after year. Thermal processing, more specifically commercial sterilization, plays an important part in today's canning industry because it provides the protocol for producing safe food that consumers can trust.

Chapter 3 - History of Thermal Processing

Nicholas Appert's work was prompted in 1795 when a reward was offered by the French government. Although the French army was winning their battles, soldiers were getting sick from malnutrition and food poisoning. The soldiers' diet consisted mainly of salted meat and bread that would spoil easily in a short period of time. An award of 12,000-francs would be given to a citizen that could invent a method for preserving food that would be safe for transport over a long period of time (National Canners Association, 1971).

At the time Appert was a confectioner and chef. His theory was that food would be safe if it was placed in a container, excluded from air, and then sufficiently heated (National Canners Association, 1971). He began experimenting and eventually devised a method to preserve food by sealing and heating the food in glass jars. Appert called his process "the art of Appertizing." Appert also defined the term "hermetic". A "hermetic" seal kept out the spirits and ferments. In general, foods treated with heat in hermetically sealed containers are called canned foods (Desrosier, 1959).

In 1810, Appert published a book outlining his findings and process titled *The Art of Preserving Animal and Vegetable Substances for Many Years* (Goldblith et al., 1920). His method was very simple and seemed to work but the rationale behind it was more trial and error. At the time Appert developed his technique of food preservation he did not understand why his method was a success. Still, he was awarded the prize from the French government and Emperor Napoleon Bonapart.

It wasn't until Louis Pasteur explained almost 50 years after Appert's book was published that the reason for the success was the process reduced or eliminated the microorganisms that cause food spoilage (Tucker and Featherstone, 2011). Pasteur became interested in the problems in the wine and beer industries. He was the son of a decorated officer in Napoleon's army and wanted to solve the problem of the wine and beer that were diseased and soured from "spontaneous generation". In 1864, Pasteur reported to the Academy of Life Sciences that he found the cause for disease in wine and beer and that the cause was microscopic vegetation. It was that same microscopic vegetation that caused spoilage in food products. Boiled food, such as those products produced by Appert's method of preservation, would not spoil, and boiled wine would not sour. The heat treatment of foods to kill inactive pathogenic organisms is called pasteurization after Louis Pasteur (Desrosier, 1959).

Since that time many others have worked on methods of food preservation. In 1810, Peter Durand applied to King George III for a patent that covered a method for preserving food for a long period of time. In the patent was a statement, "I place and enclose the said food or article in bottles or other vessels of glass, pottery, tin, or other metals of fit materials" (National Canners Association, 1971).

Durland later sold his patent to Dartford Iron Works. The company used tin canisters made of iron coated with tin and in 1813 sent tins of food to the British in far away stations such as St. Helena and the West Indies. Therefore, improving the diet of soldiers stationed in these places. "Tinned foods" also gained acceptance by civilians and were noted for being palatable while retaining nourishing qualities (National Canners Association, 1971).

The safety of canned foods was further proven when explorer, Otto von Kotzebue took tinned foods to the Artic in 1815 and then the same cans were opened and eaten in 1911 with no one suffering ill-effects (National Canners Association, 1971). In addition, several of canned foods processed by Appert in 1824 were opened in 1938 and found to be non-toxic by animals (Desrosier, 1959).

In 1817, William Underwood established the first cannery in America. His company canned fruits, pickles, and condiments that were then shipped to South America and the Far East. About five years later, Thomas Kensett and Ezra Daggett started packing seafood and were granted the first American patent for a tin canister that became known as the "can." The term "canning" became defined as "the operation of sterilizing food by heat and sealing it in airtight containers, regardless of whether the container was metal or glass, or whether the food was being prepared commercially or in the home" (National Canners Association, 1971).

Over time, canning plants were started in new areas and new products were added to the growing list of canned foods. Vegetable canneries appeared in Iowa in the 1870's and 1880's and meat canneries appeared in Chicago in 1872. Pineapple canneries were established in Hawaii in 1892 and condensed soups entered the canning industry in 1897. The number of establishments producing canned foods increased from less than 100 in 1870 to approximately 1,800 in 1900 (National Canners Association, 1971).

The National Canners Association was formed in 1907 and established a research laboratory for studying canning technology (National Canners Association, 1971). The first director, W.D. Bigelow is known for studying the mathematical problems involved in calculating sterilization processes. C.O. Ball and F.C.W. Olson also focused their research on mathematical treatment and used tables and graphs to explain their equations. In simple terms, the calculation process for determining the thermal process of canned foods is based on two factors: 1) the sensitivity of microorganisms to heat in the given medium, and 2) the speed with which heat penetrates into the products (Cheftel and Thomas, 1965).

During this timeframe, many technological developments allowed more efficient and economical production of canned foods. A.K. Shriver is noted for inventing the retort or pressure cooker. This piece of equipment allowed for more precise control of temperatures during the cooking process. Additional devices were developed that assisted in preparing the food prior to canning such as a device for cleaning and trimming fish; machine for husking corn; machines for filling cans; and conveyors for moving raw food and finished canned goods (National Canners Association, 1971).

Today, the Food and Drug Administration (FDA) breaks canned foods into several categories. There are low-acid foods, acid foods, and acidified foods. Low-acid canned foods are foods with a finished equilibrium pH greater than 4.6 and a water activity greater than 0.85. Acid foods have a natural pH of less than 4.6 (CFR(c), 2011). Acidified foods are low-acid foods to which an acid or acid food is added to produce a food with a final equilibrium pH of 4.6 or less and a water activity greater than 0.85 (CFR(d), 2011). pH is a measure of acidity or alkalinity. Water activity is a measure of the available water in a food (Weddig et al., 2007). The processing requirements are different for low-acid foods and acidified foods. The FDA Canning Regulations, established in 1973, provide guidance and requirements for producing low-acid and acidified food products. The requirements can be found in Title 21 Part 113 and Part 114 of the Code of Federal Regulations. The canning industry has changed substantially in the last two centuries and will continue to evolve as new technologies continue to emerge.

Chapter 4 - Types of Thermal Process Studies

There are two types of studies conducted frequently which are related to thermal processing: temperature distribution and heat penetration. Both are necessary to achieve commercial sterility and are used to develop a scheduled thermal process. Commercial sterility is the condition achieved by the application of heat which renders the food free of microorganisms capable of reproducing in the food under normal storage conditions and distribution; and viable microorganisms (including spores) of public health significance(CFR(c), 2011). A scheduled process is the process selected by the processor as adequate under the conditions of the manufacturer for a given product to achieve commercial sterility (Weddig et al., 2007). More specifically, the Code of Federal Regulations (2011) defines a scheduled process as "the process selected by the processor as adequate under the conditions of manufacture for a given product to achieve commercial sterility. This process may be in excess of that necessary to ensure destruction of microorganisms of public health significance, and shall be at least equivalent to the process established by a competent processing authority to achieve commercial sterility"(CFR(c), 2011).

Temperature distribution studies are tests performed to determine the time, temperature, or other parameters that must be met to ensure uniform temperature distribution is established in the retort system (Canadian Food Inspection Agency, 2008). Heat penetration testing is the measurement of the temperatures at the slowest heating point in a container of food as it is being processed (Alstrand and Ecklund, 1952).

To determine a scheduled thermal process, an acceptable temperature distribution first must be established. Through heat penetration studies, a specific F value is targeted. F is the designation used for lethality and can vary based on the type of product and the conservativeness a process. A more formal description of lethality (F) or process lethality is the time intercept from a thermal-death time curve and and its equivalent time in minutes, at a specific temperature, required to reduce the bacterial load of a target organism whose z value is known. In the canning industry, process lethalitiy is generally expressed as F_o, which is the number of minutes required to destroy a specific organism with a z value of 18°F at a reference temperature of 250°F (Canadian Food Inspection Agency, 2008). The z-value is the temperature coefficient of microbial destruction. It is the number of degrees of temperature change necessary to cause a decimal reduction time (D-value) to change by a factor of ten. D-value is the time required at a temperature, T, to reduce a specific microbial population by ninety percent (Pflug, 2003) or it also can be defined as the time required for a one log cycle reduction in microbial population (Heldman and Hartel, 1998). D-values are measured for different types of vegetative microorganisms, spore populations, food spoilage microorganisms, and microbial pathogens. Generally, as the D-value increases at a given temperature, more thermal resistance is exhibited by the microbial population (Heldman and Hartel, 1998).

