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(54) **Title**: ULTRASONIC CLEANING AND DISINFECTING DEVICE AND METHOD

(57) **Abstract**: The present invention relates to an ultrasonic cleaning and disinfecting device. Additionally, the present invention relates to a method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device.

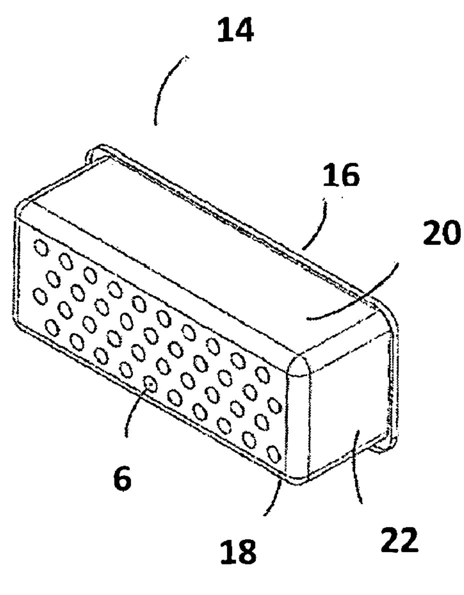

FIG 3B

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ULTRASONIC CLEANING AND DISINFECTING DEVICE AND METHOD

FIELD OF THE TECHNOLOGY

The field of the present technology relates to an ultrasonic cleaning and disinfecting device. Additionally, the field of the present technology relates to a method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device.

BACKGROUND

The use of ultrasonic cleaning for cleaning non-food articles and/or food articles (i.e., vegetables, fruits, eggs, etc.) is known in the art. Ultrasonic cleaning typically includes immersing a non-food article or food article (i.e. a vegetable, fruit, egg, etc.) to be cleaned in a suitable liquid medium, agitating or sonicating that liquid medium with high frequency ultrasonic waves for a period of time, rinsing with water, and drying.

In known ultrasonic cleaning devices that utilize piezoelectric transducers, the piezoelectric transducers typically are attached to a ultrasonic cleaning tank filled with a suitable liquid medium. The piezoelectric transducers convert applied electrical energy to mechanical energy. The mechanical energy causes the piezoelectric transducers to vibrate ultrasonically at an ultrasonic frequency thereby producing ultrasonic waves having the same ultrasonic frequency as the ultrasonic vibration. The high frequency ultrasonic waves are transferred to the liquid medium. The agitating or sonicating of the liquid medium with high frequency ultrasonic waves results in the formation of microscopic bubbles (i.e., liquid-free zones) that immediately implode or collapse under the pressure of agitation to produce shock waves which impinge on the surface of the non-food article or food article to be cleaned. Through a scrubbing action, these shock waves displace, loosen or remove contaminants from the surface of the non-food article or food article to be cleaned. The process of the formation of the bubbles in the liquid medium followed by the immediate implosion or collapse of the bubbles is known as cavitation. The collapse and implosion of cavitation bubbles throughout an ultrasonically activated liquid medium result in the cavitation effect commonly associated with ultrasonic cleaning.

The intensities of ultrasonic waves typically decrease as the ultrasonic waves move further away from their origin (i.e., the piezoelectric transducers) and if numerous piezoelectric transducers are operated simultaneously the result can be a non-uniform cavitation process and a non-uniform cavitation effect. Consequently, there can be an observed decrease in the quality and/or efficiency of cleaning.

Currently, in known ultrasonic cleaning devices and methods for cleaning fruits and vegetables, the intensity of the ultrasonic vibration and/or ultrasonic waves being used for the cavitation effect can typically be too high and, thus, cause damage to the outer skin, soft skin and/or soft tissue of fruits and vegetables during cleaning.

Also, in known ultrasonic cleaning devices and methods for cleaning fruits and vegetables, the frequency of the ultrasonic vibration and/or ultrasonic waves typically used can cause damage to the outer skin, soft skin and/or soft tissue of fruits and vegetables during cleaning. For example, an ultrasonic vibration frequency and/or ultrasonic wave frequency of 35 kHz or 38.5 kHz can cause damage to the outer skin, soft skin and/or soft tissue of fruits and vegetables during cleaning.

Additionally, known ultrasonic cleaning devices and methods currently being used for cleaning fruits and vegetables typically do not provide a homogenous distribution of ultrasonic waves throughout the ultrasonic cleaning tanks of the known ultrasonic cleaning devices. In particular, known ultrasonic cleaning devices with large ultrasonic cleaning tanks that are used on an industrial scale typically do not provide a homogenous distribution of ultrasonic waves throughout the large ultrasonic cleaning tanks.

Also, in known ultrasonic cleaning devices and methods currently being used for cleaning fruits and vegetables, the ultrasonic waves typically are not transferred to the liquid medium of the ultrasonic cleaning tanks in a consistent uninterrupted manner; rather, an ultrasonic wave emitted by one transducer can interfere with an ultrasonic wave emitted by a different transducer.

Further, known ultrasonic cleaning devices and methods currently being used for cleaning fruits and vegetables typically use ozone and/or chemicals such as chlorine or $NaHCO_3$ acid in addition to ultrasonic waves to clean and disinfect fruits and vegetables. However, ozone must be generated on-site, the equipment required to generate ozone can be complex and intricate to install, and since ozone is the most powerful oxidizing agent available, it is also potentially the most dangerous of oxidants. The use of harsh chemicals such as chlorine and $NaHCO_3$ acid can result both in chemical residue present on the fruits and vegetables at the time of consumption and in the production of undesirable by-products. Also, chemicals such as $NaHCO_3$ acid have in general proven to be ineffective with respect to the complete removal of insect eggs from fruits and vegetables.

Moreover, know ultrasonic cleaning devices and methods currently being used for cleaning fruits and vegetables do not kill or remove significant amounts of pests, pest eggs, pest larvae, insects, insect eggs, and/or insect larvae.

Therefore, there is a need to provide an ultrasonic cleaning and disinfecting device and method that avoid or at least ameliorate one or more of the disadvantages described above.

SUMMARY

A first aspect provides an ultrasonic cleaning device that can comprise: an ultrasonic cleaning tank, wherein the ultrasonic cleaning tank comprises a bottom closed base having an outer surface; and a plurality of transducers installed on the outer surface of the bottom closed base, wherein the plurality of transducers emit ultrasonic waves having a frequency in the range of about 50 kHz to about 60 kHz.

In embodiments, the ultrasonic cleaning device described above can further comprise a plurality of rows comprising: a first row comprising four or more transducers; a second row comprising four or more transducers, wherein the second row is parallel to the first row, wherein each of the four or more transducers of the second row is in positioned in staggered relation to each of the four or more transducers of the first row; a third row comprising four or more transducers, wherein the third row is parallel to the first row and the second row, wherein each of the four or more transducers of the third row is positioned directly in line with each of the four or more transducers of the first row; and a fourth row comprising four or more transducers, wherein the fourth row is parallel to the first row, the second row and the third row, wherein each of the four or more transducers of the fourth row is positioned directly in line with each of the four or more transducers of the second row; wherein the second row is positioned between the first row and the third row, wherein the third row is positioned between the second row and the fourth row.

In embodiments, the plurality of transducers can be arranged and activated according to a repeating pattern selected from the group consisting of a repeating pattern of at least two transducers on and at least two transducers off, a repeating pattern of at least two transducers off and at least two transducers on and a combination thereof.

In embodiments, the plurality of transducers can be arranged and activated according to a pattern selected from the group consisting of a repeating pattern of one row of transducers on and one row of transducers off, a repeating pattern of one row of transducers off and one row of transducers on, and a combination thereof.

In embodiments, the plurality of transducers can be arranged and activated according to a repeating pattern comprising one row of transducers on and two rows of transducers off.

In embodiments, the plurality of transducers can be arranged and activated according to a repeating pattern comprising one row of transducers off and two rows of transducers on.

A second aspect provides a method of ultrasonically cleaning one or more articles, wherein the method can comprise: providing the ultrasonic cleaning device described above; providing a volume of water in the ultrasonic cleaning tank; providing the one or more articles; immersing the one or more articles in the volume of water in the ultrasonic cleaning tank; and ultrasonically cleaning the one or more articles.

In embodiments, the method described above can comprise: arranging and activating the plurality of transducers according to a repeating pattern selected from the group consisting of a repeating pattern of at least two transducers on and at least two transducers off, a repeating pattern of at least two transducers off and at least two transducers on and a combination thereof.

