chamber that is at least partially filled with a liquid medium to form a liquid bath. The process further includes heating the article in the carrier, wherein the article is at least partially submerged in the liquid bath during the heating, and wherein at least a portion of the heating is performed using microwave energy. The process also includes one or more of adding fluid into and removing fluid from at least one location in the heating chamber to maintain a temperature profile across the heating chamber in which a temperature of the liquid bath at an inlet area of the heating chamber is at least 10°C cooler than a temperature of the liquid bath at an outlet area of the heating chamber.

[0005] In another aspect of the present disclosure, a heating system for heating articles is provided. The heating system includes a heating chamber for heating articles using microwave energy, the heating chamber configured to be at least partially filled with a fluid forming a liquid bath. The heating system further includes a fluid distribution and temperature control system. The fluid distribution and temperature control system includes at least one heat transfer device for one or more of heating and cooling the fluid and nozzles for one or more of discharging fluid into the heating chamber and removing fluid from the heating chamber. The nozzles are in fluid flow communication with the heat transfer device and are spaced apart from one another along a length of the heating chamber.

[0006] Disclosed herein is a process for heating articles that includes sequentially passing loaded carriers in a continuous manner through a first processing section and sequentially passing said plurality of loaded carriers in an incremental manner through a second processing section using an incremental convey segment. The incremental convey segment includes sequential carrier-receiving slots, each carrier-receiving slot configured to receive one of said loaded carriers and the incremental convey segment is configured to be moved incrementally at multiples of discrete intervals corresponding to the carrier-receiving slots. The process further includes sequentially passing the loaded carriers in a continuous manner through a third processing section and heating articles supported by the carriers with microwave energy in at least one of said first, second, and third processing sections, the heating of the articles occurring while the articles are submerged in a liquid bath and at a pressure greater than atmospheric pressure.

[0007] Disclosed herein is a process for heating articles in a heating system. The process includes passing a first carrier loaded with an article through a first processing section using a first convey segment, the first loaded carrier having a first residence time in said first processing

section of τ_1. The process further includes transferring the first loaded carrier from the first convey segment to a vertical convey segment, the transferring including loading the first loaded carrier into a carrier slot of the vertical convey segment. The loaded carrier is passed through a second processing section using the vertical convey segment by incrementally actuating the vertical convey segment to move the first loaded carrier vertically such that the first loaded carrier has a residence time in said second processing section of τ_2. The process further includes transferring the loaded carrier from the vertical convey segment to a third convey segment, wherein the transferring includes removing the first loaded carrier from the carrier slot of the vertical convey segment. The process also includes transporting a second loaded carrier through the first and the second processing sections by repeating each of the previously described steps.

[0008] Disclosed herein is a heating system for heating a plurality of articles. The system includes a heating chamber for heating an article in a carrier using microwave energy, a cooling chamber for cooling the article in the carrier, and a holding chamber disposed between the heating chamber and the cooling chamber. The heating chamber is adapted to be at least partially filled with a heating chamber fluid medium and the cooling chamber is adapted to be at least partially filled with a cooling chamber fluid medium.

[0009] Disclosed herein is a heating system for heating articles. The heating system includes a heating chamber for heating using microwave energy, the heating chamber configured to be at least partially filled with fluid medium. The heating system further includes a conveyor system for transporting a carrier holding an article in a convey direction through the heating chamber. The conveyor system includes at least two spaced apart convey segments disposed within the heating chamber, and the convey segments are spaced apart from one another in the convey direction.

[0010] Disclosed herein is a process for heating articles in a heating system. The process includes introducing a carrier supporting an article into a heating chamber, the article being at least partially submerged in a liquid bath in the heating chamber. The method further includes passing the carrier by a first microwave launcher along a first convey segment in a convey direction. During at least a portion of the passing by the first microwave launcher, microwave energy is discharged from the first microwave launcher toward the article in the carrier. The process further includes passing the carrier by a second microwave launcher along a second convey segment in said convey direction. During at least a portion of the passing by the second

microwave launcher, microwave energy is discharged from the second microwave launcher toward the article in the carrier. The first convey segment and the second convey segments are also spaced apart from one another in the convey direction.

[0011] Disclosed herein is a heating system for heating articles. The heating system includes a preheating section for heating an article, a cooling section for cooling the article, and a heating section for heating the article using microwave energy. The heating section is disposed between the preheating section and the cooling section and include multiple heating chamber modules. Each of the heating chamber modules includes a vessel segment having an inlet and an outlet, at least one microwave launcher configured to discharge microwave energy into the vessel segment, a convey segment disposed within the vessel segment for transporting the article in a convey direction, and a conveyor driver for driving the convey segment. The chamber modules are configured to be selectively coupled to and uncoupled from one another.

[0012] Disclosed herein is a process for heating articles in a heating system. The process includes passing a carrier loaded with an article through a vessel inlet and into a first vessel portion. The loaded carrier is moved in a first direction through the first vessel portion away from the inlet. During at least a portion of the moving in the first direction, at least a portion of the articles in the loaded carrier is contacted with a first fluid medium. The process further includes moving the loaded carrier in a second direction opposite the first direction through a second vessel portion toward a vessel outlet and, during at least a portion of the moving through the second vessel portion, contacting at least a portion of the articles in the loaded carrier with a second fluid medium.

