A method, apparatus and system for low-temperature hot-filling of a flowable food product into a sterilized container is disclosed herein. The low-temperature hot-filling temperature preferably ranges from 60°C to 82.2°C. The method applies a solution of hydrogen peroxide onto the packaging and an alkaline solution to react with the hydrogen peroxide to generate hydroxyl radicals to kill microorganism. The use of an alkaline solution allows the sterilization process to proceed at a lower temperature and a faster rate. A solution of sodium hydroxide is the preferred alkaline solution. The temperature of the process is preferably below 100°C.
Providing a container having interior surfaces and exterior surfaces

Applying a solution of 1-50% hydrogen peroxide at a temperature of from 35 to 100°C on the interior surfaces and exterior surfaces of the container

Apply an alkaline solution having a pH ranging from 10 to 14 on the interior surfaces and exterior surfaces of the container

Rinsing the interior surfaces and the exterior surfaces of the container to remove hydrogen peroxide residue

FIGURE 1
30 Providing a bottle composed of PET and having interior surfaces and exterior surfaces

31 Applying a solution of 1-50% hydrogen peroxide at a temperature of from 35 to 100°C on the interior surfaces and exterior surfaces of the bottle

32 Applying a 1 Normal solution of sodium hydroxide at a pH ranging from 10 to 14 and a temperature of 65°C on the interior surfaces and exterior surfaces of the bottle

33 Rinsing the interior surfaces and the exterior surfaces of the bottle to remove hydrogen peroxide residue

FIGURE 2
Providing a bottle composed of PET and having interior surfaces and exterior surfaces

Applying a 0.25% Normal solution of sodium hydroxide at a pH of approximately 12.5 and a temperature of 35 to 100°C on the interior surfaces of the bottle

Applying a solution of from 1-50% hydrogen peroxide on the interior surfaces and exterior surfaces of the bottle

Rinsing the interior surfaces and the exterior surfaces of the bottle to remove hydrogen peroxide residue

FIGURE 3
Providing a container having interior surfaces and exterior surfaces

Applying a solution of 1-50% hydrogen peroxide at a temperature of from 35 to 100°C on the interior surfaces and exterior surfaces of the container

Applying a 1 Normal solution of ferrous sulfate on the interior surfaces and exterior surfaces of the container

Rinsing the interior surfaces and the exterior surfaces of the container to remove hydrogen peroxide residue

FIGURE 4
METHOD AND APPARATUS FOR STERILIZING AND FILLING CONTAINERS

CROSS REFERENCES TO RELATED APPLICATION


STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention is related to a method and apparatus for sterilizing and filling containers. More specifically, the present invention relates to a method and apparatus for sterilizing and hot-filling containers at relatively low temperatures.

[0005] 2. Description of the Related Art

[0006] The introduction of heat-set polyethylene terephthalate ("PET") bottles in the late 1980s revolutionized the beverage industry by providing a heat-stable plastic container suitable for the hot-filling of high-acid beverages. The bottles used for this process were blow molded into heated cavity molds with a residence time which allowed the molecules of the plastics to orient. Thus, they became resistant to deformation by heat and could be "hot-filled." Sterilization of food and medicinal packaging is necessary to kill microorganisms that may be present on the packaging. The failure to properly sterilize food packaging could lead to contamination of the food within the packaging, which could lead to sickness and sometimes death to a consumer of the food. The food industry has developed various methods to sterilize food packaging to create aseptic packaging.

[0007] Traditional aseptic packaging is typically sterilized using hydrogen peroxide. As set forth in Title 37 of the Code of Federal Regulations ("CFR"), Section 178.1005, the U.S. Food and Drug Administration ("FDA") has determined that a hydrogen peroxide solution containing not more than 35% hydrogen peroxide may be safely used to sterilize polymeric food-contact surfaces. Sterilization using hydrogen peroxide typically requires high temperatures or ultraviolet light to generate hydroxyl radicals from the hydrogen peroxide, which in turn inactivate the microorganisms on the packaging material. The temperature needed to generate free radicals from the hydrogen peroxide is usually in excess of 65°C and is frequently in the range of 120-135°C.

[0008] Most food packaging is composed of a polymer material such as plastic bottles. The FDA has provided a list of polymer materials that may be utilized with hydrogen peroxide. The list, set forth in 37 CFR 178.1005(e), includes ethylene-acrylic acid copolymers, ethylene-carbon monoxide copolymers, ethylene-methyl acrylate copolymer resins, ethylene-vinyl acetate copolymers, ionomeric resins, isobutylene polymers, olefin polymers, polycarbonate resins, polyethylene terephthalate ("PET"), poly-1-butene resins and butane/ethylene copolymers, polystyrene and rubber modified polystyrene polymers and vinylidene chloride/methyl acrylate copolymers. Sterilization of plastic bottles is difficult at elevated temperatures since the bottles become quite fluid and deform during the sterilization process. In addition, an extended drying process is required to evaporate the residue of peroxide (35%) which boils at 108°C. Further, some plastic materials like PET bind, adsorb or absorb peroxide making it very difficult to achieve the residue limit of 0.5 parts per million ("ppm") for food packaging required by the FDA as set forth in 37 CFR 178.1005(d).

[0009] One method of sterilization is disclosed in Sizer et al., U.S. Pat. No. 5,326,542 for a Method And Apparatus For Sterilizing Cartons, which discloses using ultraviolet light to sterilize food cartons.