In embodiments, the method described above can comprise: arranging and activating the plurality of transducers according to a repeating pattern selected from the group consisting of a repeating pattern of one row of transducers on and one row of transducers off, a repeating pattern of one row of transducers off and one row of transducers on and a combination thereof.

In embodiments, the method described above can comprise: arranging and activating the plurality of transducers according to a repeating pattern comprising one row of transducers on and two rows of transducers off.

In embodiments, the method described above can comprise: arranging and activating the plurality of transducers according to a repeating pattern comprising one row of transducers off and two rows of transducers on.

In embodiments, the one or more articles can be food articles. In embodiments, the one or more food articles can be selected from the group of food articles consisting of fruits, vegetables and a combination thereof. In embodiments, the one or more articles can be non-food articles.

In embodiments, the ultrasonic cleaning step can comprise removing a contaminant selected from the group of contaminants consisting of dirt, oil, mold, chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae and a combination thereof.

In embodiments, the ultrasonic cleaning step can result in the removal of about 95% or more of insects, insect eggs, and insect larvae from the one or more food articles. In embodiments, the ultrasonic cleaning step can result in the removal of about 99% or more of insects, insect eggs, and insect larvae from the one or more food articles. In embodiments, the ultrasonic cleaning step can result in the removal of about 100% or more of insects, insect eggs, and insect larvae from the one or more food articles.

In embodiments, the ultrasonic cleaning step can result in less than about 5% of bruising or damage to the physical structure of the one or more food articles.

In embodiments, the method described above can comprise pre-washing the one or more food articles in a pre-wash tank, and the combination of the pre-washing step and the ultrasonic cleaning step can result in the removal of about 95% or more of insects, insect eggs, and insect larvae from the one or more food articles. In embodiments, the combination of the pre-washing step and the ultrasonic cleaning step can result in the removal of about 99% or more of insects, insect eggs, and insect larvae from the one or more food articles. In embodiments, the combination of the pre-washing step and the ultrasonic cleaning step can result in the removal of about 100% or more of insects, insect eggs, and insect larvae from the one or more food articles.

In embodiments, the plurality of transducers can be arranged and activated according to a Z-1 pattern as defined in FIG 7. In embodiments, the plurality of transducers can be arranged and activated according to an A-1 pattern as defined in FIG 7. In embodiments, the plurality of transducers can be arranged and activated according to an O-1 pattern as defined in FIG 7. In embodiments, the plurality of transducers can be arranged and activated according to a C-1 pattern as defined in FIG 7.

In embodiments, the method described above can include arranging and activating the plurality of transducers according to a Z-1 pattern as defined in FIG 7. In embodiments, the method described above can include arranging and activating the plurality of transducers according to an A-1 pattern as defined in FIG 7. In embodiments, the method described above can include arranging and activating the plurality of transducers according to an O-1 pattern as defined in FIG 7. In embodiments, the method described above can include arranging and activating the plurality of transducers according to a C-1 pattern as defined in FIG 7.

In embodiments, the method described above can include pre-washing the one or more food articles in a pre-wash tank, and wherein the combination of the pre-washing step and the ultrasonic cleaning step can result in the removal of about 90% or more, about 95% or more, about 98% or more, about 99% or more, or about 100% of insects, insect eggs, and/or insect larvae from the one or more food articles.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are described herein with reference to the drawings in which:

FIG 1 depicts a three-dimensional view of an ultrasonic wave emitted by a transducer, wherein the intensity of the ultrasonic wave decreases as the ultrasonic wave moves further away from the transducer.

FIG 2 illustrates an embodiment of an ultrasound generator of the present disclosure, wherein the ultrasound generator includes a plurality of piezoelectric transducers, wherein each of the plurality of piezoelectric transducers emits an ultrasonic wave having a dome shape.

FIG 3A illustrates a two dimensional view of an embodiment of an ultrasonic cleaning tank of the present disclosure.

FIG 3B illustrates a three dimensional view of an embodiment of an ultrasonic cleaning tank of the present disclosure.

FIG 3C illustrates an embodiment of the positioning of transducers on the outer surface of the bottom closed base of an ultrasonic cleaning tank of the present disclosure.

FIG 4C illustrates an embodiment of the positioning of transducers on the outer surface of the bottom closed base of an ultrasonic cleaning tank of the present disclosure.

FIG 5 illustrates an embodiment of an ultrasonic cleaning and disinfecting device of the present disclosure.

FIG 6A is a side view including the length and height of an embodiment of a pre-wash tank of the present disclosure that includes an overflow system to provide for the transport and removal of contaminants out of the pre-wash tank.

FIG 6B is a side view including the width and height of an embodiment of a pre-wash tank of the present disclosure that includes an overflow system to provide for the transport and removal of contaminants out of the pre-wash tank.

FIG 6C illustrates a blower system of a pre-wash tank in accordance with an embodiment of the present disclosure.

FIG 7 illustrates the transducer activation patterns A-1, O-1, C-1 and Z-1 of the present disclosure.

FIG 8 illustrates the results of the tests of the transducer activation patterns A-1, O-1, C-1 and Z-1 in different volumes of water.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments can be utilized, and other changes can be made, without departing from the spirit or scope of the subject matter presented herein.

Unless specified otherwise, the terms "comprising" and "comprise" as used herein, and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, un-recited elements.

As used herein, the term "about", in the context of measurement values, conditions, concentrations of components, etc., means +/- 5% of the stated value, or +/- 4% of the stated value, or +/- 3% of the stated value, or +/- 2% of the stated value, or +/- 1% of the stated value, or +/- 0.5% of the stated value, or +/- 0% of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from

1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

As used herein, unless specified otherwise, the terms “vegetable” and “vegetables” include all edible plants, parts of plants that may or may not propagate into offspring, members of the plant kingdom, culinary vegetables, mushrooms, edible fungi, and nuts.

As used herein, unless specified otherwise, the term “fruit” and “fruits” include all botanic fruits and culinary fruits.

Ultrasonic Cleaning and Disinfecting Device

The present disclosure relates to an ultrasonic cleaning and disinfecting device. In embodiments, the ultrasonic cleaning and disinfecting device can be used to remove dirt, oil, mold, chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae, and/or the like from the surface of fruits (i.e., the skin of fruits) and vegetables (i.e., the skin of vegetables and/or the leaves of vegetables).

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can be used to vitalize fruits and vegetables during the cleaning and disinfecting process via the use of ultrasonic vibration and/or ultrasonic waves. In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can be used to prolong the shelf-life of fruits and vegetables via the use of ultrasonic vibration and/or ultrasonic waves.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can exhibit an increase in efficiency in cleaning and disinfecting fruits and vegetables with soft skin and/or soft tissue without damaging the outer skin, soft skin and/or soft tissue of the fruits and vegetables when compared to other known ultrasonic cleaning and disinfecting devices.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can exhibit an improvement in cleaning and disinfecting fruits and vegetables when compared to other known ultrasonic cleaning and disinfecting devices. In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can improve the quality of cleaning and disinfecting fruit and vegetables when compared to other known ultrasonic cleaning and disinfecting devices.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables without damaging the outer skin, soft skin and/or soft tissue of the fruits and vegetables can be achieved by the use of an optimal frequency of ultrasonic vibration and/or ultrasonic waves in the range of about 50 to about 60 kilohertz (kHz). In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting vegetables with fragile leaves without damaging the outer surface, outer skin, soft skin and/or soft tissue of the fragile vegetables leaves can be achieved by the use of an optimal frequency of ultrasonic vibration and/or ultrasonic waves of about 60 kilohertz (kHz).

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables without damaging the outer skin, soft skin and/or soft tissue of the fruits and vegetables can be achieved by the use of an optimal intensity of ultrasonic vibration and/or ultrasonic waves.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can include a plurality of piezoelectric transducers that can generate an optimal frequency of ultrasonic vibration and/or ultrasonic waves in the range of about 50 to about 60 kilohertz (kHz). In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can include a plurality of piezoelectric transducers that can generate a frequency of ultrasonic vibration and/or ultrasonic waves of about 60 kilohertz (kHz).

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can include a plurality of piezoelectric transducers that can generate an optimal intensity of ultrasonic vibration and/or ultrasonic waves.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can include a plurality of piezoelectric transducers that can generate an optimal intensity of ultrasonic vibration and/or ultrasonic waves to effectively remove small insects and small pests including eggs and larvae from the surface of fruits (i.e., the skin of fruits) and the surface of vegetables (i.e., the skin of vegetables or the leaves of leafy vegetables).