Scheduled processes for low-acid canned foods must meet or exceed a 12D process to eliminate *Clostridium botulinum* (FDA, 1987). A 12D process is a 12-log reduction of *C. botulinum* spores in a low-acid canned food (Pflug, 2003) or the equivalent process that provides a one in a billion chance of a surviving spore. Several factors are taken into consideration when calculating a specific D-value, one of them being the species of microorganisms present. Vegetative cells and yeast and molds require lower D-values than thermophylic spores. A greater D-value is required for low-acid foods due to the ability of *C. botulinum* to survive and grow at pH values greater than 4.6. Acidified foods, because of their pH of less than 4.6, inhibit *C. botulinum*. Another factor to consider when determining D-values is the ability of the microbial population to grow in an anaerobic environment. This is critical since canned foods are hermitically sealed. Other factors include water activity levels and food composition (levels of fat, protein, carbohydrates, and other additives) (Heldman and Hartel, 1998).

According to the CFR Title 21 Part 113, “scheduled processes for low-acid foods shall be established by qualified persons having expert knowledge of thermal processing requirements for low-acid canned foods in hermetically sealed containers and having adequate facilities for making such determinations”. Acceptable scientific methods of establishing heat sterilization processes shall include, when necessary, but shall not be limited to, microbial thermal death time data, process calculations based on product hear penetration data, and inoculated packs (CFR(c), 2011).

The results of heat penetration can vary based on factors including but not limited to container size, particle size, and whether the product is subject to convection or conduction treatment. In convection heating, the heat is dispersed by movement or displacement of the material and in conduction heating the temperature is not uniform throughout the product as heat is progressively conducted from the hotter to the colder portions (Larouse and Brown, 1997).

Thermal process authorities, or other designated people within a processing facility, factor in can size, type of product, headspace, fill weight, rotation, as well as other variables when determining a scheduled process for a product. Critical process parameters are defined, and must be followed as part of the scheduled process. A process authority is the person(s) or organization(s) having expert knowledge of thermal processing requirements for foods in hermetically sealed containers, having access to facilities for making such determinations, and designated by the establishment to perform certain functions as indicated in this subpart (CFR(c), 2011).

Bigelow developed the general method of evaluating heat penetration data in 1920 (Park, 1996). Ball developed a newer method in 1923, which allowed for more flexibility in evaluating data. Numerical, a computer-modeling program, was developed in 1988, and provides process authorities an additional tool in creating safe food processes (Park, 1996).

Inoculated pack studies are sometimes desired to confirm the mathematically calculated process (Weddig et al., 2007). In the inoculated pack procedure, the test product is prepared under commercial operating conditions and then the appropriate test microorganism of known heat resistance is added to the product. The product is inoculated with a known number of microorganisms and then processed at a variety of time/temperature combinations. A satisfactory process is one demonstrated by the absence of spoilage (Weddig et al., 2007). For low-acid canned foods, commercial sterility is achieved by destruction of all pathogenic organisms and nonpathogenic spoilage microorganisms such as *Clostridium sporogenes* (PA 3679) allowing canned foods to be shelf stable at room temperature (Weng, 2006).

The organism most frequently used for inoculated pack studies in low acid foods is *Clostridium sporogenes* (PA 3679) which was isolated by the National Canners Association (Esty and Meyer, 1922). It is the only *Clostridium* surrogate for *Clostridium botulinum* (FDA 2000, 2001). *Clostridium sporogenes* is approximately 3 to 5 times more heat resistant than *Clostridium botulinum* (Cameron et al., 1980; Brown, 2000). For example, a thermal process that yields a 5D or 5 log reduction of *Clostridium sporogenes* (PA 3679) is equivalent to a thermal process that would yield a 12D reduction of *Clostridium botulinum*. Therefore, the number of *C. sporogenes* spores used in an inoculated pack study can be reduced. The organism also is nonpathogenic allowing it to be safely used for inoculated pack studies (Grischy et al., 1983).

After companies have developed and validated a scheduled process, there are training requirements that must be met in order for operations to commence. Regulations are enforced for thermally processed low-acid and acidified foods packaged in hermetically sealed containers. These regulations can be found in the CFR Title 21 Parts 108, 113, and 114 (CFR(c)(d)(e),2011). The purpose of the regulations is to prevent public health problems from occurring due to consumption of commercially canned foods. The regulations require that operators of processing and packaging systems and container closure inspectors be under the operating supervision of a person who has attended and successfully completed appropriate instruction prescribed by FDA. The United States Department of Agriculture (USDA) has similar training requirements in their regulations which include regulations for thermally processed meat and poultry products (CFR(a)(b), 2010) and thermally processed low acid animal foods.

CFR Title 21 Section 113.10 related to personnel states: “the operator of processing systems, retorts, aseptic processing and packaging systems (including systems wherein water activity is used in conjunction with thermal processing) and container closure inspectors shall be under the operating supervision of a person who has attended a school approved by the Commissioner for giving instruction appropriate to preservation technology involved and who has been identified by the school as having satisfactory completed prescribed course of instruction. This person shall supervise only in those areas for which a school approved by the Commissioner identifies the person as having, satisfactorily completed training” (CFR(c), 2011).

The training program is referred to as Better Process Control School (BPCS). BPCS provides a practical application of the principles set forth in the regulations. Universities are approved by the FDA to offer these schools which satisfy the FDA, USDA, and state education requirements for canned low acid and acidified foods. Many universities offer BPCS, including but not limited to, Kansas State University, Purdue University, Pennsylvania State University, Washington State University, Ohio State University, and New Mexico State University. For instance, Washington State University offers a two-day course for processors of acidified foods in glass containers as well as the four-day course which covers all process systems and all types of containers and closures. Private instruction tailored specifically to individual company needs is also available (WSU BPCS, 2011).

Chapter 5 - Types of Packaging for Canned/Commercially Sterile Foods

Food products come in a variety of packing materials. Food packaging is an integral and essential part of modern food processing. Packaging has several functions including containment, protection, preservation, distribution, identification and communication, and convenience. A food product must be contained before packaging can protect, preserve, or be used to identify it before transportation. Packaging will protect its contents from the environment and serve as a way to preserve the product for an extended shelf life. Packaging aids in transportation of the product from the production facility to the consumer. Identification and communication panels inform the consumer about what is inside the package. Consumers demand products that fit in their lifestyles so packaging must also make the product convenient (Mauer and Ozen, 2004).

The type of packaging is determined by the type of product it will contain; the type of package consumers expect or demand, as well as processing procedures the packaging must endure. For example, containers that require over-pressure would not do well in a still steam retort. Overpressure during retorting is required to maintain the integrity of containers that, due to package construction and/or type of closure, have a limited resistance to pressure (Weddig et al., 2007),

The packaging part of the canning industry has advanced considerably from the glass jars sealed with corks that Appert used in his early experimentation. Early metal containers were bulky, crude, and difficult to seal. In 1823, a can with a hold in the top was invented allowing the food to be heated in boiling water baths with the hole covered with a loose lid. The lid was then soldered into place after the heat treatment. These cans were known as hole-in-top cans (Desrosier, 1959). In the 1900's, the invention of the sanitary end was a big improvement over the hole-and-cap cans because it allowed larger food particles to be filled without damage to the particles, and the sanitary can lid was able to be applied by machine (National Canners Association, 1971).