[0010] Another method is disclosed in Sizer et al., U.S. Pat. No. 5,770,232 for a Method Of Disinfecting The Food Contact Surfaces Of Food Packaging Machines And Disinfecting Solution Thereof, which discloses using a solution of 0.1% to about 1% by weight of hydrogen peroxide and from about 0.001% to about 0.1% by weight of sodium pyrophosphate at a temperature of about 70°C for at least fifteen minutes.

[0011] Another method is disclosed in Frisk, U.S. Pat. No. 5,928,607 for a Bottle Sterilization Method And Apparatus, which discloses using ultraviolet radiation from an excimer lamp to generate ozone from oxygen to sterilize plastic bottles.

[0012] Another method is disclosed in Lentch et al., New Zealand Patent Number 282691 for a Method For Sanitizing And Destaining Food Ware And Utensils Using A Composition Comprising Peroxyacetic Acid, Carboxylic Acid, Peroxide And A Carrier, discloses a sanitizing concentrate composition of 1-20% weight % peroxycarboxylic acid, 10-50 weight % carboxylic acid, 3-35 weight % hydrogen peroxide and the balance a carrier.

[0013] Yet another method is disclosed in Wang, European Patent Number 0411970 for Sterilization Of Containers By Means Of Hydrogen Peroxide, Peroxides, And U.V. Radiation, which discloses using between 15 to 25% concentration of hydrogen peroxide and peracetic acid at a temperature of 20-30°C with U.V. light at a wavelength of less than 300 nanometers for 8-12 seconds to effectuate a greater than 6.0 log reduction in the number of B. subtilis spores.

[0014] Yet another method is disclosed in Smith et al., U.S. Pat. No. 6,479,454 for Antimicrobial Compositions And Method Containing Hydrogen Peroxide And Octyl Amine Oxide, which discloses using a composition of an amine oxide hydrogen peroxide to sanitize food contact surfaces.

[0015] Another method is disclosed in Taggart, U.S. Pat. No. 6,209,591 for an Apparatus And Method For Providing Container Filling In An Aseptic Processing Apparatus, which discloses spraying atomized hydrogen peroxide onto bottles within a sterilization chamber that has sterile air present at a temperature of 135°C.

[0016] Another method is disclosed in Taggart, U.S. Pat. No. 6,536,188 for a Method And Apparatus For Aseptic Packaging, which discloses spraying hot hydrogen peroxide onto bottles, allowing approximately 24 seconds for activa-
tion and removal of the hydrogen peroxide, and then filling the bottle with a low acid beverage.

[0017] Hall, II et al., U.S. Pat. No. 5,344,652 for an Anticorrosive Microbicide discloses a two-part component containing a first part of hydrogen peroxide, peracetic acid and acetic acid, and a second part of VICTAWET®, which is a sodium hydrogen peroxide reaction product of an aliphatic alcohol (2-ethyl hexyl) and phosphorous pentoxide. The VICTAWET® reduces the corrosiveness of the peroxide/peracetic biocide.


[0019] Japanese Patent Publication Number 02-154763 for a Method For Removing Hydrogen Peroxide discloses removing excess hydrogen peroxide from soft contact lenses subjected to a hydrogen peroxide sterilization treatment by using a removing agent essentially consisting of sodium thiosulfate, sodium pyruvate, peroxidase and a metallic catalyst, with the soft contact lenses also subjected to ultrasonic waves.

[0020] Japanese Patent Publication Number 07-291236 for a Method Of Sterilizing Food Container discloses using hot water with a germicide forced into an interior of a food container, with the germicide being hydrogen peroxide, peracetic acid, mixture of hydrogen peroxide and peracetic acid or sodium hypochlorite.

[0021] Production of beverages for filling in PET bottles was accomplished by heating the fluid food product in a continuous flow heat exchanger to a temperature appropriate (~195°) for the inactivation of both spoilage and pathogenic bacteria. The product was then held for 10-30 seconds in a hold tube, trim cooled to 185° F., and filled into the heat-set PET bottle. The PET bottle was then capped and tilted on its side to simultaneously sterilize both the container and the bottle cap. Following this step, the product, inside the PET bottle, was cooled in a cooling tunnel to ambient temperature.

[0022] One of the problems with this technology was inefficiency in the manufacturing of PET bottles since the blow molding equipment for manufacturing the PET bottles was required to operate at very low production rates to allow for the crystallization of the PET resins during the formation of the PET bottles. Reducing the temperature of the blow molding cavity would allow the blow molding equipment to be operated at higher production rates, however the resulting PET bottle would not possess the necessary "heat set" characteristics required for hot-filling.

BRIEF SUMMARY OF THE INVENTION

[0023] The present invention provides a solution to the need for a low temperature sterilization and low temperature hot-filling process. The present invention is able to accomplish this by using a two component solution of hydrogen peroxide and an alkaline solution for sterilization which permits low temperature hot-filling of a sterilized container. The alkaline solution quickly reacts with hydrogen peroxide to generate active oxygen species including hydroxyl radicals to destroy microorganisms.

[0024] One aspect of the present invention is a method for aseptically hot-filling packaging. The method begins by applying a hydrogen peroxide solution having from 1% to 50% hydrogen peroxide to packaging. The hydrogen peroxide solution is applied at a temperature ranging from 35°C to 100°C. Next, the hydrogen peroxide solution is permitted to activate on the packaging for an activation period of at least about one second. Next, an alkaline solution is applied to the packaging subsequent to the activation period. The alkaline solution has a pH in the range of 10-14. The alkaline solution is applied at a temperature ranging from 35°C to 100°C. Next, the packaging is rinsed with sterile water to remove the residue alkaline solution and residue hydrogen peroxide. Next, the sterilized packaging is conveyed to a filling station. Next, a fluid food product is hot-filled into the sterilized packaging at the filling station to create a hot-filled packaging. The temperature of the fluid food product ranges from 140°F to 180°F during the hot-filling. Next, the hot-filled packaging is cooled at a temperature less than 100°F for a period of time ranging from ten seconds to ten minutes.