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by the strategic placement or arrangement of a plurality of transducers in specific locations of the ultrasonic cleaning and disinfecting device of the present disclosure. The strategic placement of the transducers in specific locations can improve the homogeneity or homogenous distribution of the ultrasonic waves throughout the entire volume or substantially entire volume of the liquid medium of the ultrasonic cleaning tank or cleaning bath of the ultrasonic cleaning and disinfecting device of the present disclosure. In embodiments, a plurality of transducers can be placed or installed directly beneath the bottom surface of the ultrasonic cleaning tank or cleaning bath. In embodiments, a plurality of transducers can be placed or installed directly outside one or more of the side surfaces of the ultrasonic cleaning tank or cleaning bath.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by using the strategically designed transducers in precise patterns. The use of the strategically placed transducers in precise patterns can improve the homogeneity or homogenous distribution of the ultrasonic waves throughout the entire volume or substantially entire volume of the liquid medium of the ultrasonic cleaning tank or cleaning bath of the ultrasonic cleaning and disinfecting device of the present disclosure.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruit and vegetables can be achieved by the ratio of the number of transducers to the volume of liquid medium in the ultrasonic cleaning tank or cleaning bath. The ratio of the number of transducers to the volume of the liquid medium in the ultrasonic cleaning tank or cleaning bath can improve the homogeneity or homogenous distribution of the ultrasonic waves throughout the entire volume or substantially entire volume of the liquid medium of the ultrasonic cleaning tank or cleaning bath. In an embodiment, there is one transducer per one litre to eight litres of liquid medium.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by the design of the ultrasonic waves emitted by the transducers. FIG. 1 illustrates the design of the ultrasonic waves emitted by the transducers of the present disclosure in accordance with an embodiment. FIG. 1 depicts a three-dimensional view of an ultrasonic wave **2** emitted by a transducer **4** in accordance with an embodiment of the present disclosure, wherein profile 3dB represents a position of the ultrasonic wave **2** where the intensity value of the ultrasonic wave **2** is one-half (½) of the intensity value released from the transducer **4**, wherein the position is called the half intensity beam.

As illustrated in FIG. 2, in accordance with an embodiment of the present disclosure, the ultrasonic cleaning and disinfecting device can include an ultrasound generator **12** having a plurality of piezoelectric transducers **6**, wherein the plurality of transducers **6** produce ultrasonic waves **8**, and wherein each ultrasonic wave **8** has a dome shape **10**.

In particular, in accordance with an embodiment of the present disclosure, FIG. 2 illustrates a positional arrangement of a plurality of transducers **6** that produce ultrasonic waves **8**, wherein each ultrasonic wave **8** has a dome shape **10** design, wherein the profile of each ultrasonic wave **8** dome shape **10** represents a half intensity beam generated from each piezoelectric transducer **6**, and wherein the positional arrangement of the transducers **6** and the dome shape **10** design of the ultrasonic waves **8** can minimize or reduce the occurrence of interference between the ultrasonic waves **8**. In embodiments, each ultrasonic wave **8** emitted by a transducer **6** can be designed such that minimal interference, reduced interference, substantially no interference or no interference occurs between the ultrasonic waves **8** emitted.

Additionally, the dome shape **10** of the ultrasonic waves **8** emitted by the transducers **6** can provide for an increase in the homogeneity or homogenous distribution of ultrasonic waves **8** throughout the entire volume or substantially entire volume of the liquid medium in the ultrasonic cleaning tank or cleaning bath.

In embodiments, the ultrasonic waves **8** emitted by the piezoelectric transducers **6** generate fine microscopic bubbles during the cavitation process that can be used to clean complex areas or difficult to clean areas of fruits and vegetables.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure does not use any chemical compounds or substances.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure reduces water consumption and energy consumption when compared with known ultrasonic cleaning devices. For example, in accordance with an embodiment of the present disclosure, the ultrasonic cleaning and disinfecting device can reduce water consumption by up to 81% in comparison to a known running water type ultrasonic cleaning device.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can be used for cleaning and disinfecting other food articles such as but not limited to eggs and meats. In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure can be used for cleaning and disinfecting non-food articles.

In embodiments, an ultrasonic cleaning and disinfecting device of the present disclosure can be used as a household appliance for cleaning fruits and vegetables on a small scale.

In embodiments, an ultrasonic cleaning and disinfecting device of the present disclosure can be used on an industrial scale.

The ultrasonic cleaning and disinfecting device of the present disclosure can be used in the agricultural industry, fruit production industry, vegetable production industry, fruit export industry, vegetable export industry, fruit import industry, vegetable import industry, fruit cleaning industry and/or vegetable cleaning industry.

FIGS 3A – 3B illustrate an embodiment of an ultrasonic cleaning tank **14** or cleaning bath **14** of an ultrasonic cleaning and disinfecting device of the present disclosure. FIG 3A illustrates a two dimensional view of the ultrasonic cleaning tank **14** or cleaning bath **14**, wherein the ultrasonic cleaning tank **14** includes a top open portion **16** defining the length and width of the ultrasonic cleaning tank **14**, and a bottom closed base **18** defining the length and width of the ultrasonic cleaning tank **14**, having a surface area, and having an outer surface and inner surface. The outer surface of the bottom closed base **18** is outside the ultrasonic cleaning tank **14** and the inside surface is inside the ultrasonic cleaning tank **14**. FIG 3B illustrates a three dimensional view of the ultrasonic cleaning tank **14** or cleaning bath **14**, wherein the ultrasonic cleaning tank **14** includes: the top open portion **16**; the bottom closed base **18**; a first side **20** defining the length and height of the cleaning tank **14** and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**; a second side (not shown) defining the length and height of the ultrasonic cleaning tank **14** opposite the first side **20**, and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**; a third side **22** defining the width and height of the ultrasonic cleaning tank **14**, and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**; and a fourth side (not shown) defining the width and height of the ultrasonic cleaning tank **14** opposite the third side **22**, and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**.

FIGS 3B-3C and FIG 4 illustrate an embodiment of the positioning of transducers **6** on the outer surface of the bottom closed base **18**. In embodiments, an ultrasonic cleaning tank **14** can have 2 or more, 10 or more, 20 or more, 30 or more, 40 or more, 60 or more, 80 or more, or 100 or more transducers **6** installed on the outer surface of the bottom closed base **18.** In embodiments, an ultrasonic cleaning tank **14** can have 2 or more rows, 4 or more rows, 6 or more rows, 8 or more rows, 10 or more rows, 12 or more rows, 14 or more rows, 16 or more rows, 18 or more rows, or 20 or more rows of transducers **6** installed on the outer surface of the bottom closed base **18**. In embodiments, each row can include 2 or more, 10 or more, 20 or more, 30 or more, 40 or more, 60 or more, 80 or more, or 100 or more transducers **6**.

In embodiments, the ultrasonic cleaning tank **14** can be an industrial scale size ultrasonic cleaning tank **14**. In embodiments, the ultrasonic cleaning tank **14** can a small scale size ultrasonic cleaning tank **14** for application in a home.

In embodiments, transducers **6** may be installed and similarly positioned (i.e., similar to the positioning shown in FIGS 3B and 3C) on the outer surface of the first side **20**, the outer surface of the second side (not shown), the outer surface of the third side **22** and/or the outer surface of the fourth side (not shown). In embodiments, the number of transducers **6** on each of the outer surfaces of the first side **20**, second side (not shown), third side **22**, and fourth side can be 2 or more, 10 or more, 20 or more, 30 or more, 40 or more, 60 or more, 80 or more, or 100 or more.

FIG 5 depicts an embodiment of an ultrasonic cleaning and disinfecting device **24** of the present disclosure. As illustrated in FIG 5, the ultrasonic cleaning and disinfecting device **24** can include: a pre-wash tank **26** or pre-wash bath **26**; an ultrasonic cleaning tank **14** or ultrasonic cleaning bath **14**; and/or a post-wash electrolysis tank **28** or post-wash electrolysis bath **28**. In embodiments, the ultrasonic cleaning and disinfecting device **24** can include wheels operably connected to the pre-wash tank **26**, ultrasonic cleaning tank **14** and/or post-wash electrolysis tank **28**.