Today's canning industry uses a variety of containers to package canned foods. They come in many shapes, sizes, and materials. The main classifications are rigid containers, semi-rigid containers, and flexible containers (Weddig et al., 2007).

A rigid container is neither affected by the enclosed contents nor deformed by external pressure up to 10 psig (Weddig et al., 2007). Glass jars and metal cans are considered rigid containers. The American Society has defined Glass for Testing and Materials as "an amorphous inorganic product of fusion that has been cooled to a rigid condition without crystallizing (ASTM, 2003)." Most glass used in food packaging is a soda-lime glass consisting of silica sand, limestone, soda ash, and aluminum oxide with small amounts of magnesia, ferric oxide, and sulfur trioxide (Mauer and Ozen, 2004). The composition is melted together at very high temperatures exceeding 1500ºC and then cooled to a rigid state.

The two types of glass containers are bottles which have narrow necks and jars which have wide openings. Glass food packages are typically made out of soda-lime glass and are formed by the blow-and-blow process which produces the narrow neck bottles or by the press-and-blow process which produces the wide-mouth jars and (Mauer and Ozen, 2004). For both of these processes a lump of molten glass is transferred from the furnace to a blank mold and then a plunger in the base is used to form the finish. An advantage of glass is its ability to withstand high temperatures that are used in canning operations or hot-fill processes. Glass has other advantages such as chemical inertness, nonpermeability, strength, and resistance to high internal pressure. Clear glass allows the consumer to see the product. Also, glass maintains its normal integrity overtime and weathering is not a problem. Although glass may be fragile and heavy, efforts have been made to increase glass strength by applying hot-end coatings prior to the annealing oven (tin or titanium chloride) or cold end coatings after the annealing process (waxes, silicones, and polyethylenes). The results of these efforts are glass that is lighter and stronger, reducing the weight of bottles and jars by 25 to 50%. An applied coating also helps to prevent scratching (Robertson, 2006; Mauer and Ozen, 2004).

Metal cans may be two-piece or three-piece. Three-piece cans are made from tinplate or electrolytic chromium coated steel sheets and consist of two ends and a body. Two-piece cans are made from electrolytic chromium-coated steel or aluminum sheets and consist of one end and a body (Mauer and Ozen, 2004). These cans are coated on the inside and outside. An example of an internal coating is epoxy and an example of an external coating is modified acrylic (Hormel Foods, 2011). Advantages of using metal cans in canned food packaging are thermal stability, mechanical strength and rigidity, ease of processing on high-speed lines, recyclability, excellent barrier properties, and consumer acceptance. Some disadvantages include the weight of the cans, cost, corrosion, and reactivity with foods, but the advantages outweigh the disadvantages. Cans are most commonly used for thermal processed, shelf-stable food products (Mauer and Ozen, 2004).

A semi-rigid container is a container, the shape or contour of which, when filled and sealed, is not significantly affected by the enclosed product under normal atmospheric temperature and pressure, but which can be deformed by external mechanical pressure of less than 10 psig (Weddig et al., 2007). Plastic containers, plastic trays, and tetra-pak cartons are considered semi-rigid containers. In general, plastics are a group of synthetic and modified natural polymers that can be formed into a wide variety of shapes using heat and pressure. Plastics can be made by compression molding, extrusion, thermoforming, injection molding, and blow molding. Advantages of using plastics include ease and versatility of shaping; plastics are lightweight, and resistant to breakage; and can range from brilliant colors to transparent (Mauer and Ozen, 2004). An example of a plastic container is a plastic microwave cup constructed of layers of polypropylene, regrind, adhesive, and ethyl vinyl alcohol (Hormel Foods, 2011). The plastic microwavable cup is retortable and can be heated by the consumer in the microwave.

A flexible container is a container, the shape or contour of which, when filled and sealed, is significantly affected by the enclosed product (Weddig et al., 2007). Pouches are considered flexible containers. Foils are used in retort pouches as a way to package thermally processed foods because they serve as a barrier to moisture, gases, and light. The layers of a retort pouch, from outside to inside, are polyethylene terephthalate (PET)/adhesive/foil/polyolefin/food product (Mauer and Ozen, 2004) or three film layers consisting of polyester, aluminum foil, and cast polypropylene (Griffin, 1987)

Various research has shown quality attributes are better in pouched products versus canned products (Mohan et. al, 2006); this is due to the reduction of heating time in pouched products. Other advantages of pouches are increased shelf life, lower container weight, decreased storage space, and ease of opening and preparation for the consumer.

Processors have been experimenting with the use of retortable pouches to replace the traditional can. Shrimp are among the most valuable of seafood and are consumed all over the world. Preserving shrimp in a palatable condition is important. Mohan et al. (2006) evaluated the effect of processing time on quality of Shrimp Kuruma in retortable pouches and aluminum cans.

The Shrimp Kuruma formulation used in this study included shrimp, chopped onion, tomatoes, chopped green chillis, ginger pieces, coriander powder, red chili powder, tumeric powder, salt, refined sunflower oil, and water. Shrimp Kuruma weighing 196 g was processed at different F_o values in both cans and pouches and submitted for sensory evaluation. The panel evaluated the product for sensory characteristics using the following scale: like extremely=9 to dislike extremely=1. A score of 6 or higher was considered acceptable (Mohan, et al., 2006).

The time required to heat the 16 cm x 20 cm pouch to a F_o=8 was 33 minutes and 48 seconds compared to 52 minutes and 30 seconds for the 301 x 206 [77 mm x 60 mm (diameter x height)] metal can resulting in a 35% reduction of processing time. In addition, the amount of water loss during thermal processing was 5% less for pouched products versus canned products (Mohan, et al., 2006).

In regards to sensory evaluation scores, the panel rated pouched product as lighter in color and firmer and chewier in texture compared to the canned product. For overall acceptability, both the canned and pouched products received sensory scores of 7.73 and 8.58, respectively and were different ($P>0.05$). Therefore, both types of packaging yielded acceptable products but the pouched products were preferred.

The shape of the packaging can also have an effect on processing time (Table 5.1). The Shaka process was used to compare sterilization times for a 99 mm plastic bowl (double-seamed with a 99 mm diameter easy open end) and a 73 mm x 110 mm metal can at a retort temperature, of 130ºC. The come-up time refers to the time it takes the retort to reach acceptable distribution and the process time refers to the time in minutes it takes to reach an F_o of 5. The come-up time in minutes for the plastic bowl was 20 seconds less than the metal can, and the process time and total time was longer for the plastic bowl than the metal can. Due to the poor conductivity of plastic compared to metal, the total process time was 5 minutes and 20 seconds longer for the plastic bowl (Walden, 2010).

Overall, types of packaging material used for commercially sterile food products are important for determining thermal processing times and end product quality. By knowing the effect different package types have on the food product quality and how certain thermal processing equipment systems can impact different packaging material, good decisions can be made by food processors regarding packaging materials to ensure food products are commercially sterile and meet consumer’s demands.

Table 5.1 Comparative sterilization times for plastic bowl versus metal can using Shaka process[a] (Walden, 2010).

Package Type	Come-Up Time in Minutes:Seconds	Time F_o 5 in Minutes:Seconds	Cooling Time in Minutes:Seconds	Total Time in Minutes:Seconds
99 mm Plastic Bowl	1:40	6:20	3:20	11:20
73 mm x 110 mm Metal Can	2:00	2:20	1:50	6:10

[a]Product in bowl ((double-seamed with a 99 mm diameter easy open end) and metal can consisted of 7% bentonite; process temperature=130ºC; and agitation=150 rpm x 150 mm. The agitation is in revolutions per minute (rpm) of the crank reciprocating the basket and the movement (stroke) of the basket in millimeters (mm).