[0025] Another aspect of the present invention is a method for aseptically hot-filling a pre-crystallized plastic bottle. The method begins with applying a hydrogen peroxide solution having from 30% to 40% hydrogen peroxide to an exterior surface of the pre-crystallized plastic bottle and an interior surface of the pre-crystallized plastic bottle. The hydrogen peroxide solution is applied at a temperature ranging from 40°C to 60°C. Next, the hydrogen peroxide solution is permitted to activate on the exterior surface of the pre-crystallized plastic bottle and the interior surface of the pre-crystallized plastic bottle for an activation period ranging from 1 second to 10 seconds. Next, a solution of 0.25 Normal sodium hydroxide is applied to the exterior surface of the pre-crystallized plastic bottle and the interior surface of the pre-crystallized plastic bottle subsequent to the activation period. The solution of 0.25 Normal sodium hydroxide has a pH in the range of 11-13. The solution of 0.25 Normal sodium hydroxide is applied at a temperature ranging from 50°C to 75°C. Next, the pre-crystallized plastic bottle is rinsed with sterile water to remove the residue sodium hydroxide and residue hydrogen peroxide. Next, the sterilized pre-crystallized plastic bottle is conveyed to a filling station. Next, a fluid food product is hot-filled into the sterilized pre-crystallized plastic bottle at the filling station to create a hot-filled pre-crystallized plastic bottle. The temperature of the fluid food product ranges from 140 to 180 F during the hot-filling. Next, the hot-filled pre-crystallized plastic bottle is cooled at a temperature of less than 100 F for a period of time ranging from ten seconds to ten minutes.

[0026] Yet another aspect of the present invention is a method for sterilizing packaging at a low temperature. The method begins by applying a hydrogen peroxide solution having from 1% to 50% hydrogen peroxide to packaging. The hydrogen peroxide solution is applied at a temperature no greater than 65°C. Next, the hydrogen peroxide solution is permitted to activate on the packaging for an activation period ranging from 1 second to 30 seconds. Next, an alkaline solution is applied to the packaging subsequent to the activation period. The alkaline solution has a pH in the range of 10-14. The alkaline solution is applied at a temperature no greater than 65°C. Next, the packaging is rinsed with sterile water to remove the residue alkaline solution and residue hydrogen peroxide.
Yet another aspect of the present invention is a method for sterilizing packaging at a low temperature and low temperature aseptic hot filling of a flowable food product into the packaging. The method begins by applying a hydrogen peroxide solution having from 1% to 50% hydrogen peroxide to packaging. The hydrogen peroxide solution is applied at a temperature of approximately 60°C. Next, the hydrogen peroxide solution is permitted to activate on the packaging for an activation period ranging from 1 second to 30 seconds. Next, an alkaline solution is applied to the packaging subsequent to the activation period. The alkaline solution has a pH in the range of 10-14. The alkaline solution is applied at a temperature of approximately 60°C. Next, the packaging is rinsed to remove the residue alkaline solution and residue hydrogen peroxide. Next, the packaging is aseptically hot filled with a flowable food product at a low temperature ranging from 50°C to 80°C. The flowable food product may be orange juice, soup, other juices, and like flowable food products.

Yet another aspect of the present invention is a method for aseptically hot-filling a pre-cristallized plastic bottle. The method begins with applying a hydrogen peroxide solution having from 30% to 40% hydrogen peroxide to an exterior surface of a pre-cristallized plastic bottle and an interior surface of the pre-cristallized plastic bottle. The hydrogen peroxide solution is applied at a temperature ranging from 40°C to 60°C. Next, the hydrogen peroxide solution is permitted to activate on the exterior surface of the pre-cristallized plastic bottle and the interior surface of the pre-cristallized plastic bottle for an activation period. Next, a solution of 0.05 Normal sodium hydroxide is applied to the exterior surface of the pre-cristallized plastic bottle and the interior surface of the pre-cristallized plastic bottle subsequent to the activation period. The solution of 0.05 Normal sodium hydroxide has a pH in the range of 11-13. The solution of 0.05 Normal sodium hydroxide is applied at a temperature ranging from 50°C to 75°C. Next, the pre-cristallized plastic bottle is rinsed with sterile water to remove the residue sodium hydroxide and residue hydrogen peroxide. Next, the sterilized pre-cristallized plastic bottle is conveyed to a filling station. Next, a fluid food product is hot-filled into the sterilized pre-cristallized plastic bottle at the filling station to create a hot-filled pre-cristallized plastic bottle.

The temperature of the fluid food product ranges from 140°F to 180°F during the hot-filling. Next, the hot-filled pre-cristallized plastic bottle is cooled at a temperature less than 100°F for a period of time ranging from ten seconds to ten minutes.