In embodiments, the pre-wash tank **26** has a width of about 90 centimeters (cm) to about 100 cm, a length of about 70 cm to about 90 cm, and a height of about 40 cm to about 50 cm. In embodiments, the ultrasonic cleaning tank **14** has a width of about 40 cm to about 60 cm, a length of about 100 cm to about 130 cm, and a height of about 30 cm to about 60 cm. In embodiments, the post-wash electrolysis tank **28** has a width of about 40 cm to about 60 cm, a length of about 100 cm to about 150 cm, and a height of about 30 cm to about 60 cm.

In embodiments, the ultrasonic cleaning device **24** includes the ultrasonic cleaning tank **14** but does not include a pre-wash tank and post-wash electrolysis tank. In embodiments, the ultrasonic cleaning tank **14** can be used to removing dirt, oil, mold, chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae or a combination thereof.

As illustrated in FIG 5, the ultrasonic cleaning and disinfecting device **24** can include a controller **30** for controlling the pre-washing, ultrasonic cleaning, and/or post-wash electrolysis processes. In embodiments, the controller **30** can be operably connected to the ultrasonic cleaning tank **14**. In embodiments, the controller **30** can be operably connected to the ultrasonic cleaning tank **14**, pre-wash tank 26 and post-wash electrolysis tank **28**. In embodiments, the controller **30** can be placed below the ultrasonic cleaning tank **14**. In embodiments, the controller **30** can be placed below the ultrasonic cleaning tank **14**, pre-wash tank **26** or post-wash electrolysis tank **28**.

In embodiments, the controller **30** can be operably connected to a pH meter to monitor the pH of the electrolyte solution in the post-wash electrolysis tank **28**. The controller **30** operably linked to the pH meter can be used to ensure that the electrolyte solution in the post-wash electrolysis tank **28** is within the pH range of 6-8.

In embodiments, the controller **30** can be operably connected to a temperature measuring device to monitor the temperature of the water in the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28**. In embodiments, the temperature of the water in the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28** is about 25 to about 30°C.

In embodiments, the controller **30** can be operably connected to one or more sensors (i.e., optical sensors) in the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28**, wherein the sensors measure the cleanliness or purity of the water and/or the water level. Based on the measurement of the one or more sensors and the resulting measurement values sent to the controller **30**, the controller **30** can be used to determine whether the water needs to be drained and/or changed. If the one or more sensors indicate that the water level is too low or too high, the controller **30** can be used to determine that the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28** need more water or less water. In embodiments, the controller **30** can be used to monitor the number of cycles of pre-washing, ultrasonic cleaning, and/or post-wash electrolysis. Based on the number of cycles of pre-washing, ultrasonic cleaning, and/or post-wash electrolysis, the controller **30** can be used to determine if the respect tank needs to be re-filled.

In embodiments, the ultrasonic cleaning and disinfecting device **24** can be operated automatically using the controller **30** with minimal oversight by an operator.

As illustrated in FIG 5, the post-wash electrolysis tank **28** can include an electrolysis tank **32** and water tank **34**. The electrolysis tank **32** can be used for killing or removing micro-organisms and reducing chemical residues. In embodiments, sodium chloride (NaCl) can be added to the post-wash electrolysis tank **32**, which in turn produces hypochlorous acid (HOCl) under conditions that include an oxidation/reduction potential that is greater than 700 mV and a pH of 6 to 7. The water tank **34** can be used for removing electrolyte residue.

In embodiments, the pre-washing, ultrasonic cleaning, and post-wash electrolysis processes are performed with water.

In embodiments, the ultrasonic cleaning and disinfecting device **24** is portable and/or mobile. In embodiments, the ultrasonic cleaning and disinfecting device **24** can be positioned on a portable or mobile apparatus. In embodiments, the ultrasonic cleaning and disinfecting device **24** can be used on an industrial scale. In embodiments, the ultrasonic cleaning and disinfecting device **24** can be used on a smaller scale for home or domestic use.

In embodiments, water is used for pre-washing of the fruits and/or vegetables. Water can be provided to the pre-wash tank **26** from a water source (not shown in FIG 5). The pre-washing of the fruits and/or vegetables can be achieved via the use of a bubble system that can be created by water pressure at the bottom of the pre-wash tank **26** moving to the top surface of the water. The bubbles provided by the bubble system can create relatively large waves that can collide with the outer surfaces of the fruits and/or vegetables. The collision of the waves of water with the outer surfaces of the fruits and/or vegetables can remove large contaminants such as but not limited to dirt. In embodiments, the water pressure in the pre-wash tank **16** can be controlled by adjusting the pressure value via the use of an air compressor.

As illustrated in FIGS 6A and 6B, in embodiments, the pre-wash tank **26** includes an overflow system **36** on a side of the pre-wash tank **26** to provide for the transport and removal of contaminants out of the pre-wash tank **26**.

In accordance with an embodiment of the present disclosure, the pre-wash tank **26** includes a blower system **36'** on a side of the pre-wash tank **26**. The blower system **36'** blows air into the liquid medium (i.e., water) in the pre-wash tank **26**. The blower system **36'** includes a tube **36''** located inside the pre-wash tank **26** having holes **36'''** positioned along the length of the tube **36''**, wherein the holes **36'''** are positioned on the side length of the tube **36''** facing the top of the pre-wash tank **26**, thus, the holes **36'''** also face the top of the pre-wash tank **26**. The blower system **36'** blows air into the pre-wash tank **26** through the holes **36'''** in the tube **36''** resulting in the production of bubbles that float upward to the liquid medium surface. The production of bubbles and the floatation of the bubbles upward to the liquid medium (i.e., water) surface results in the circulation of the liquid medium (i.e., water).

In embodiments, the pre-wash tank **26** can be made from stainless steel grade SUS 304 and have a volume of about 350 litres. In embodiments, the pre-wash tank **26** can have a volume of about 350 litres or less or a volume of about 350 litres or more. It is contemplated that the pre-wash tank **26** can be made from can also be made from different materials than stainless steel grade SUS 304. Additionally, as illustrated in FIGS 6A and 6B, the pre-wash tank **26** can include wheels **38** at the base of the tank in order that the tank **26** may be moved easily. In embodiments, the pre-wash tank **26** can include four wheels **38** at the base of the tank **26**.

After the fruits and/or vegetables have been pre-washed in the pre-wash tank **26** the pre-washed fruits and/or vegetables can be moved to the ultrasonic cleaning tank **14** for ultrasonic cleaning and disinfecting. In embodiments, the ultrasonic cleaning tank **14** can be used for removing small contaminants from fruits and/or vegetables. In embodiments, the ultrasonic cleaning tank **14** can be used for removing chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae, and/or the like from the surface of fruits and/or vegetables. In embodiments, the ultrasonic cleaning tank **14** can include a means for keeping the fruits and/or vegetables underwater (i.e., under the water surface). In embodiments, the means for keeping the fruits and/or vegetables underwater can be a sieve. In embodiments, the ultrasonic cleaning tank **14** can include a means for stirring the fruits, vegetables, and/or water. In embodiments, the ultrasonic cleaning tank **14** can be made from stainless steel grade SUS 304 and have a volume of about 150 to about 200 litres. In embodiments, the ultrasonic cleaning tank **14** can have a volume of less than about 150 litres. In embodiments, the ultrasonic cleaning tank 14 can have a volume of greater than about 200 litres. It is contemplated that the ultrasonic cleaning tank **14** can also be made from different materials than stainless steel grade SUS 304.

As illustrated in FIGS 3B-3C and FIG 4, the ultrasonic cleaning tank **14** can include a plurality of transducers **6**. In embodiments, the plurality of transducers **6** can be piezoelectric transducers **6**. In embodiments, the plurality of transducers **6** can be piezoelectric ceramic crystals **6** having frequencies of about 50 kHz to about 60 kHz. In embodiments, each piezoelectric ceramic crystal **6** can have a circular shape with a diameter of about 38 mm and a thickness of about 3 mm. Other shapes of piezoelectric ceramic crystals **6** are contemplated. In embodiments, each piezoelectric ceramic crystal **6** can have a circular shape with a diameter of about 38 mm or less or of about 38 mm or more. In embodiments, each piezoelectric ceramic crystal **6** can have a thickness of about 3 mm or less or of about 3 mm or more.