Chapter 6 - Types of Retorts

Several retort systems are currently in place to provide commercially sterile thermal processes within the U.S. and additional systems can be found worldwide. These include still retorts, hydrostatic retorts, rotary retorts, and agitating retorts (Weddig, et al., 2007). New retorts entering the industry include Shaka retorts (Walden, 2011). Retorts are large processing vessels used to produce commercially sterile food. More specifically retorts are pressure vessels designed for thermally processing food, packed in hermetically sealed containers, by an appropriate heating media and where necessary super-imposed pressure (Canadian Food Inspection Agency, 2008). Retorts are similar to a pressure cooker one can find in a home kitchen in that they are closed vessels that control pressure during cooking. There are multiple designs of retorts and a variety of processing media used to thermally process food products and accomplish commercial sterility for food products.

Processing medias within these retort systems can include steam (moist heat), steam/air (moist heat), water spray (spray heat in liquid), water immersion (immersion heat in liquid), and water cascade (spray heat in liquid). Steam and steam/air are considered direct steam processing media while water spray, water immersion, and water cascade would be considered indirect steam processing media (Weddig, et al., 2007). Still retorts have been in existence since the middle of the 19^{th} century (Walden, 2010). Most early retorts used steam as the method of heating. The traditional still steam retort has been studied and proven over time to administer safe and consistent thermal processes. Still steam retorts also work well for a variety of food products.

The Shaka process is a new methods of thermal processing that is now entering the industry. Shaka uses reciprocal agitation, and can decrease processing times and improve product quality. However the safety margin has yet to be determined for some of these systems.

Batch Retorts

Batch retorts are used in many processing facilities because of their low cost and simple operation. They are also flexible in the types of containers and container sizes that can be processed. However, they have the disadvantage of low heating rates (Saravacos and Kostaropoulos, 2004).

The containers are loaded into crates or baskets and then placed inside the vessel for processing. These retorts can be used for multiple container sizes, common sizes of metal cangs range from 208 x 108 ($2^{8/16"}$ diameter x $1^{8/16"}$ height) metal cans to 603 x 700 ($6^{3/16"}$ diameter x $7^{0/16"}$ height. Once the cans are loaded, saturated steam is used to heat the retort and cold water is used to cool the retort (Saravacos and Kostaropoulos, 2004).

Still Retorts

A still retort is a batch-type, non-agitating pressure vessel for processing foods packaged in hermetically sealed containers. Still retorts can be horizontal or vertical in orientation; horizontal is easier to load and unload, but take up more space (Fellows, 2009). Figure 6.1 shows a schematic drawing of a horizontal still retort and Figure 6.2 shows a schematic of a vertical still retort. A still retort is a closed vessel that is able to withstand the steam pressure required to achieve temperatures up to 140 °C. Therefore, it is important that the seal of the vessel and the contol mechanisms (valves or bleeders) for adjusting steam pressure and temperature, maintain their integrity throughout processing. Still retorts can be heated by steam (moist heat), steam/air (moist heat), water spray (spray heat in liquid), water cascade (spray heat in liquid), or water immersion (immersion heat in liquid) (Weddig et al., 2007).

For pure steam processes, steam is forced into the retort and therefore forces the air out through a venting process. Steam is the most efficient heating medium for containers that do not require over-pressure during the process such as metal cans. During a steam process, a direct temperature/pressure relationship can be observed. Through adequate temperature distribution, as previously defined, an appropriate thermal process can be applied to food products. For controlling thermal process schedules, most still retorts are equipped with continuous recording devices for time and temperature (Helman and Hartel, 1998).

Containers requiring overpressure are better suited to steam/air, water spray, water cascade, or water immersion processes. Steam/air and water cascade are less common and will not be addressed further in this report.

Figure 6.1 Schematic of a horizontal retort (Warne, 1988).

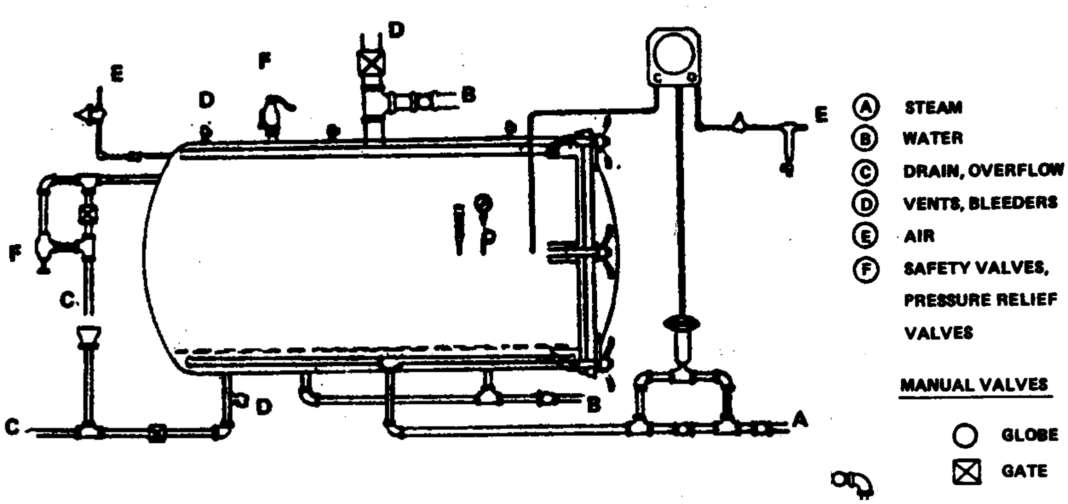
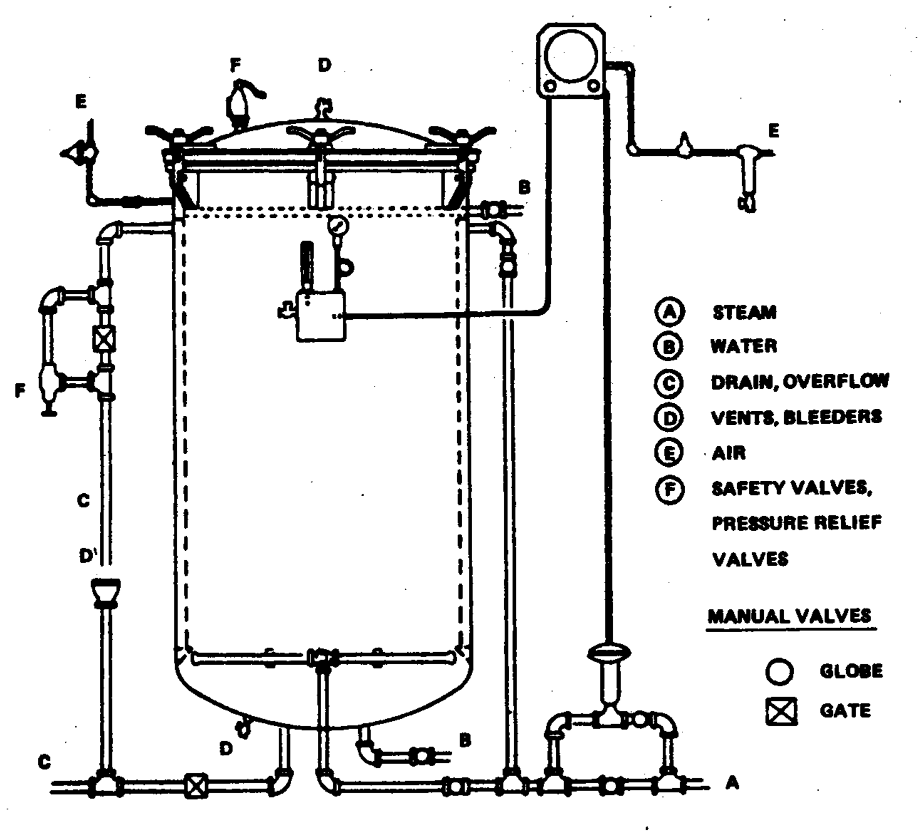