Having briefly described the present invention, the above and further objects, features and advantages thereof will be recognized by those skilled in the pertinent art from the following detailed description of the invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a flow chart of a general method of the present invention.
FIG. 2 is a flow chart of a specific method of the present invention.
FIG. 3 is a flow chart of a specific method of the present invention.
FIG. 4 is a flow chart of a specific method of the present invention.
FIG. 5 is a schematic view of containers being sterilized on an apparatus of the present invention.
FIG. 6 is a schematic view of an apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

As illustrated in FIG. 1, a general method of sterilizing containers, especially food containers, is designated 20. At block 21, a container is provided for sterilization. The container has interior surfaces and exterior surfaces, with both surfaces preferably requiring sterilization. The container is preferably a food container, although other types of containers requiring sterilization such as containers for eye-care products, medical products and the like are within the scope and spirit of the present invention. Preferably the container is composed of a polymer material or glass, although containers composed of other materials are within the scope and spirit of the present invention. A preferred polymer material is PET or high density polyethylene.

At block 22, a solution of 1% to 50% hydrogen peroxide is applied to the interior surfaces and the exterior surfaces of the container. The hydrogen peroxide solution is prebably applied at a temperature ranging from 35°C to 100°C, more preferably at a temperature ranging from 35°C to 85°C, even more preferably at a temperature ranging from 40°C to 60°C, and most preferably at a temperature of 50°C or 60°C. The solution of hydrogen peroxide preferably has a concentration ranging from 1% to 50% hydrogen peroxide, more preferably 30% to 40%, and most preferably 35%. The hydrogen peroxide is preferably applied to the container in a liquid form. Alternatively, the hydrogen peroxide is applied as a vapor and allowed to condense on the surfaces of the container. The solution of hydrogen peroxide is preferably allowed to remain on the surfaces of the container for an activation time period of 30 seconds, more preferably less than 30 seconds, even more preferably less than 10 seconds, and most preferably one second or less.

After the activation time period, an alkaline solution is applied to the surfaces of the container as set forth in block 23. The alkaline solution preferably has a pH ranging from 10 to 14, more preferably from 11 to 13, and most preferably 12.5 or 12.9. The alkaline solution is preferably a sodium hydroxide solution or potassium hydroxide solution. However, those skilled in the pertinent art will recognize that other alkaline solutions may be utilized without departing from the scope and spirit of the present invention. The alkaline solution is preferably applied at a temperature ranging from 35°C to 100°C, more preferably at a temperature ranging from 35°C to 85°C, even more preferably at a temperature ranging from 50°C to 75°C, and most preferably at a temperature of 65°C or 60°C. The alkaline solution is preferably a 0.05 Normal solution of sodium hydroxide (approximately 0.20% concentration of sodium hydroxide). Alternatively, a one Normal solution of
sodium hydroxide is utilized as the alkaline solution. In yet another alternative embodiment, a 0.1 Normal solution of potassium hydroxide is utilized as the alkaline solution. The alkaline solution reacts with the hydrogen peroxide to generate active oxygen species and hydroxyl radicals which kill the microorganisms on the surfaces of the container. The alkaline solution lessens the sterilization time to achieve aseptic conditions. Further, the alkaline solution decreases the absorption of hydrogen peroxide by the container and also hydrogen peroxide residue. Yet further, the alkaline solution allows the sterilization process to be performed at lower temperatures than the prior art sterilization methods, which allows for the use of thinner wall containers.

At block 24, the interior surfaces and exterior surfaces of the container are rinsed to remove hydrogen peroxide residue and also any alkaline solution. Preferably, the surfaces of the container are rinsed with sterile water, or alternatively an acid rinse such as citric acid or other similar acids. Subsequent to the rinsing, the containers are filled with a product. Preferably the containers are filled with a food product such as orange juice (high acid product), milk (low acid product), water, juices, soups or other similar foods. More preferably, the containers are aseptically hot filled with a flowable food product at a temperature preferably ranging from 60° C. to 70° C. This allows for the use of inexpensive thinner wall containers since the low temperature hot-filling will not heat distort the containers. Typically, inexpensive thinner wall containers will distort at temperatures of around 80° C. or higher.

A more specific sterilization method is illustrated in FIG. 2. The specific sterilization method is generally designated 30. At block 31, a bottle composed of PET or a PET derivative is provided for sterilization, generally on a filling machine. Most water bottles and orange juice containers are composed of PET or a PET derivative.

At block 32, a solution of 1% to 50% hydrogen peroxide is applied to the interior surfaces and the exterior surfaces of the container. The hydrogen peroxide solution is preferably applied at a temperature ranging from 35° C. to 100° C., more preferably at a temperature ranging from 35° C. to 85° C., even more preferably at a temperature ranging from 40° C. to 60° C., and most preferably at a temperature of 50° C. or 60° C. The solution of hydrogen peroxide preferably has a concentration ranging from 1% to 50% hydrogen peroxide, more preferably 30% to 40%, and most preferably 35%. The hydrogen peroxide is preferably applied to the container in a liquid form. Alternatively, the hydrogen peroxide is applied as a vapor and allowed to condense on the surfaces of the container. Although there is no upper limit, the solution of hydrogen peroxide is preferably allowed to remain on the surfaces of the container for an activation time period of 30 seconds, more preferably less than 30 seconds, even more preferably less than 10 seconds, and most preferably one second or less.