After the fruits and/or vegetables have undergone ultrasonic washing and disinfection in the ultrasonic cleaning tank **14**, the ultrasonically cleaned fruits and/or vegetables can be moved to the post-wash electrolysis tank **28** for treatment of the fruits and/or vegetables with electrolyzed water. In embodiments, the post-wash electrolysis tank **28** can be made from stainless steel grade SUS 304 and have a volume of about 200 litres, wherein the electrolysis tank **32** can have a volume of about 100 litres and the water tank **34** can have a volume of about 100 litres. It is contemplated that the post-wash electrolysis tank **28** can also be made from different materials than stainless steel grade SUS 304.

In embodiments, the ultrasonic cleaning and disinfecting device **24** can include a means for recycling the water used in the pre-washing, ultrasonic cleaning, and/or post-wash electrolysis processes, wherein the recycled water can be re-used in a separate cycle of pre-washing, ultrasonic cleaning, and/or post-wash electrolysis.

Method of Cleaning and Disinfecting Fruits and Vegetables

The present disclosure also relates to a method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device of the present disclosure. In embodiments, the method of cleaning and disinfecting fruits and vegetables of the present disclosure can include removing dirt, oil, mold, chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae and/or the like from the surface of fruits and vegetables from the surface of fruits (i.e., the skin of fruits) and vegetables (i.e., the skin of vegetables and/or the leaves of vegetables).

In embodiments, the method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device of the present disclosure can be used to vitalize fruits and vegetables during the cleaning and disinfecting process via the use of ultrasonic vibration and/or ultrasonic waves. In embodiments, the method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device of the present disclosure can be used to prolong the shelf-life of fruits and vegetables via the use of ultrasonic vibration and/or ultrasonic waves.

In embodiments, the method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device of the present disclosure can be a more efficient method of cleaning and disinfecting fruit and vegetables with soft skin and/or soft tissue without damaging the outer skin, soft skin and/or soft tissue of the fruits and vegetables when compared to other known methods of ultrasonic cleaning and disinfecting of fruits and vegetables.

In embodiments, the method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device of the present disclosure can result in improved cleaning and disinfecting of fruit and vegetables when compared to other known methods of ultrasonic cleaning and disinfecting of fruits and vegetables. The method of cleaning and disinfecting fruits and vegetables using the ultrasonic cleaning and disinfecting device of the present disclosure can improve the quality of cleaning and disinfecting fruit and vegetables when compared to other known methods of ultrasonic cleaning and disinfecting of fruits and vegetables.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables without damaging the outer skin, soft skin and/or soft tissue of the fruits and vegetables can be achieved by the use of an optimal frequency of ultrasonic vibration and/or ultrasonic waves in the range of about 50 to about 60 kilohertz (kHz). In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting vegetables with fragile leaves without damaging the outer surface, outer skin, soft skin and/or soft tissue of the fragile vegetables leaves can be achieved by the use of an optimal frequency of ultrasonic vibration and/or ultrasonic waves of about 60 kilohertz (kHz).

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables without damaging the outer skin, soft skin and/or soft tissue of the fruits and vegetables can be achieved by the use of an optimal intensity of ultrasonic vibration and/or ultrasonic waves.

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure includes a plurality of piezoelectric transducers that can generate an optimal frequency of ultrasonic vibration and/or ultrasonic waves in the range of about 50 to about 60 kilohertz (kHz).

In embodiments, the ultrasonic cleaning and disinfecting device of the present disclosure includes a plurality of piezoelectric transducers that can generate an optimal intensity of ultrasonic vibration and/or ultrasonic waves.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by the strategic placement or arrangement of a plurality of transducers in specific locations of the ultrasonic cleaning and disinfecting device of the present disclosure. The strategic placement of the transducers in specific locations can improve the homogeneity or homogenous distribution of the ultrasonic waves throughout the entire volume or substantially entire volume of the liquid medium in the cleaning tank or cleaning bath of the ultrasonic cleaning and disinfecting device of the present disclosure. In embodiments, a plurality of transducers can be placed or installed directly beneath the bottom surface of the cleaning tank or cleaning bath. In embodiments, a plurality of transducers can be placed or installed directly outside one or more of the side surfaces of the cleaning tank or cleaning bath.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by using the strategically designed transducers in precise patterns. The use of the strategically placed transducers in precise patterns can improve the homogeneity of homogenous distribution of the ultrasonic waves throughout the entire volume or substantially entire volume of the liquid medium of the cleaning tank or cleaning bath of the ultrasonic cleaning and disinfecting device of the present disclosure.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruit and vegetables can be achieved by the ratio of the number of transducers to the volume of the cleaning tank or cleaning bath. The ratio of the number of transducers to the volume of the cleaning tank or cleaning bath can improve the homogeneity or homogenous distribution of the ultrasonic waves throughout the entire volume or substantially entire volume of the liquid medium of the cleaning tank or cleaning bath.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by the design of the ultrasonic waves emitted by the transducers. As mentioned earlier, and as illustrated in FIG. 1, the intensities of ultrasonic waves **2** produced in known ultrasonic cleaning devices currently being used typically decrease as the ultrasonic waves **2** move further away from their origin (i.e., the transducers **4**). FIG. 1 depicts a three dimensional view of an ultrasonic wave **2** emitted by a transducer **4**, wherein the intensity of the ultrasonic wave **2** decreases as the ultrasonic wave **2** moves further away from the transducer **4**.

On the other hand, as illustrated in FIG. 2, in embodiments of the ultrasonic cleaning and disinfecting device of the present disclosure, a plurality of piezoelectric transducers **6** can produce ultrasonic waves **8**, wherein each ultrasonic wave has a dome shape **10**. The dome shape **10** of the ultrasonic wave **8** can minimize or reduce the loss of intensity as the ultrasonic wave **8** moves further way from its origin (i.e. the piezoelectric transducer **6**). Consequently, the dome shape **10** of the ultrasonic waves **8** emitted by the transducers **6** can provide for an increase in the homogenous distribution of ultrasonic waves **8** throughout the cleaning tank or cleaning bath.

In an embodiment, the intensities of the ultrasonic waves can be changed or altered by factors such as the reflection and refraction of ultrasonic waves from fruits and vegetables being cleaned and disinfected in the ultrasonic cleaning and disinfecting device.

In embodiments, the increase in efficiency and/or improvement in cleaning and disinfecting of fruits and vegetables can be achieved by the directional movement of the ultrasonic waves emitted by the transducers. As illustrated in FIG. 2, in embodiments, the ultrasonic waves **8** emitted by the transducers **6** can be designed to move in the forward direction (i.e., in a direction that is perpendicular to the front surface a transducer **6**). Also, as illustrated in FIG. 2, In embodiments, each ultrasonic wave **8** emitted by a transducer **6** can be designed to move in the forward direction (i.e., in a direction that is perpendicular to the front surface a transducer **6**) with minimal interference, reduced interference, substantially no interference or no interference of other ultrasonic waves emitted by other transducers **6**. In embodiments, the ultrasonic waves **8** emitted by transducers **6** in the forward direction (i.e., in a direction that is perpendicular to the front surface a transducer **6**) generate fine microscopic bubbles during the cavitation process that can be used to clean complex areas or difficult to clean areas of fruits and vegetables.

In embodiments, the method of cleaning and disinfecting of the present disclosure does not include the use of any chemical compounds or substances.

In embodiments, the method of cleaning and disinfecting of the present disclosure results in a reduction in water consumption and energy consumption when compared with known ultrasonic cleaning methods.

In embodiments, the method of cleaning and disinfecting of the present disclosure can be used for cleaning and disinfecting other food articles such as but not limited to eggs and meats. In embodiments, the method of cleaning and disinfecting of the present disclosure can be used for cleaning and disinfecting non-food articles.

In embodiments, a method of cleaning and disinfecting fruits and vegetables of the present disclosure can be used to clean fruits and vegetables on a small scale. In embodiments, a method of cleaning and disinfecting fruits and vegetables of the present disclosure can be used for household applications.

In embodiments, a method of cleaning and disinfecting fruits and vegetables of the present disclosure can be used to clean fruits and vegetables on an industrial scale.

The method of cleaning and disinfecting fruits and vegetables of the present disclosure can be used in the agricultural industry, fruit production industry, vegetable production industry, fruit export industry, vegetable export industry, fruit import industry, vegetable import industry, fruit cleaning industry and/or vegetable cleaning industry.