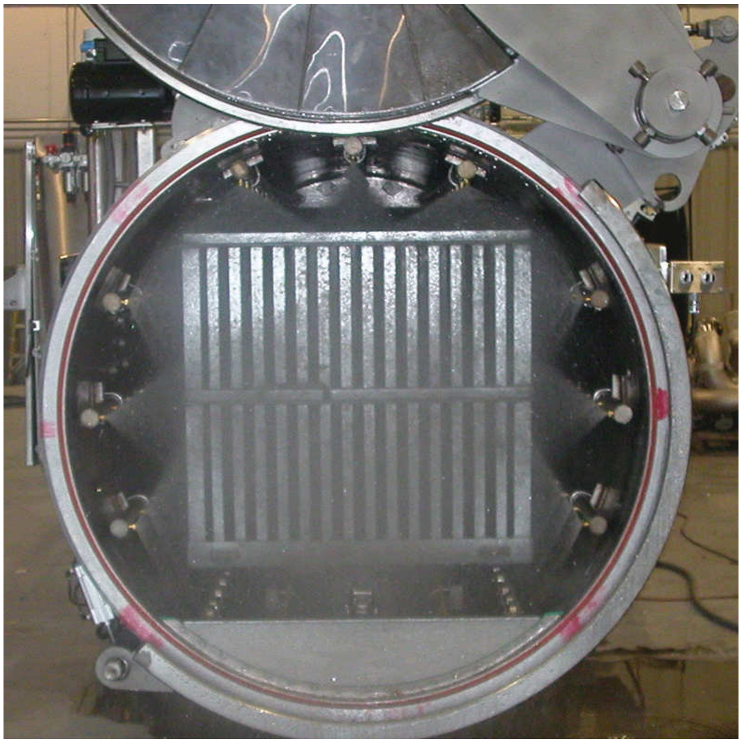
Figure 6.2 Schematic of vertical retort (Warne, 1988).



Water Spray Retorts

Water spray retorts are retorts that operate by circulating water from the base of the retort through an external heat exchanger and then distributing it inside the retort through spray nozzles (Tucker and Featherstone, 2011). These are designed to use a low volume of water that does not completely cover the containers. Figure 6.3 shows an example of a water spray retort with the door open so the flow of water can be seen. These retorts are designed to allow and maintain overpressure which is needed to maintain package integrity for certain types of containers such as glass, plastic trays, large micrwavable bowls, tetra-pak cartons, and pouches. Overpressure retorts are also beneficial for processing containers with easy open ends.

Figure 6.3 Water spray retort (Allpax Products, LLC(b), 2011).



Water Immersion Retorts

Water immersion retorts have processing water that is preheated in the upper vessel and then released at the start of the process to fill the processing vessel or lower vessel. Water is then pumped through an external heat steam injection heat exchanger and back into the top of the same vessel (Tucker and Featherstone, 2011). Figure 6.4 shows an example of an Allpax water immersion retort. Water immersion retorts also have the capability of providing overpressure during the sterilization and cooling processes and therefore can be beneficial for processing containers such as plastic trays and pouches.

Figure 6.4 Water immersion retort (Allpax Products, LLC(c), 2011).

Continuous Retorts

Continuous retorts involve continuous container handling throughout the system. The design is dependent on several factors, including product, container type, and process conditions (Weddig et al., 2007). Continuous retorts provide several advantages including higher production rates, lower operating costs, better process control, and improved product quality (Saravacos and Kostaropoulos, 2004). However, a disadvantage is that the systems can only accommodate a limited range of container sizes (Weddig et al., 2007).

Hydrostatic Retorts

A hydrostatic retort operates at a constant process temperature and has a continuous container carrier chain which transports containers at a constant rate throughout the retort. The carrier chain transports the containers through in-feed legs (also known as water legs), into the steam dome, and then through discharge legs (also know as water legs). This is a continuous process with the containers remaining in a static position in the carrier chain. These systems are beneficial when producing a large number of containers that are uniform in size, such as a large quantity of chili in a 300 x 407 metal can. The main heating occurs in the sterile dome which is a pure steam environment. Figure 6.5 shows the schematics of a hydrostatic retort. Hydrostatic retorts generally do not allow overpressure capabilities (Weddig et al., 2007).

Figure 6.5 Schematic of a hydrostatic retort with a standard steam cook sterilizer (JBT Foodtech(a), 2011).

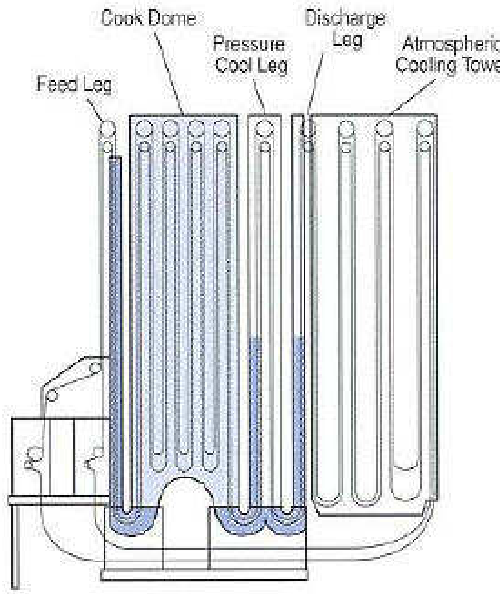
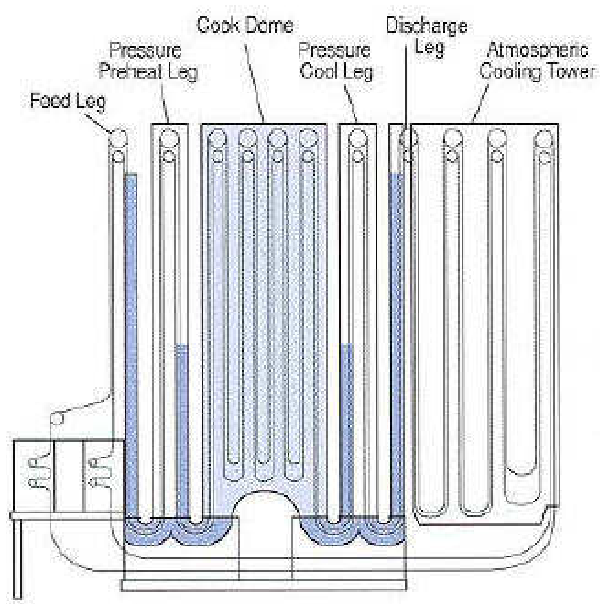


Figure 6.6 Schematic of a hydrostatic retort with an overpressure sterilizer (JBT Foodtech(a), 2011).



Rotary Retorts

A continuous rotary retort provides continuous container handling and intermittent product agitation. These retorts are sometimes referred to as continuous agitating retorts. Figure 6.6 shows a bank of rotary retorts in a retort room. The continuous process includes both heating and cooling. These retorts are typically set up for one container size and work well for operations with large volumes of that container size. These retorts allow for side-over-side (or axial) rotation during the process. This slight agitation and movement of the headspace bubble allows the product to have better heat penetration and a slightly decreased processing time. The negative aspect of this retort system is the increased sensitivity to process variables and the number of critical limits that must be monitored and met. In addition to minimum process time and minimum process temperature; critical factors include but are not limited to reel speed and container head space (Weddig et al., 2007).

Figure 6.6 Continuous rotary retort (JBT Foodtech(b), 2011).