After the activation time period, a solution of sodium hydroxide is applied to the surfaces of the container as set forth in block 33. The sodium hydroxide solution preferably has a pH ranging from 10 to 14, more preferably from 11 to 13, and most preferably 12.5 or 12.9. The sodium hydroxide solution is preferably applied at a temperature of approximately 65° C. or approximately 60° C. The sodium hydroxide solution is preferably a 0.05 Normal solution of sodium hydroxide (approximately 0.20% concentration of sodium hydroxide). Alternatively, a one Normal solution of sodium hydroxide is utilized as the alkaline solution. The sodium hydroxide solution reacts with the hydrogen peroxide to generate active oxygen species and/or hydroxyl radicals which kill the microorganisms on the surfaces of the container. The sodium hydroxide solution lessens the sterilization time to achieve aseptic conditions. Further, the sodium hydroxide solution decreases the absorption of hydrogen peroxide by the container and also hydrogen peroxide residue. Yet further, the sodium hydroxide solution allows the sterilization process to be performed at lower temperatures than the prior art sterilization methods, which allows for the use of thinner wall containers.

At block 34, the interior surfaces and exterior surfaces of the PET bottle are rinsed to remove hydrogen peroxide residue and also any sodium hydroxide solution. Preferably, the surfaces of the container are rinsed with sterile water. Subsequent to the rinsing, the containers are filled with a product. Preferably the containers are filled with a food product such as orange juice (high acid product), milk (low acid product), water, juices, soups or other similar foods. More preferably, the containers are aseptically hot filled with a flowable food product at a temperature preferably ranging from 50° C. to 80° C., and more preferably from 60° C. to 70° C. This allows for the use of inexpensive thinner wall containers since the low temperature hot-filling will not heat distort the containers. Typically, inexpensive thinner wall containers will distort at temperatures of around 80° C. or higher.

An alternative method with a different sequence is illustrated in FIG. 3. The method is generally designated 40. At block 41, a bottle composed of PET or a PET derivative is provided for sterilization, generally on a filling machine. Most water bottles and orange juice containers are composed of PET or a PET derivative.

A solution of sodium hydroxide is first applied to the surfaces of the container as set forth in block 42. The sodium hydroxide solution preferably has a pH of approximately 12.5. The sodium hydroxide solution is preferably applied at a temperature ranging from 35° C. to 100° C., more preferably at a temperature ranging from 35° C. to 85° C., even more preferably at a temperature ranging from 50° C. to 75° C., and most preferably at a temperature of 65° C. or approximately 60° C. The sodium hydroxide solution is preferably a 0.05 Mole solution of sodium hydroxide (approximately 0.20% concentration of sodium hydroxide). Alternatively, a one Normal solution of sodium hydroxide is utilized as the alkaline solution.

At block 43, a solution of 1% to 50% hydrogen peroxide is applied to the interior surfaces and the exterior surfaces of the container. The hydrogen peroxide solution is preferably applied at a temperature ranging from 35° C. to 100° C., more preferably at a temperature ranging from 35° C. to 85° C., even more preferably at a temperature ranging from 40° C. to 60° C., and most preferably at a temperature of 50° C. or approximately 60° C. The solution of hydrogen peroxide preferably has a concentration ranging from 1% to 50% hydrogen peroxide, more preferably 30% to 40%, and most preferably 35%. The hydrogen peroxide is preferably applied to the container in a liquid form. Alternatively, the hydrogen peroxide is applied as a vapor. The sodium
hydroxide solution reacts with the hydrogen peroxide to generate hydroxyl radicals which kill the microorganisms on the surfaces of the container. The sodium hydroxide solution lessens the sterilization time to achieve aseptic conditions. Further, the sodium hydroxide solution decreases the absorption of hydrogen peroxide by the container and also hydrogen peroxide residue. Yet further, the sodium hydroxide solution allows the sterilization process to be performed at lower temperatures than the prior art sterilization methods, which allows for the use of thinner wall containers.

At block 44, the interior surfaces and exterior surfaces of the PET bottle are rinsed to remove hydrogen peroxide residue and also any sodium hydroxide solution. Preferably, the surfaces of the container are rinsed with sterile water. Subsequent to the rinsing, the containers are filled with a product. Preferably the containers are filled with a food product such as orange juice (high acid product), milk (low acid product), water, juices, soups or other similar foods. More preferably, the containers are aseptically hot filled with a flowable food product at a temperature preferably ranging from 50° C. to 80° C., and more preferably from 60° C. to 70° C. This allows for the use of inexpensive thinner wall containers since the low temperature hot-filling will not heat distort the containers. Typically, inexpensive thinner wall containers will distort at temperatures of around 80° C. or higher. Although plastic containers capable of withstanding higher fill temperatures, typically thicker-walled containers, can be filled up to 100° C.

An alternative sterilization method is illustrated in FIG. 4. The alternative sterilization method is generally designated 50. At block 51, a container is provided for sterilization, generally on a filling machine. The container is preferably composed of a polyethylene or polypropylene material. Most milk jugs are composed of polyethylene.

At block 52, a solution of 1% to 50% hydrogen peroxide is applied to the interior surfaces and the exterior surfaces of the container. The hydrogen peroxide solution is preferably applied at a temperature ranging from 35° C. to 100° C., more preferably at a temperature ranging from 35° C. to 85° C., even more preferably at a temperature ranging from 50° C. to 75° C., and most preferably at a temperature of 65° C. The solution of hydrogen peroxide preferably has a concentration ranging from 1% to 50% hydrogen peroxide, more preferably 30% to 40%, and most preferably 35%. The hydrogen peroxide is preferably applied to the container in a liquid form. Alternatively, the hydrogen peroxide is applied as a vapor and allowed to condense on the surfaces of the container. Although there is no upper limit, the solution of hydrogen peroxide is preferably allowed to remain on the surfaces of the container for an activation time period of 30 seconds, more preferably less than 30 seconds, even more preferably less than 10 seconds, and most preferably one second or less.