FIGS 3A – 3B illustrate an embodiment of an ultrasonic cleaning tank **14** or cleaning bath **14** of an ultrasonic cleaning and disinfecting device of the present disclosure. FIG 3A illustrates a two dimensional view of the ultrasonic cleaning tank **14** or cleaning bath **14**, wherein the ultrasonic cleaning tank **14** includes a top open portion **16** defining the length and width of the ultrasonic cleaning tank **14**, and a bottom closed base **18** defining the length and width of the ultrasonic cleaning tank **14**, having a surface area, and having an outer surface and inner surface. The outer surface of the bottom closed base **18** is outside the ultrasonic cleaning tank **14** and the inside surface is inside the ultrasonic cleaning tank **14**. FIG 3B illustrates a three dimensional view of the ultrasonic cleaning tank **14** or cleaning bath **14**, wherein the ultrasonic cleaning tank **14** includes: the top open portion **16**; the bottom closed base **18**; a first side **20** defining the length and height of the cleaning tank **14** and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**; a second side (not shown) defining the length and height of the ultrasonic cleaning tank **14** opposite the first side **20**, and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**; a third side **22** defining the width and height of the ultrasonic cleaning tank **14**, and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**; and a fourth side (not shown) defining the width and height of the ultrasonic cleaning tank **14** opposite the third side **22**, and having an outer surface outside of the ultrasonic cleaning tank and an inside surface inside the ultrasonic cleaning tank **14**.

FIGS 3B-3C and FIG 4 illustrate an embodiment of the positioning of transducers **6** on the outer surface of the bottom closed base **18**. In embodiments, an ultrasonic cleaning tank **14** can have 2 or more, 10 or more, 20 or more, 30 or more, 40 or more, 60 or more, 80 or more, or 100 or more transducers **6** installed on the outer surface of the bottom closed base **18.**

In embodiments, the ultrasonic cleaning tank **14** can be an industrial scale size ultrasonic cleaning tank **14**. In embodiments, the ultrasonic cleaning tank **14** can be a small scale size ultrasonic cleaning tank **14** for application in a home.

In embodiments, transducers **6** may be installed and similarly positioned (i.e., similar to the positioning shown in FIGS 3B and 3C) on the outer surface of the first side **20**, the outer surface of the second side (not shown), the outer surface of the third side **22** and/or the outer surface of the fourth side (not shown). In embodiments, the number of transducers **6** on each of the outer surfaces of the first side **20**, second side (not shown), third side **22**, and fourth side can be 2 or more, 10 or more, 20 or more, 30 or more, 40 or more, 60 or more, 80 or more, or 100 or more.

FIG 5 depicts an embodiment of an ultrasonic cleaning and disinfecting device **24** of the present disclosure. As illustrated in FIG 5, the ultrasonic cleaning and disinfecting device **24** can include: a pre-wash tank **26** or pre-wash bath **26**; an ultrasonic cleaning tank **14** or ultrasonic cleaning bath **14**; and/or a post-wash electrolysis tank **28** or electrolysis bath **28**. In embodiments, the ultrasonic cleaning and disinfecting device **24** can include wheels operably connected to the pre-wash tank **26**, ultrasonic cleaning tank **14** and/or post-wash electrolysis tank **28**.

In embodiments, the ultrasonic cleaning device **24** includes the ultrasonic cleaning tank **14** but does not include a pre-wash tank and post-wash electrolysis tank. In embodiments, the ultrasonic cleaning tank **14** can be used to removing dirt, oil, mold, chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae or a combination thereof.

As illustrated in FIG 5, the ultrasonic cleaning and disinfecting device 24 can include a controller **30** for controlling the pre-washing, ultrasonic cleaning, and/or post-wash electrolysis processes. In embodiments, the controller **30** can be operably connected to the ultrasonic cleaning tank **14**. In embodiments, the controller **30** can be operably connected to the ultrasonic cleaning tank **14**, pre-wash tank 26 and post-wash electrolysis tank **28**. In embodiments, the controller **30** can be placed below the ultrasonic cleaning tank **14.** In embodiments, the controller **30** can be placed below the ultrasonic cleaning tank **14**, pre-wash tank **26** or post-wash electrolysis tank **28**.

In embodiments, the controller **30** can be operably connected to a pH meter to monitor the pH of the electrolyte solution in the post-wash electrolysis tank **28**. The controller **30** operably linked to the pH meter can be used to ensure that the electrolyte solution in the post-wash electrolysis tank **28** is within the pH range of 6-8.

In embodiments, the controller **30** can be operably connected to a temperature measuring device to monitor the temperature of the water in the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28**. In embodiments, the temperature of the water in the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28** is about 25 to about 30°C.

In embodiments, the controller **30** can be operably connected to one or more sensors (i.e., optical sensors) in the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28**, wherein the sensors measure the cleanliness or purity of the water and/or the water level. Based on the measurement of the one or more sensors and the resulting measurement values sent to the controller **30**, the controller **30** can be used to determine whether the water needs to be drained and/or changed. If the one or more sensors indicate that the water level is too low or too high, the controller **30** can be used to determine that the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28** need more water or less water. In embodiments, the controller **30** can be used to monitor the number of cycles of pre-washing, ultrasonic cleaning, and/or post-wash electrolysis. Based on the number of cycles of pre-washing, ultrasonic cleaning, and/or post-wash electrolysis, the controller **30** can be used to determine if the respect tank needs to be re-filled.

In embodiments, the ultrasonic cleaning and disinfecting device **24** can be operated automatically using the controller **30** with minimal oversight by an operator.

In embodiments, food articles and/or non-food articles to be cleaned can be placed in the ultrasonic cleaning and disinfecting device **24** manually or automatically. In embodiments, food articles and/or non-food articles can be manually transferred or automatically transferred between the pre-wash tank **26**, ultrasonic cleaning tank **14**, and/or post-wash electrolysis tank **28**. In embodiments, ultrasonically cleaned and disinfected food articles and/or non-food articles can be removed from the ultrasonic cleaning and disinfecting device **24** manually or automatically.

As illustrated in FIG 5, the post-wash electrolysis tank **28** can include an electrolysis tank **32** and water tank **34**. The electrolysis tank **32** can be used for killing or removing micro-organisms and reducing chemical residues. In embodiments, sodium chloride (NaCl) can be added to the post-wash electrolysis tank 32, which in turn produces hypochlorous acid (HOCl) under conditions that include an oxidation/reduction potential that is greater than 700 mV and a pH of 6 to 7. The water tank **34** can be used for removing electrolyte residue.

In embodiments, the pre-washing, ultrasonic cleaning, and post-wash electrolysis processes are performed with water.

In embodiments, the ultrasonic cleaning and disinfecting device **24** is portable and/or mobile. In embodiments, the ultrasonic cleaning and disinfecting device **24** can be positioned on a portable or mobile apparatus. In embodiments, the ultrasonic cleaning and disinfecting device **24** can be used on an industrial scale. In embodiments, the ultrasonic cleaning and disinfecting device **24** can be used on a smaller scale for home or domestic use.

In embodiments, water is used for pre-washing of the fruits and/or vegetables. Water can be provided to the pre-wash tank **26** from a water source (not shown in FIG 5). The pre-washing of the fruits and/or vegetables can be achieved via the use of a bubble system that can be created by water pressure at the bottom of the pre-wash tank **26** moving to the top surface of the water. The bubbles provided by the bubble system can create relatively large waves that can collide with the outer surfaces of the fruits and/or vegetables. The collision of the waves of water with the outer surfaces of the fruits and/or vegetables can remove large contaminants such as but not limited to dirt. In embodiments, the water pressure in the pre-wash tank **16** can be controlled by adjusting the pressure value via the use of an air compressor.

As illustrated in FIGS 6A and 6B, the pre-wash tank **26** includes an overflow system **36** on the side of the pre-wash tank **26** to provide for the transport and removal of contaminants out of the pre-wash tank **26**.

In accordance with an embodiment of the present disclosure, the pre-wash tank **26** includes a blower system **36′** on a side of the pre-wash tank **26**. The blower system **36′** blows air into the liquid medium (i.e., water) in the pre-wash tank **26**. The blower system **36′** includes a tube **36″** located inside the pre-wash tank **26** having holes **36‴** positioned along the length of the tube **36″**, wherein the holes **36‴** are positioned on the side length of the tube **36″** facing the top of the pre-wash tank **26**, thus, the holes **36‴** also face the top of the pre-wash tank **26**. The blower system **36′** blows air into the pre-wash tank **26** through the holes **36‴** in the tube **36″** resulting in the production of bubbles that float upward to the liquid medium surface. The production of bubbles and the floatation of the bubbles upward to the liquid medium (i.e., water) surface results in the circulation of the liquid medium (i.e., water).