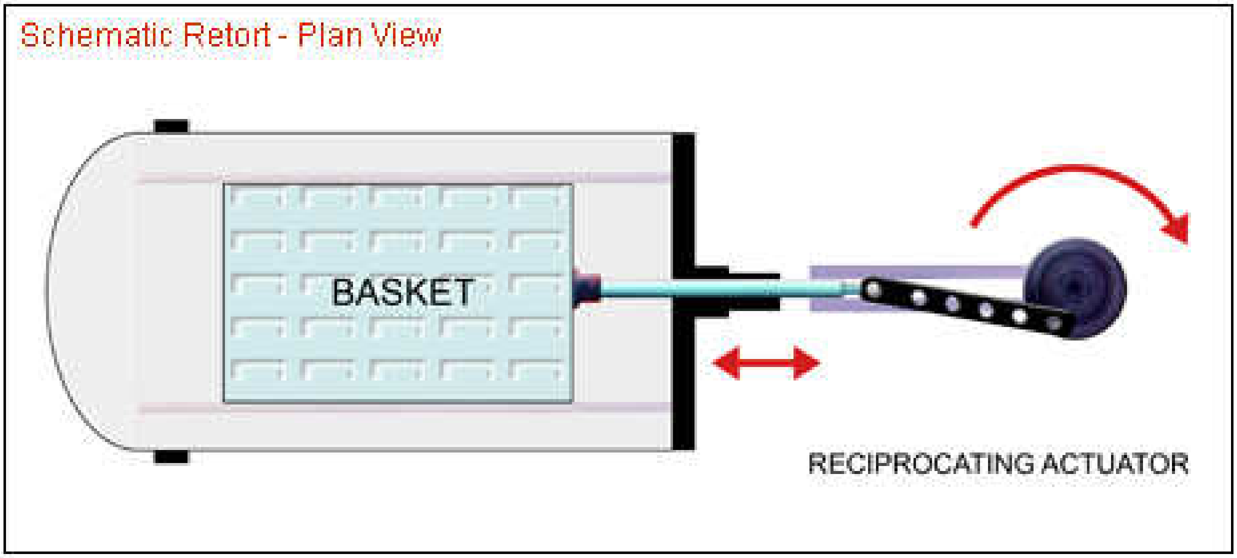
Batch Agitating Retorts

A batch agitating retort is a processing vessel that uses steam, water, or steam/air mixture that processes the product while providing product agitation. These are also known as discontinuous batch retorts. Product agitation is achieved through end-over-end agitation or side-over-side agitation. The containers normally receive agitation during the entire scheduled process. Similar to rotary retorts, additional critical factors must be taken into consideration such as head space and rotational speed. Several advantages of these systems include increased agitation and reduced process time, which can lead to increased product quality. These systems can generally rotate more quickly than a rotary retort because the containers are secured within a crate or basket during processing. Rotational speed capabilities will vary by manufacturer (Weddig et al., 2007).

Shaka Retorts

A Shaka retort is a recent technology on the market for thermal processing of foods. The first pilot Shaka retorts were manufactured in 2006 (Walden, 2010). The Shaka retort is equipped with high frequency longitudinal agitation (Tucker and Featherstone, 2011). The Shaka retort was first developed in the United Kingdom ten years ago by Richard Walden (Dunn, 2009). The Shaka retort is one of the first major improvements to retorts in over 60 years. It is still a relatively new and unproven process. This system utilizes a current retort system and adds licensed technology to induce a vigorous shaking motion. The Shaka system is fundamentally different in that it uses reciprocal agitation in addition to gravity (Walden, 2010). Figure 6.7 shows a schematic view of the Shaka process as well as the reciprocating actuator.

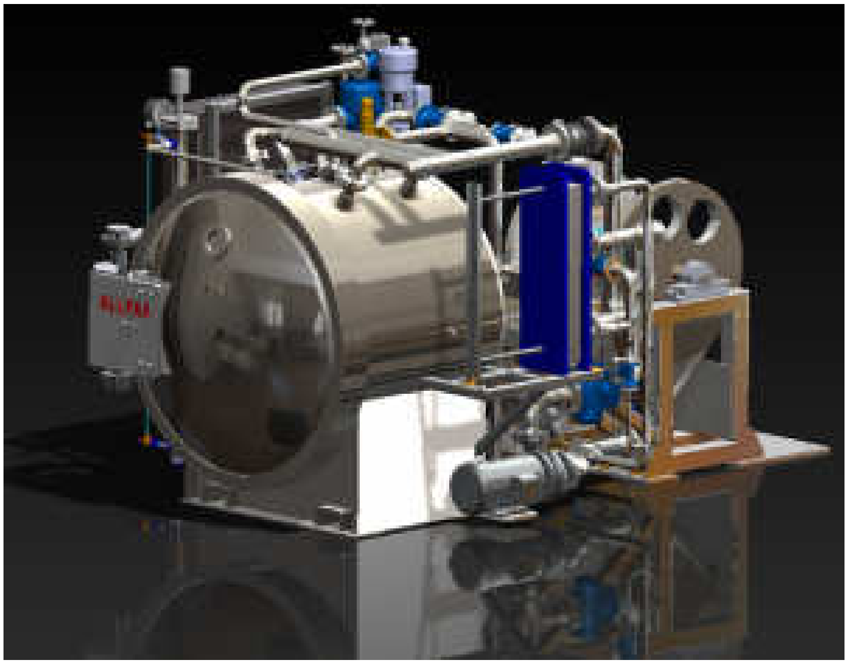
Figure 6.7 Shaka retort – schematic view of the Shaka system (Zinetec, 2009).



Allpax, a U.S. based manufacturer located in Covington, LA, is currently licensed to use the Shaka technology in their water spray retort system and Steriflow, a European based manufacturer located in Paris, France, is licensed to use the Shaka technology in their water drench (water cascade) retort system. Figure 6.8 shows a prototype of the Allpax Shaka retort. By shaking cans and jars during sterilization the Shaka process can dramatically cut down the time it takes to commercially sterilize, or thermally process, canned and bottled foods. This process can commercially sterilize a 400 g product in approximately six or seven minutes verses the normal 90 minutes required from a still process (Dunn, 2009). The drastic time reduction by Shaka can allow for larger throughput through the process facility. This process time reduction is even greater when comparing the difference between a still retort time and a rotary retort time. The Shaka system also can allow for better quality characteristics such as more desirable color, less burn on, improved texture, and higher nutrient retention.

Like all retort systems, Shaka has some drawbacks. These include uncertainness of consistent processing due to unknown and moving cold spots in the containers (Dunn, 2009). With Shaka's drastically reduced process time, the processing variables must be held to a tighter standard to prevent and eliminate the potential for under-processed containers of food.

Figure 6.8 Allpax Shaka prototype (Allpax Products, LLC(a), 2011).



The first prototype Shaka retort was large enough to hold fifty 73 mm x 110 mm cans, allowed strokes of 25-300 mm and rotational speeds up to 250 rpm, and was able to come up to temperature quickly and cool down quickly (Walden, 2010). The Allpax Shaka water spray production retort is a 1300 mm (52 inch) diameter unit that holds one crate. The Steriflow Shaka water cascade production retort is also a 1300 mm (52 inch) diameter unit that holds one crate. Standard water spray retorts and water cascade retorts can be found in a variety of diameters ranging from 600 mm (24 inch) diameter to 1800 mm (72 inch) diameter and range from one basket to eight baskets in length. The number of containers that each unit can hold will vary based on retort diameter, number of baskets per retort, as well as container size and type of container racking system.

The initial validation, which consisted of microbiological studies as well as studies consisting of various Bentonite concentrations, was sufficient to apply for and be granted a patent. The Zinetec Shaka process was granted European patent number EP0804095 and U.S. patent number 5,854,312 (Walden, 2010). Part of the initial validation was to conduct microbiological challenge studies to compare calculated F_o values and actual bacterial kill. *Bacillus stearothermophilus* and *Clostridium sporogenes* were used and were inoculated in a nutrient broth for these tests. Table 6.1 illustrates that there was good correlation between the F_o value achieved and the bacterial kill.