After the activation time period, a solution of ferrous sulfate is applied to the surfaces of the container as set forth in block 53. A one Normal solution of ferrous sulfate is utilized as the solution. The solution of ferrous sulfate is preferably applied at a temperature ranging from 35° C. to 100° C., more preferably at a temperature ranging from 35° C. to 85° C., even more preferably at a temperature ranging from 40° C. to 60° C., and most preferably at a temperature of 50° C. The ferrous sulfate solution reacts with the hydrogen peroxide to generate hydroxyl radicals which kill the microorganisms on the surfaces of the container. The ferrous sulfate solution lessens the sterilization time to achieve aseptic conditions. Further, the ferrous sulfate solution decreases the absorption of hydrogen peroxide by the container and also hydrogen peroxide residue. Yet further, the ferrous sulfate solution allows the sterilization process to be performed at lower temperatures than the prior art sterilization methods, which allows for the use of thinner wall containers.

At block 54, the interior surfaces and exterior surfaces of the container are rinsed to remove hydrogen peroxide residue and also any ferrous sulfate solution. Preferably, the surfaces of the container are rinsed with sterile water. Subsequent to the rinsing, the containers are low temperature hot-filled with a product, preferably as described above.

As shown in FIG. 5, an apparatus for sterilizing containers is generally designated 100. Each of a plurality of containers 102a-c with openings 120 to the interior surfaces is preferably transported on a conveyor means 104 form various stations. In one embodiment, at a first station 106 hydrogen peroxide is applied to the interior surfaces and exterior surfaces of the container 102a. At a second station 108, the alkaline solution is applied to the interior surfaces and exterior surfaces of the container 102b. At a third station 110, the interior surfaces and exterior surfaces of the container 102c are rinsed, preferably with sterile water. The conveyor means 104 is preferably a conveyor belt that moves according to the activation period necessary for the hydrogen peroxide.

Alternatively, the containers 102 are conveyed upside down to allow gravity to assist in draining the solutions and rinse from the containers subsequent to sterilization.

Yet further in an alternative embodiment, each container 102 is placed at a station and dispensers 112a-c containing or in flow communication with the various solutions and rinses are moved over or under the containers to dispense each solution or rinse onto the container.

As shown in FIG. 6, a system of the present invention is generally designated 50. The system preferably comprises a bottle sterilizing and filling apparatus 60. The apparatus 60 preferably comprises a sterilization station 70, a rinsing station 75, a hot-filling station 80, a capping station 85 and a cooling station 90.

At the bottle sterilizing and filling apparatus 60, each of the bottles 40 is conveyed to the sterilization station 70. The conveying means for bottles is preferably a conveyor chain with places for holding each bottle 40. At the sterilization station 70, each bottle 40 is sterilized for subsequent low temperature hot-filling as described above. The sterilization of each bottle 40 is preferred since the low temperature hot-filling process operates at temperatures that are typically inadequate to inactivate spoilage organism that may be found the plastic bottles, caps for the bottles or which may inadvertently contaminate a fluid food product 45 during the low temperature hot-filling process.

From the sterilization station 70, each of the bottles is conveyed to the rinsing station 75 for rinsing any chemical sterilant residue from the bottle. Each of the bottles 40 is
preferably rinsed with sterile water or alternatively an acid rinse such as citric acid or other similar acids. Caps 42 for the bottles 40 are rinsed either at the rinsing station 75 or at a separate but substantially identical cap rinsing station which is not shown.

From the rinsing station 75, each of the sterilized bottles 40 is conveyed to the low temperature hot-filling station 80. At the low temperature hot-filling station 80, each sterilized bottle 40 is filled with a desired volume of a sterilized flowable food product 45. The sterilized flowable food product 45 is dispensed into each bottle through an opening in the each bottle 40. The sterilized flowable food product 45 is sterilized at a flowable food sterilization station, not shown. The low temperature hot-filling station 80 is preferably a closed aseptic environment in order to prevent contamination of the sterilized bottles 40 and sterilized flowable food product 45. Techniques for creating a closed aseptic environment are well-known in the industry.

As mentioned above, the temperature within the low temperature hot-filling station 80 preferably ranges from about 50°C to about 80°C, more preferably from about 60°C (140°F) to about 70°C (158°F), with a most preferred temperature of approximately 65°C (149°F). During the filling of each of the bottles 40 within the low temperature hot-filling station 80, the sterilized flowable food product 45 is preferably maintained at a temperature ranging from 60°C (140°F) to about 70°C (158°F), and most preferably 65°C (149°F).

Once each bottle 40 is filled with the sterilized flowable food product 45, the filled bottle 40 is conveyed to the capping station 85, which is at least partially within the low temperature hot-filling station 80. At the capping station 85, a pre-sterilized cap 42 is placed over the opening of the filled bottle 40 to seal the filled bottle 40 and prevent contamination of the sterilized flowable food product within the bottle 40. Techniques for placing caps 42 or lids over bottles 40 are well known in the pertinent art.

From the capping station 85, each capped and filled bottle 40 is conveyed to the cooling station 90. At the cooling station 90, the capped and filled bottle 40 is cooled from the previous temperature of about 60°C (140°F) to about 71°C (160°F) to a temperature of about 37.5°C (100°F) to about 35°C (95°F). The cooling station 90 is preferably maintained at a much lower temperature relative to the low temperature hot-filling station 80. Once the capped and filled bottle 40 is cooled within the cooling station 90, the cooled bottle 40 is ready for distribution to wholesale or retail channels.