[0013] Disclosed herein is a heating system that includes a heating chamber configured to heat articles using microwave energy. The heating chamber includes a chamber adapted to be at least partially filled with a fluid medium, a conveyor for transporting carriers holding the articles through the heating chamber in a convey direction, and a vessel. The vessel includes an inlet side and an outlet side with the inlet side and the outlet side being at least partially fluidly isolated from one another. The vessel further includes a carrier inlet configured to receive one of said carriers into said inlet side, a carrier outlet configured to discharge one of said carriers out of said outlet side, a first convey segment located in the inlet side configured to move the carriers vertically away from the carrier inlet; and a second convey segment located in the outlet side configured to move the carriers vertically toward the carrier outlet.

[0014] Disclosed herein is a process for heating articles. The process includes preheating an article in a carrier in a preheat section and, after the preheating, heating the article in the carrier in a heating section, wherein at least a portion of the heating is performed using microwave energy. The process further includes passing the article in the carrier through a holding section, wherein a coldest temperature of the article is maintained at or above a hold temperature for a hold time and cooling the article in the carrier in a cooling section. At least a portion of one or more of the preheating, the passing, and the cooling are performed by moving the carrier at least one of upwardly and downwardly using at least one convey segment, and the article is contacted by at least one fluid medium during movement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The foregoing and other aspects, features, and advantages of the present disclosure set forth herein will be apparent from the following description of particular embodiments of those inventive concepts as illustrated in the accompanying drawings. It should be noted that the drawings are not necessarily to scale; however, emphasis instead is being placed on illustrating the principles of the inventive concepts. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than limiting.

[0016] FIG. 1A is a block diagram illustrating an example heating system in accordance with the present disclosure.

[0017] FIG. 1B is a schematic illustration of the heating system of FIG. 1A.

[0018] FIG. 2A is an isometric view of an example carrier that may be used in heating systems according to the present disclosure, such as the heating system of FIGs. 1A and 1B

[0019] FIG. 2B is an elevation view of an end of the carrier of FIG. 2A.

[0020] FIG. 2C is an elevation view along a side of the carrier of FIG. 2A.

[0021] FIG. 3A is an isometric view of a vessel that may be included for various purposes in heating systems according to the present disclosure.

[0022] FIG. 3B is a cross-sectional view along a side of the vessel of FIG. 3A.

[0023] FIG. 3C is a cross-sectional view from an end of the vessel of FIG. 3A.

[0024] FIG. 3D is a schematic illustration of support members of the vessel of FIG. 3A used to convey carriers, such as the carrier of FIGs. 3A–3C.

CLAIMS

1. A process for heating articles in a heating system, said process comprising:

(a) passing an article in a carrier through a heating chamber that is at least partially filled with a liquid medium to form a liquid bath;

(b) heating said article in said carrier, wherein said article is at least partially submerged in said liquid bath during said heating, and wherein at least a portion of said heating is performed using microwave energy; and

(c) one or more of adding fluid into and removing fluid from at least one location in said heating chamber to maintain a temperature profile across said heating chamber in which a temperature of said liquid bath at an inlet area of said heating chamber is at least 10°C cooler than a temperature of said liquid bath at an outlet area of said heating chamber.

2. The process of claim 1, wherein passing said article in said carrier through said heating chamber includes transporting said carrier including said article using a conveyance system.

3. The process of claim 1, wherein said adding of step (c) occurs simultaneously with at least a portion of said heating of step (b).

4. The process of claim 1, wherein the change in temperature per linear foot of said liquid bath remains substantially constant between said inlet area and said outlet area.

5. The process of claim 1, wherein the change in temperature per linear foot of said liquid bath is at least 0.50°C/ft.

6. The process of claim 1, wherein the temperature of said liquid bath at said inlet area of said heating chamber is at least 50°C.

7. The process of claim 1, wherein the temperature of said liquid bath at said outlet area of said heating chamber is at least 60°C.

8. The process of claim 1, wherein said heating of step (b) is sufficient to increase the temperature of a coldest portion of said article to a temperature at or above a target temperature, and wherein one or more of the temperature of said liquid bath at said inlet area and the temperature of said liquid bath at said outlet area is lower than said target temperature.

9. The process of claim 1, wherein said one or more of adding and removing liquid of step (c) includes discharging a portion of said liquid into said heating chamber and withdrawing a portion of said liquid from said heating chamber, respectively, via a nozzle located along a length of said heating chamber between the inlet area and said outlet area.

10. The process of claim 9, wherein said nozzle is one of plurality of nozzles distributed along said length of said heating chamber between said inlet and said outlet.

11. The process of claim 10, wherein said plurality of nozzles includes at least one nozzle pair, said nozzle pair including a first nozzle for discharging warmed fluid and a second nozzle for discharging cooled fluid into the heating chamber.