Table 6.1 Microbiological challenge experiments comparing F_o and F_s values using the Shaka process (Walden, 2010).

	Thermal Lethality (F_o)[a]	Bacterial Kill (F_s)[b]
Bacillus stearothermophilus	12.6 – 13.2	13.0 – 18.1
Clostridium sporogenes	4.4 – 5.7	4.0 – 7.6

[a] F_o=Mathematically calculated thermal lethality.

[b] F_s=Actual bacterial kill from thermal death time studies.

Research was also conducted on optimal agitation speeds as outlined in Table 6.2 and Table 6.3. Bentonite was used to simulate a conduction heating product. Bentonite is inert and can be thermally processed repeatedly without its characteristics being changed (Walden, 2010).

As presented in Table 6.2, a small amount of reciprocal motion made an improvement in the heat up process time. The reciprocal motion is made up of two parts: the revolutions per minute (rpm) of the crank reciprocating the basket and the movement (stroke) of the basket in millimeters (mm). The reciprocal motion combinations ranged from a stroke of 25 mm to 300 mm and 40 rpm to 230 rpm. The reduction from a 50 minutes static process time to a 37 minutes Shaka process time at 100 rpm and 25 mm to a 1:50 min:sec Shaka process time at the optimum 140 rpm and 300 mm (Walden, 2010).

The same reciprocal motion that helps to heat products more quickly, and therefore reduces cook times, also allows the product to cool more quickly and reduce the overall process time. As presented in Table 6.3, for a static process it took the container 43:15 minutes and seconds to cool from 120 to 40ºC. During the Shaka process, it took 22:10 minutes to cool at 80 rpm and 50 mm and 1:47 minutes to cool at the optimum 140 rpm and 300 mm (Walden, 2010).

Studies have been conducted on products containing particulates such as vegetable soup. Therefore, the reduction in overall process time depends on the size of the particulate as heat transfers into the center of a particulate through conduction (Walden, 2010). As more research is conducted, and commercial units begin to be used more will be understood about this new and novel retorting technology.

Table 6.2 Heat up times to 120ºC from steam on for variety of agitation conditions using Shaka process[ab] (Walden, 2010).

	Revolutions per minute (rpm) of the crank reciprocating the basket										
Movement (stroke) of the basket in millimeters (mm)	40	60	80	100	120	140	160	180	200	220	230
	Time in minutes:seconds for each combination to reach 120ºC										
25	-	-	-	37:00	7:05	7:00	7:08	6:55	6:24	5:10	5:22
50	-	-	35:07	6:24	5:24	5:06	4:23	3:48	3:21	2:49	2:51
75	-	-	6:56	4:35	4:15	3:23	2:54	2:44	2:38	-	-
150	-	8:15	3:43	3:20	2:48	2:26	2:07	2:03	-	-	-
225	-	5:46	2:58	2:44	2:15	1:59	1:55	-	-	-	-
300	27:02	4:12	2:28	2:18	1:53	1:50	-	-	-	-	-

[a]Product in 73 mm x 110 mm metal can consisted of 8% bentonite; process temperature=130ºC; and varying agitation speeds. The times in min and seconds to reach 120ºC.
[b]For the still process (no agitation), the time to reach 120ºC = 50 min.

Table 6.3 Cooling time from 120 to 40ºC for variety of agitation conditions using Shaka process[ab] (Walden, 2010).

	Revolutions per minute (rpm) of the crank reciprocating the basket									
Movement (stroke) of the basket in millimeters (mm)	40	60	80	100	120	140	160	180	200	230
	Time in minutes:seconds for each combination to cool from 120 to 40ºC									
25	-	-	-	-	9:33	8:09	6:58	6:51	5:23	4:20
50	-	-	22:10	6:57	5:34	4:55	4:03	3:34	3:13	2:52
75	-	-	7:38	5:06	4:06	3:42	3:10	2:49	2:34	2:27
150	-	7:06	4:25	2:56	2:37	2:15	1:59	1:49	-	-
225	-	6:19	3:48	2:38	2:11	1:54	1:48	-	-	-
300	14:00	4:52	3:05	2:20	1:59	1:47	-	-	-	-

[a]Product in 73 mm x 110 mm metal can consisted of 7% bentonite; and varying agitation speeds. The times in minutes and seconds to cool from 120 to 40ºC.
[b]For the still process (no agitation), the time from 120 to 40ºC = 43:15 min:sec.

Chapter 7 - New Technologies Impact on Processing Time

In thermal processing (Chapter 4), a specific F_o value is targeted to establish a commercially sterile product. Thermal process authorities, or other designated personnel within a processing facility, factor in container size, type of product, head space, fill weight, rotation, as well as other variables, in order to determine and establish a scheduled process for a food product, as well as the critical process parameters. Historically, food products processed in still retorts require longer thermal processing schedules and time and temperature are the main critical factors to monitor during processing. Other factors might include fill weight or product formulation. Rotary processes have slightly shorter processes but have additional critical factors to take into account such as head space and viscosity. Newer technologies, such as Shaka, have the potential for drastically reducing thermal processing times because of the vigorous shaking during the commercial sterilization process. It is likely the critical factors will be even more stringent for this technology because of the unknowns that may be introduced and the margin of safety that needs to be ensured (Walden, 2010).

Still retort systems, such as the tradition steam retort and the water-spray retort, are efficient and are well known vessels for processing foods. The still process does not allow for food particles to move around in the container and therefore, the cold spot in the container will heat more slowly. Since commercial sterility must be achieved for all particles in the container, sufficient heat must reach all food particles including the cold spots. To achieve this in a still process, processors often overcook products and this leads to increased utility costs as well as decreased product quality. Undesirable quality characteristics might include burn-on or burnt flavor as well as darker coloring then a fresh product along with reduction in nutritional content (Dunn, 2009).

Rotary retort systems allow the containers to rotate, and therefore the food particles are able to move a small amount during the process. This small amount of mixing allows the container to heat more rapidly and therefore, the container’s cold spot is heated more rapidly. This can allow for a shorter process time and an improvement in product quality. The amount of improvement will vary depending on the specific retort system and the type of product being processed. Rotation can be accomplished through side-over side rotation, also referred to as axial rotation, or end-over-end rotation (Wedding et al., 2007).

Ansur et al. (2008) studied the effects of using still retort processes versus rotary processes on thermally processed mackerel packaged in aluminum cans with a 236.6 ml (8 oz) fluid capacity. They studied various accumulated lethal rates (F_o) in a still and rotated retort process (at various rpms). The raw materials were controlled throughout so they would not be a determining factor. Table 7.1 summarizes their results. As expected, to increase lethality, processors must increase process time or increase process temperatures, both which can have a negative effect on food quality depending on the food product in question. Also, as indicated in the study by Ansur et al. (2008) increasing the rotation has the potential to decrease processing. For instance when F_o=9 for the still retort (0 rpm) the process time was 45:05 min:sec and when the rotary retort was 2, 4, and 6 rpm the process time was 42:10, 41:23, and 38:13 min:sec, respectively resulting in process reductions of 2:49, 3:43, and 6:52 min:sec, respectively over the still process. Therefore, rotation reduces processing time while still achieving the target lethality. The reduction of processing time, even when minimal, can increase product capacity and decrease energy consumption (Ansur et al., 2008).

Table 7.1 Comparison of still retort and rotary retort for time, F_o[a] and rpm[b] at 121.1°C processing temperature (Ansur et al., 2008).

Still Retort		Rotary Retort	
F_o, Rotation Speed	Time in Minutes:Seconds	F_o, Rotation Speed	Time in Minutes:Seconds
F_o=5, 0 rpm	34:04	F_o=9, 2 rpm	42:17
F_o=7, 0 rpm	41:17	F_o=9, 4 rpm	41:23
F_o=9, 0 rpm	45:05	F_o=9, 6 rpm	38:13

[a]F_o=Mathematically calculated thermal lethality.