In embodiments, the pre-wash tank **26** can be made from stainless steel grade SUS 304 and have a volume of about 350 litres. In embodiments, the pre-wash tank **26** can have a volume of about 350 litres or less or a volume of about 350 litres or more. It is contemplated that the pre-wash tank **26** can be made from can also be made from different materials than stainless steel grade SUS 304. Additionally, as illustrated in FIGS 6A and 6B, the pre-wash tank **26** can include wheels **38** at the base of the tank in order that the tank **26** may be moved easily. In embodiments, the pre-wash tank **26** can include four wheels **38** at the base of the tank **26**.

After the fruits and/or vegetables have been pre-washed in the pre-wash tank **26** the pre-washed fruits and/or vegetables can be moved to the ultrasonic cleaning tank **14** for ultrasonic cleaning and disinfecting. In embodiments, the ultrasonic cleaning tank **14** can be used for removing small contaminants from fruits and/or vegetables. In embodiments, the ultrasonic cleaning tank **14** can be used for removing chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae, and/or the like from the surface of fruits and/or vegetables. In embodiments, the ultrasonic cleaning tank **14** can include a means for keeping the fruits and/or vegetables underwater (i.e., under the water surface). In embodiments, the means for keeping the fruits and/or vegetables underwater can be a sieve. In embodiments, the ultrasonic cleaning tank **14** can include a means for stirring the fruits, vegetables, and/or water. In embodiments, the ultrasonic cleaning tank **14** can be made from stainless steel grade SUS 304 and have a volume of about 150 to about 200 litres. In embodiments, the ultrasonic cleaning tank **14** can have a volume of less than about 150 litres. In embodiments, the ultrasonic cleaning tank 14 can have a volume of greater than about 200 litres. It is contemplated that the ultrasonic cleaning tank **14** can also be made from different materials than stainless steel grade SUS 304.

As illustrated in FIGS 3B-3C and FIG 4, the ultrasonic cleaning tank **14** can include a plurality of transducers **6**. In embodiments, the plurality of transducers **6** can be piezoelectric transducers **6**. In embodiments, the plurality of transducers **6** can be piezoelectric ceramic crystals **6** having frequencies of about 50 kHz to about 60 kHz. In embodiments, each piezoelectric ceramic crystal **6** can have a circular shape with a diameter of about 38 mm and a thickness of about 3 mm. Other shapes of piezoelectric ceramic crystals **6** are contemplated. In embodiments, each piezoelectric ceramic crystal **6** can have a circular shape with a diameter of about 38 mm or less or of about 38 mm or more. In embodiments, each piezoelectric ceramic crystal **6** can have a thickness of about 3 mm or less or of about 3 mm or more.

After the fruits and/or vegetables have undergone ultrasonic washing and disinfection in the ultrasonic cleaning tank **14**, the ultrasonically cleaned fruits and/or vegetables can be moved to the post-wash electrolysis tank **28** for treatment of the fruits and/or vegetables with electrolyzed water. In embodiments, the post-wash electrolysis tank **28** can be made from stainless steel grade SUS 304 and have a volume of about 200 litres, wherein the electrolysis tank **32** can have a volume of about 100 litres and the water tank **34** can have a volume of about 100 litres. It is contemplated that the post-wash electrolysis tank **28** can also be made from different materials than stainless steel grade SUS 304.

In embodiments, the ultrasonic cleaning and disinfecting device **24** can include a means for recycling the water used in the pre-washing, ultrasonic cleaning, and/or post-wash electrolysis processes, wherein the recycled water can be re-used in a separate cycle of pre-washing, ultrasonic cleaning, and/or post-wash electrolysis.

EXAMPLES

__Example 1__

Referring to FIG 7, an experiment was conducted to determine the most effective positioning of transducers on an ultrasonic cleaning tank and the most effective transducer activation pattern for cleaning food articles such as but not limited to fruits and vegetables.

As illustrated in FIG 7, four transducer activation patterns were designed: A-1, O-1, C-1 and Z-1. The A-1 transducer pattern included forty transducers **6** strategically positioned on the outer surface of the bottom closed base **18** of the ultrasonic cleaning tank **14**. Four rows of transducers **6** are installed on the outer surface of the bottom closed base **18**, and wherein each of the four rows includes ten transducers **6** each. The second row **40** is positioned in staggered relation to the first row **42**. The third row **44** is positioned in staggered relation to the second row **40**, wherein each of the transducers **6** of the third row **44** is directly or substantially directly lined up with each of the transducers **6** of the first row **42**. The fourth row **46** is positioned in staggered relation to the third row **44**, wherein each of the transducers **6** of the fourth row **46** is directly or substantially directly lined up with each of the transducers **6** of the second row **40**.

As depicted in FIG 7, the A-1 transducer activation pattern can have one of two activation patterns. In the first A-1 transducer activation pattern, the first row **42** of transducers **6** and third row **44** of transducers **6** are activated, while the second row **40** of transducers **6** and fourth row **46** of transducer **6** are not activated. In the second A-1 transducer activation pattern, the second row **40** of transducers **6** and fourth row **46** of transducers **6** are activated while the first row **42** of transducers **6** and third row **44** of transducers **6** are not activated. The activated transducers **48** are represented by the shaded or filled in transducers **6** while the un-activated transducers **50** are represented by the un-shaded transducers **6**.

In embodiments, the first A-1 transducer activation pattern and second A-1 transducer activation pattern can include the transducers **6** that are activated during use in the same positioning described above but do not include the transducers **6** that are not activated during use.

In embodiments, the first A-1 transducer activation pattern and second A-1 transducer activation pattern can include four or more rows, six or more rows, eight or more rows, 10 or more rows, 12 or more rows, 14 or more rows, 16 or more rows, 18 or more rows, or 20 or more rows of transducers **6**. In embodiments, the first A-1 transducer activation pattern and second A-1 transducer activation pattern can include six or more, eight or more, ten or more, twelve or more, fourteen or more, sixteen or more, eighteen or more, or twenty or more transducers **6** in each row.

In embodiments, the transducers **6** are operably connected to a controller and selectively activated by the controller. In embodiments, the controller selectively activates the first A-1 transducer activation pattern, the second A-1 transducer activation pattern or a combination thereof. In embodiments, the controller is programmed such that the transducers **6** alternate between the first A-1 transducer activation pattern and the second A-1 transducer activation pattern according to a specific timed alternation system.

As illustrated in FIG 7, the O-1 transducer activation pattern included forty transducers **6** strategically positioned on the outer surface of the bottom closed base **18** of the ultrasonic cleaning tank **14**. Four rows of transducers **6** are installed on the outer surface of the bottom closed base **18**, and wherein each of the four rows includes ten transducers **6** each. The second row **40** is positioned in staggered relation to the first row **42**. The third row **44** is positioned in staggered relation to the second row **40**, wherein each of the transducers **6** of the third row **44** is directly or substantially directly lined up with each of the transducers **6** of the first row **42**. The fourth row **46** is positioned in staggered relation to the third row **44**, wherein each of the transducers **6** of the fourth row **46** is directly or substantially directly lined up with each of the transducers **6** of the second row **40**.

As depicted in FIG 7, in the O-1 transducer activation pattern, the first row **42** of transducers **6** and fourth row **46** of transducers **6** are activated, while the second row **40** of transducers **6** and third row **44** of transducer **6** are not activated. The activated transducers **48** are represented by the shaded or filled in transducers **6** while the un-activated transducers **50** are represented by the un-shaded transducers **6**.

In embodiments, the O-1 transducer activation pattern can include the transducers **6** that are activated during use in the same positioning described above but do not include the transducers **6** that are not activated during use.

In embodiments, the O-1 transducer activation pattern can include four or more rows, six or more rows, eight or more rows, 10 or more rows, 12 or more rows, 14 or more rows, 16 or more rows, 18 or more rows, or 20 or more rows of transducers **6**. In embodiments, the O-1 transducer activation pattern can include six or more, eight or more, ten or more, twelve or more, fourteen or more, sixteen or more, eighteen or more, or twenty or more transducers **6** in each row.