12. The process of claim 11, wherein said warmed fluid has a temperature of at least 35°C and wherein said cooled fluid has a temperature of not more than 35°C.

13. The process of claim 10, wherein said plurality of nozzles includes a nozzle pair including an inlet nozzle and an outlet nozzles for respectively discharging fluid into and removing fluid from a portion of said heating chamber.

14. The process of claim 9, wherein said one or more adding and removing of step (c) includes simultaneously discharging fluid into said heating chamber and removing fluid from said heating chamber.

15. The process of claim 14, wherein a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near said inlet area is greater than a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near said outlet area.

16. The process of claim 1 further comprising, prior to said one or more adding and removing of step (d)–

(i) measuring a fluid temperature selected from the group consisting of an inlet fluid temperature, an outlet fluid temperature, and a combination thereof to provide at least one measured temperature value;

(ii) comparing said at least one measured temperature value to a target value for said liquid temperature measured in step (i) to determine a difference; and

(iii) selectively adding or removing fluid from said heating chamber until said difference is lower than a maximum allowable difference.

17. The process of claim 16, wherein each of steps (i) through (iii) is performed automatically by a computerized control system.

18. The process of claim 1 further comprising prior to said passing of step (a), preheating said article in said carrier in a preheating chamber, wherein said preheating chamber is at least partially filled with another fluid to form a second liquid bath and said article is at least partially submerged in said second liquid bath during said preheating.

19. The process of claim 1 further comprising, subsequent to said heating of step (b), passing said article in said carrier through a holding zone, wherein a temperature of a coldest portion of said article is maintained at or above a target temperature for a period of time in said holding zone.

20. The process of claim 19, wherein said heating of step (c) and said holding are sufficient to at least one of pasteurize and sterilize said article.

21. The process of claim 1, wherein said article comprises packaged foodstuffs or a beverage.

22. The process of claim 1, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.

23. A heating system for heating, said heating system comprising:

a heating chamber for heating articles using microwave energy, wherein said heating chamber is configured to be at least partially filled with a fluid forming a liquid bath; and

a fluid distribution and temperature control system comprising:

at least one heat transfer device for one or more of heating and cooling said fluid; and

a plurality of nozzles for one or more of discharging fluid into said heating chamber and removing fluid from said heating chamber,

wherein said nozzles are in fluid flow communication with said at least one heat transfer device, and said nozzles are spaced apart from one another along a length of said heating chamber.

24. The heating system of claim 23, wherein said fluid distribution system is configured to maintain a temperature profile along said heating chamber in which a temperature of said liquid bath at an outlet area of said heating chamber is at least 10°C higher than a temperature of said liquid bath at an inlet area of said heating chamber and a change in temperature per linear foot of said liquid bath through said heating chamber remains substantially constant between said inlet area and said outlet area.

25. The heating system of claim 24 further comprising, an automatic control system for selectively regulating a flow of fluid of said plurality of nozzles and said at least one heat transfer device to maintain said temperature profile along said heating chamber.

26. The heating system of claim 23 further comprising a carrier configured to hold said articles.

27. The heating system of claim 26 further comprising a convey line for transporting said carrier in a convey direction.

28. The heating system of claim 23 further comprising a microwave generator for generating said microwave energy and a microwave distribution system for directing said microwave energy from said generator into said heating chamber, wherein said microwave distribution system includes at least one pair of microwave launchers for discharging microwave energy into said heating chamber.

29. The heating system of claim 28, wherein said pair of launchers is disposed on an upper side of said heating chamber.

30. The heating system of claim 28, wherein said pair of microwave launchers includes an upper microwave launcher and a lower microwave launcher, the upper microwave launcher and the lower microwave launcher positioned on opposite sides of said heating chamber.

31. The heating system of claim 23, wherein said plurality of nozzles includes at least two pairs of nozzles spaced apart from one another along the length of said heating chamber, wherein each of said pairs of nozzles includes one discharge nozzle for adding fluid to said heating chamber and one withdraw nozzle for removing fluid from said heating chamber.

32. The heating system of claim 23, wherein the plurality of nozzles includes adjacent pairs of nozzles, the system further comprising a divider disposed between said adjacent pairs of nozzles.

33. The heating system of claim 23, wherein said fluid distribution system comprises a first heat transfer device to provide heated fluid to a first nozzle of said plurality of nozzles and a second heat transfer device to provide cooled fluid to a second nozzle of said plurality of nozzles, said first nozzle and said second nozzle being disposed adjacent to each other along a length of said heating chamber.

34. The heating system of claim 23, wherein said plurality of nozzles includes at least two pairs of nozzles positioned on opposite sides of said heating chamber.

35. The heating system of claim 23 further comprising a preheating chamber located prior to said heating chamber for preheating said articles to a preheat temperature.

37. The heating system of claim 23 further comprising a holding chamber located after said heating chamber for maintaining said articles at a hold temperature such that a coldest portion of each of said articles is at or above a target temperature for a hold time.

38. The heating system of claim 23, wherein said heating system is at least one of a pasteurization or sterilization system.

39. The heating system of claim 23, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.