[b]rpm=Rotation speed in rotations per minute.

The Shaka process, with its licensed reciprocal motion, has made some remarkable reductions in processing times. The current Shaka process has a stroke of about 150 mm and at most 150 rotations per minute (rpm's), which is slightly less then the initial pilot model allowed. This process is best suited for homogenous products, such as soups and sauces, or for products with small particulates. Table 7.2 summarizes five studies by Richard Walden, director of Zinetec and founder of Shaka, showing the reductions in processing times from a still process to a rotary process to the Shaka process. The still process has no agitation, the rotary process has a rotation speed of 15 rpm, and the Shaka process has an agitation of 150 mm x 180 rpm. The still and rotary processes utilize a 121°C retort temperature and the Shaka process utilizes a 131°C retort temperature. Many products do not perform well at high temperatures for a long time, but the Shaka process has a short overall process time so they are able to utilize a slightly higher retort temperature. The higher retort temperature will have an effect on the heating rate of the product but this will be small because of the short process times. For example, the pea and ham soup in a 300 x 406 metal can, had a come up time of 2 minutes for a still process, 5 minutes for a rotary process, and 2:05 min:sec for a Shaka process. The process time was 72 minutes for a still process, 36 minutes for a rotary process, and 1:25 minutes:seconds for a Shaka process. The cooling time for a still process was 50 minutes, 17 minutes for the rotary process, and 2:20 min:sec for the Shaka process. The overall time was 124 minutes for the still process, 58 minutes for the rotary process and 5:50 min:sec for the Shaka process for an overall reduction of 66 minutes from still to rotary and 52:10 minutes:seconds from rotary to Shaka process.

When comparing total process reduction times, the reductions ranged from 27 to 53% from still to rotary, and from 83 to 95% from still to Shaka. Instead of thermal processes taking hours, processes can be completed in a manner of minutes and seconds. The time reduction allows a single basket Shaka retort to replace a full-size, multi-basket, still or rotary retort saving space and utilities.

In addition to time savings the Shaka process could lead to improvements in energy reduction and sustainability. Based on some pilot model studies, the Shaka process appears to save 53% of the energy compared with a 2-basket static and 66% compared with a 2-basket rotary using the saturated steam process. For water spray, the energy savings are estimated at 10% and 39%, respectively (Walden, 2009). More research will be needed to be conducted to see how these numbers compare to savings in full-scale production model retorts.

Table 7.2 Comparing Shaka[a], rotary[b], and still[c] process schedules in a variety of products and containers (Walden, 2011).

Product / Container	Process Type	Agitation Speed	Retort Temperature °C	Come Up Time in Minutes[d]	Process Time F_o 6 in Minutes	Cooling Time in Minutes	Total Time in Minutes
Pea & Ham Soup Metal Can 300 x 406	Shaka	150 mm x 180 rpm	130	2:05	1:25	2:20	5:50
	Rotary	15 rpm	121	5	36	17	58
	Still	None	121	2	72	50	124
4 Cheese Sauce Metal Can 300 x 406	Shaka	150 mm x 180 rpm	130	1:55	3:50	3:30	9:15
	Rotary	14.5 rpm	121	6	35	29	70
	Still	None	121	5	84	54	143
Country Vegetable Soup Metal Can 300 x 406	Shaka	150 mm x 180 rpm	130	2:05	1:25	2:20	5:50
	Rotary	14.5 rpm	121	8	35	16	59
	Still	None	121	5	70	48	123
Pea & Ham Soup Pouch	Shaka	150 mm x 135 rpm	130	1:29	4:31	3:00	9:00
	Rotary	15 rpm	121	5	21	14	40
	Still	None	121	1.5	30.5	22.5	54.5
White Sauce Metal Can 300 x 406	Shaka	150 mm x 180 rpm	130	1:54	2:42	3:54	8:30
	Rotary	15 rpm	121	6	42	28	76
	Still	None	121	5	82	60	147

[a]The Shaka agitation is in revolutions per minute (rpm) of the crank reciprocating the basket and the movement (stroke) of the basket in millimetres (mm).

[b]The rotary agitation is in revolutions per minute (rpm).

[c]The still process requires no agitation.

[d]Minutes:seconds.

Chapter 8 - New Technologies Impact on Food Quality

Consumers are demanding higher quality food that is safe. Consumers prefer fresh foods to processed foods.

Ansur et al. (2008) also studied the effects of product quality between a still and rotary process. The raw materials were controlled throughout the study so that they would not be a factor when determining quality and sensory attributes. A process time of F_o=9 produced a product with the most acceptable sensory attributes (soft bone and firm texture)

In a study by Mritunjay and Ramaswamy (2010), heat transfer rates were compared for end-over-end and axial rotation using glycerin to simulate Newtonian fluids with a broad range of viscosities. Rapid and uniform heating helps to promote higher quality canned products because the target lethality can be achieved with minimum destruction of the food color, texture, and nutrients. The two different methods or rotational cooking, end-over-end and axial, help achieve uniform heating. Minimal agitation helps achieve a uniform product that can be heated without too vigorous a motion that has the potential to break up or destroy a product from a quality perspective. A headspace bubble, or space towards the top of the container, allows movement within the container during the rotation process. Axial rotation is more commonly found in continuous rotary retorts and end-over end is found in batch retorts. Mritunjay and Ramaswamy (2010) concluded that axial rotation better preserves the quality of the product due to the fact that it was better at achieving uniform heating, although both methods can have advantages over a still process.

Shaka's drastically reduced processing times previously discussed have an impact on food quality. As consumers demand higher quality, fresher food products, the short process time of Shaka produces a food product that is comparable to aseptic processing and unretorted food products. For example, quality improvement has been demonstrated with soups, sauces, ready meals, spreads, dips, desserts, beverages, baby food, and pet food. It has the potential to improve color, flavor and texture, and because of the shorter time, and therefore less thermal burden, it means that flavor enhancers and artificial colors can likely be reduced (Walden, 2010). The improvements seen in quality allow the Shaka process to produce a retortable, shelf stable product similar to products found in aseptic processing or products that can be found in the freezer or refrigerated section of the grocery store.

Chapter 9 - Conclusion and Future Work

In summary, technologies currently employed in the food industry for commercially sterilizing food products each have their own set of benefits as well as downsides. It is a matter of matching the correct processing system to the correct food product in order to reach the optimum result.

Overall, thermal processing at higher temperature for shorter times has the potential to produce a product that has more desirable quality characteristics. Some research studies showed that rotation during the commercial sterilization process could lead to shorter processing times because a forced convection environment is created in place of a standard conduction environment. The shorter process time has the potential to lead to the increase in desirable quality characteristics as well as increased production capacity. Shaka, because of its newness to the industry, still has many questions that need to be answered. Like some agitation processes, Shaka has the potential to increase product quality. The results are comparable to products produced in an aseptic process or ultra high temperature (UHT) process, both of which are non-retort type processes that produce high quality food products. Shaka processes also reduce total process time.

Future work will need to be conducted when the Shaka process goes into commercial production. More research and commercial validation is needed regarding the Shaka process to determine whether it will be economical and whether the quality improvement will justify the potential cost increase. More research is needed for the food industry to deem the Shaka process as a viable commercial sterilization option for foods since the margin of error is much smaller than is allowed in a traditional still retort system. Shaka, and other agitation based retort systems, have their limits on the type of food products that can handle the movement and mixing within the container. Additional retort technologies that are currently being introduced to the food industry and will need to be researched further include Allpax's Gentle Motion retort system, JBT Foodtech's Super-Agi retort system, and Surdry's Oscillating retort systems.

As the food industry continues to learn and conduct more research on new retort systems, there is the potential for these systems to replace the traditional retort systems. New retort technologies, when properly researched and used correctly, have the potential to continue to revolutionize the canning industry.

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