The following examples illustrate the efficacy of the method of the present invention. The experiments were designed to identify the conditions optimal for polymer sterilization and also explore the boundary areas to determine the conditions limiting the efficacy of the treatment. Polymer materials were inoculated with 10^8 of B. subtilis var. globigii (ATCC, 9372) as set forth in the tables. Each polymer strip was inoculated by drop spotting approximately 100 micro-liters and coating the surface by swabbing the surface of the polyethylene strip. The culture was allowed to dry before sterilization. Each strip of polyethylene was treated by vigorously agitating the strip in the appropriate treatment solutions. Each treated polymer strip was then treated with catalase to inactivate residual peroxide, swabbed and plated using TGE incubated at 35°C for two days.

In Table One, a NaOH control, an inoculated untreated control, and two methods of the present invention were measured and the results set forth in Table 1. Five replicate polymer strips were used for each of the two methods of the present invention. A log measurement value is provided below each of the non-log values. The first method uses hydrogen peroxide first and then an alkaline solution of sodium hydroxide. The second method uses an alkaline solution of sodium hydroxide first and then hydrogen peroxide. The sterilization was conducted at 50°C.

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<th>TABLE ONE</th>
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<tr>
<td>1CFU/Swab</td>
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<td>1logCFU/Swab</td>
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<tr>
<td>5CFU/Swab</td>
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<td>5logCFU/Swab</td>
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</tbody>
</table>

In Table Two, the methods of the present invention (the two far right columns) killed the microorganisms. The untreated control had 1,800,000 colony forming units ("CFU") while the methods of the present invention successfully sterilized the polymer strips to obtain a value of <10 CFU. Further, the log reduction of CFU was essentially from log 6.26 to <1.0.

<table>
<thead>
<tr>
<th>TABLE TWO</th>
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<tbody>
<tr>
<td>Replicate</td>
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<tr>
<td>1CFU/Swab</td>
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<tr>
<td>4CFU/Swab</td>
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<tr>
<td>4logCFU/Swab</td>
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</tbody>
</table>
In Table Two, results are presented for a test where the bacteria were spotted, spread on a Petri dish and allowed to dry prior to treatment. The harshness of the sterilization conditions were decreased from the previous run by reducing the concentration of the alkali treatment and by using stagnant, unagitated solutions. The results for the inoculated untreated control are set forth in column two, results for a 0.25M NaOH control are set forth in column three, results for a solution having 35% H₂O₂ applied and an activation time period of 30 seconds followed by a catalase having an activation period of 10 seconds are set forth in column four, results for a solution having 35% H₂O₂ applied and an activation time period of 30 seconds followed by a solution of 0.25M NaOH having an activation period of 10 seconds are set forth in column five, results for a solution having 3.5% H₂O₂ and an activation time period of 30 seconds followed by a catalase having an activation period of 10 seconds are set forth in column six, results for a solution having 3.5% H₂O₂ applied and an activation time period of 30 seconds followed by application of a solution of 0.25M NaOH having an activation period of 10 seconds are set forth in column seven, and the results for an application of a solution of 0.25M NaOH having an activation period of 10 seconds, then application of a solution having 35% H₂O₂ and an activation time period of 10 seconds followed by a catalase having an activation period of 10 seconds are set forth in column eight. A log measurement value is provided below each of the non-log values. The sterilization was conducted at 50°C. The results in Table 2 clearly define the synergy of the combined treatment. Column 2 is the inoculated, untreated control having 10^7.666 bacteria per plate. Column 3 represents the survival for treatment with 0.25% sodium hydroxide and clearly shows no bacteriocidal effect. A thirty second hydrogen peroxide treatment (column 4) results in a 4.35 log inactivation (1.45 log per 10 seconds of treatment) while combining peroxide with sodium hydroxide (column 5) results in one log greater inactivation of bacteria. Hydrogen peroxide at 3.5% concentration alone (column 6) and in combination with 0.25% sodium hydroxide (column 7) had no effect under these conditions. Pretreatment of the spores with 0.25 M sodium hydroxide in combination with a short 10 second treatment with 35% hydrogen peroxide inactivated 2.48 logs of bacteria. This rate of kill per unit time was significantly increased from the treatment with hydrogen peroxide alone (1.45 logs per 10 seconds). Both treatments using the combination of hydrogen peroxide/sodium hydroxide resulted in an order of magnitude increase in the microbial inactivation. The sterilization method of column five had the best results.

Graph One and Graph Two illustrate the distortion of plastic bottles hot filled at three different temperatures, 60°C, 70°C and 80°C. The bottle hot filled at 60°C has very little distortion, and only a 0.43 millimeter change in diameter. The bottle hot filled at 70°C has a greater amount of distortion, with a shrinkage in height and a diameter distortion of 2.17 millimeters. The bottle hot filled at 80°C has...
has the greatest amount of distortion, with a shrinkage in height down to 197.11 millimeters, and a diameter distortion of 3.63 millimeters. The present invention allows for aseptically hot filling a flowable food product at a temperature preferably ranging from 60° C. to 80° C., and more preferably from 60° C. to 70° C. This allows for the use of inexpensive thinner wall containers since the low temperature hot-filling will not heat distort the containers as demonstrated in Graphs One and Two. As demonstrated in Graphs One and Two, inexpensive thinner wall containers will distort at temperatures of around 80° C. or higher.
GRAPH ONE

Bottle Height as a Function of Fill Temperature

Fill Temperature (Centigrade Degrees)

Bottle Height in Millimeters
GRAPH TWO

Bottle Distortion (max/min difference in mm)

Temperature (Centigrade Degrees)

Diameter Difference (mm max-min)
From the foregoing it is believed that those skilled in the pertinent art will recognize the meritorious advancement of this invention and will readily understand that while the present invention has been described in association with a preferred embodiment thereof, and other embodiments illustrated in the accompanying drawings, numerous changes modification and substitutions of equivalents may be made therein without departing from the spirit and scope of this invention which is intended to be unlimited by the foregoing except as may appear in the following appended claim. Therefore, the embodiments of the invention in which an exclusive property or privilege is claimed are defined in the following appended claims.

I claim as my invention:

1. A method for aseptically hot-filling a PET bottle, the method comprising:
   
   applying a hydrogen peroxide solution having from 1% to 50% hydrogen peroxide to pre-crystallized PET bottle, the hydrogen peroxide solution applied at a temperature ranging from 35° C. to 100° C.;
   
   permitting the hydrogen peroxide solution to activate on the pre-crystallized PET bottle for an activation period;
   
   applying an alkaline solution to the pre-crystallized PET bottle subsequent to the activation period, the alkaline solution having a pH in the range of 10-14, the alkaline solution applied at a temperature ranging from 35° C. to 100° C.;
   
   rinsing the pre-crystallized PET bottle to remove the residue alkaline solution and residue hydrogen peroxide to create a sterilized PET bottle;
   
   conveying the sterilized PET bottle to a filling station;
   
   hot-filling a fluid food product into the sterilized PET bottle at the filling station to create a hot-filled PET bottle, the temperature of the fluid food product ranging from 140° F. to 180° F. during the hot-filling; and
   
   cooling the hot-filled PET bottle at a temperature less than 100° F. for a period of time ranging from ten seconds to ten minutes.

2. The method according to claim 1 wherein the alkaline solution is a sodium hydroxide solution, a potassium hydroxide solution or a ferrous sulfate solution.

3. The method according to claim 1 wherein the alkaline solution is a solution of 0.05 Normal sodium hydroxide having a pH of approximately 12.5.

4. The method according to claim 1 wherein the alkaline solution is first applied to the PET bottle and then the solution of hydrogen peroxide is applied to the PET bottle to react with the alkaline solution to generate active oxygen species and/or hydroxyl radicals.

5. The method according to claim 1 wherein the solution of hydrogen peroxide is first applied to the PET bottle and the activation period is 30 seconds and then the alkaline solution is applied to the PET bottle to react with the hydrogen peroxide to generate hydroxyl radicals.

6. A method for aseptically hot-filling a PET bottle, the method comprising:
   
   applying a hydrogen peroxide solution having from 1% to 50% hydrogen peroxide to a pre-crystallized PET bottle, the hydrogen peroxide solution applied at a temperature no greater than 65° C.;
   
   permitting the hydrogen peroxide solution to activate on the pre-crystallized PET bottle for an activation period ranging from 1 second to 30 seconds;
   
   applying an alkaline solution to the pre-crystallized PET bottle subsequent to the activation period, the alkaline solution having a pH in the range of 10-14, the alkaline solution applied at a temperature no greater than 65° C.; and
   
   rinsing the pre-crystallized PET bottle with sterile water to remove the residue alkaline solution and residue hydrogen peroxide;
   
   filling the sterilized pre-crystallized PET bottle with a fluid food product within a sterile environment to create a hot-filled PET bottle, the fluid food product having a temperature ranging from 140° F. to 180° F.;
   
   sealing the hot-filled PET bottle with a sterilized seal to create a seal hot-filled PET bottle;
   
   cooling the sealed hot-filled PET bottle at a temperature less than 100° F. for a period of time ranging from ten seconds to ten minutes.

7. The method according to claim 6 wherein the alkaline solution is a solution of 0.05 Normal sodium hydroxide having a pH of approximately 12.5.

8. The method according to claim 6 wherein the alkaline solution is first applied to the pre-crystallized PET bottle and then the solution of hydrogen peroxide is applied to the pre-crystallized PET bottle to react with the alkaline solution to generate active oxygen species and/or hydroxyl radicals.

9. The method according to claim 6 wherein the solution of hydrogen peroxide is first applied to the pre-crystallized PET bottle and the activation period is 30 seconds and the alkaline solution is applied to the pre-crystallized PET bottle to react with the hydrogen peroxide to generate hydroxyl radicals.

10. An apparatus for sterilizing and hot-filling containers, the apparatus comprising:

   a conveyor mechanism for moving a plurality of containers through the apparatus;
   
   a station for applying hydrogen peroxide to an interior surface and exterior surface of each of the plurality of containers;
   
   a station for applying an activation agent to the interior surface and exterior surface of each of the plurality of containers, the activation agent reacting with the hydrogen peroxide to generate hydroxyl radicals; and
   
   a station for hot-filling a fluid food product in each of the plurality of containers at a temperature ranging from 140° F. to 180° F.

11. The apparatus according to claim 10 further comprising a station for rinsing the interior surface and the exterior surface of each of the plurality of containers.

12. The apparatus according to claim 10 wherein each of the plurality of containers is inverted while conveyed along the conveyor means.
13. The apparatus according to claim 10 wherein the activation agent is a solution of sodium hydroxide.

14. The apparatus according to claim 10 wherein each of the plurality of containers is composed of a material selected from the group consisting of PET, PET derivative, polypropylene and polyethylene.

15. The apparatus according to claim 10 wherein each of the plurality of containers is composed of a polymer material.