As illustrated in FIG 7, the C-1 transducer activation pattern included forty transducers **6** strategically positioned on the outer surface of the bottom closed base **18** of the ultrasonic cleaning tank **14**. Four rows of transducers **6** are installed on the outer surface of the bottom closed base **18**, and wherein each of the four rows includes ten transducers **6** each. The second row **40** is positioned in staggered relation to the first row **42**. The third row **44** is positioned in staggered relation to the second row **40**, wherein each of the transducers **6** of the third row **44** is directly or substantially directly lined up with each of the transducers **6** of the first row **42**. The fourth row **46** is positioned in staggered relation to the third row **44**, wherein each of the transducers **6** of the fourth row **46** is directly or substantially directly lined up with each of the transducers **6** of the second row **40**.

As depicted in FIG 7, in the C-1 transducer activation pattern, the first row **42** of transducers **6** and fourth row **46** of transducers **6** are un-activated, while the second row **40** of transducers **6** and third row **44** of transducer **6** are activated. The activated transducers **48** are represented by the shaded or filled in transducers **6** while the un-activated transducers **50** are represented by the un-shaded transducers **6**.

In embodiments, the C-1 transducer activation pattern can include the transducers **6** that are activated during use in the same positioning described above but do not include the transducers **6** that are not activated during use.

In embodiments, the C-1 transducer activation pattern can include four or more rows, six or more rows, eight or more rows, 10 or more rows, 12 or more rows, 14 or more rows, 16 or more rows, 18 or more rows, or 20 or more rows of transducers **6**. In embodiments, the C-1 transducer activation pattern can include six or more, eight or more, ten or more, twelve or more, fourteen or more, sixteen or more, eighteen or more, or twenty or more transducers **6** in each row.

As illustrated in FIG 7, the Z-1 transducer activation pattern included forty transducers **6** strategically positioned on the outer surface of the bottom closed base **18** of the ultrasonic cleaning tank **14**. Four rows of transducers **6** are installed on the outer surface of the bottom closed base **18**, and wherein each of the four rows includes ten transducers **6** each. The second row **40** is positioned in staggered relation to the first row **42**. The third row **44** is positioned in staggered relation to the second row **40**, wherein each of the transducers **6** of the third row **44** is directly or substantially directly lined up with each of the transducers **6** of the first row **42**. The fourth row **46** is positioned in staggered relation to the third row **44**, wherein each of the transducers **6** of the fourth row **46** is directly or substantially directly lined up with each of the transducers **6** of the second row **40**.

As depicted in FIG 7, the Z-1 transducer activation pattern can have one of two activation patterns. In the first Z-1 transducer pattern or first zig-zag activation pattern, the first row **42** of transducers **6** has a pattern of two transducers **6** activated and two transducers **6** un-activated and so on. The second row **40** of transducers **6** has a pattern of two transducers **6** un-activated and two transducers **6** activated and so on. The third row **44** of transducers **6** has a pattern of two transducers **6** activated and two transducers **6** un-activated and so on. The fourth row **46** of transducers **6** has a pattern of two transducers **6** un-activated and two transducers **6** activated and so on. The activated transducers **48** are represented by the shaded or filled in transducers **6** while the un-activated transducers **50** are represented by the un-shaded transducers **6**.

In the second Z-1 transducer activation pattern or second zig-zag activation pattern, the first row **42** of transducers **6** has a pattern of two transducers **6** un-activated and two transducers **6** activated and so on. The second row **40** of transducers **6** has a pattern of two transducers **6** activated and two transducers **6** un-activated and so on. The third row **44** of transducers **6** has a pattern of two transducers **6** un-activated and two transducers **6** activated and so on. The fourth row **46** of transducers **6** has a pattern of two transducers **6** activated and two transducers **6** un-activated and so on. The activated transducers **48** are represented by the shaded or filled in transducers **6** while the un-activated transducers **50** are represented by the un-shaded transducers **6**.

In embodiments, the first Z-1 transducer activation pattern can have a pattern of two transducers **6** activated and two transducers **6** un-activated and so on in a repeating manner, three transducers **6** activated and three transducers **6** un-activated and so on in a repeating manner, four transducers **6** activated and four transducers **6** un-activated and so on in a repeating manner, five transducers **6** activated and five transducers **6** un-activated and so on in a repeating manner, six transducers **6** activated and six transducers **6** un-activated and so on in a repeating manner, or seven or more transducers **6** activated and seven or more transducers **6** un-activated and so on in a repeating manner.

In embodiments, the second Z-1 transducer activation pattern can have a pattern of two transducers **6** un-activated and two transducers **6** activated and so on in a repeating manner, three transducers **6** un-activated and three transducers **6** activated and so on in a repeating manner, four transducers **6** un-activated and four transducers **6** activated and so on in a repeating manner, five transducers **6** un-activated and five transducers **6** activated and so on in a repeating manner, six transducers **6** un-activated and six transducers **6** activated and so on in a repeating manner, or seven or more transducers **6** un-activated and seven or more transducers **6** activated and so on in a repeating manner.

In embodiments, the first Z-1 transducer activation pattern and second Z-1 transducer activation pattern can include the transducers **6** that are activated during use in the same positioning described above but do not include the transducers **6** that are not activated during use.

In embodiments, the first Z-1 transducer activation pattern and second Z-1 transducer activation pattern can include four or more rows, six or more rows, eight or more rows, 10 or more rows, 12 or more rows, 14 or more rows, 16 or more rows, 18 or more rows, or 20 or more rows of transducers **6**. In embodiments, the first Z-1 transducer activation pattern and second Z-1 transducer activation pattern can include six or more, eight or more, ten or more, twelve or more, fourteen or more, sixteen or more, eighteen or more, or twenty or more transducers **6** in each row.

Each of the transducers **6** used in the transducer patterns of A-1, O-1, C-1 and Z-1 was an piezoelectric ceramic transducer having a circular shape with a diameter of 38 mm and a thickness of 3 mm.

In embodiments, the transducers **6** are operably connected to a controller and selectively activated by the controller. In embodiments, the controller selectively activates the first Z-1 transducer activation pattern, the second Z-1 transducer activation pattern or a combination thereof. In embodiments, the controller is programmed such that the transducers **6** alternate between the first Z-1 transducer activation pattern and the second Z-1 transducer activation pattern according to a specific timed alternation system.

In embodiments, the transducers **6** are operably connected to a controller and selectively activated by the controller. In embodiments, the controller is programmed such that the transducers **6** alternate between the A-1, O-1, C-1 and Z-1 transducer activation patterns according to a specific timed alternation system.

Each of the transducer patterns of A-1, O-1, C-1 and Z-1 were tested on an ultrasonic cleaning tank **14** having a volume of 150 litres of water and an ultrasonic cleaning tank **14** having a volume of 200 litres of water. Due to the weight of the water, the different volumes of water can affect the compressive force at the bottom of the ultrasonic cleaning tanks **14** where the transducers **6** have been installed. Each of the ultrasonic cleaning tanks **14** was a 200 litre tank. An ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz was used to test each of the transducer patterns of A-1, O-1, C-1 and Z-1.

Test specimens of aluminium foil were placed in the lower level, middle level and upper level of the water in the ultrasonic cleaning tanks **14** for the tests.

Results for Example 1

As illustrated in FIG 8, with respect to the ultrasonic cleaning tank **14** having a volume of 150 litres of water and the ultrasonic cleaning tank **14** having a volume of 200 litres of water, the first Z-1 transducer pattern exhibited a continuous release of ultrasonic waves covering the entire or substantially entire volume of the water in the ultrasonic cleaning tanks **14** and the second Z-1 transducer pattern also exhibited a continuous release of ultrasonic waves covering the entire or substantially entire volume of the water in the ultrasonic cleaning tanks 14. With respect to the ultrasonic cleaning tank **14** having a volume of 150 litres of water and the ultrasonic cleaning tank **14** having a volume of 200 litres of water, the transducer patterns of A-1, O-1 and C-1 exhibited a reduction in coverage with ultrasonic waves of the volume of water in the ultrasonic cleaning tanks **14**.

Thus, both the first Z-1 transducer pattern and the second Z-1 transducer pattern exhibited the greatest homogeneity or homogenous distribution of ultrasonic waves throughout the entire or substantially entire volume of water in the ultrasonic cleaning tanks **14**.

As illustrated in FIG 8, with respect to the ultrasonic cleaning tank **14** having a volume of 150 litres of water and the ultrasonic cleaning tank **14** having a volume of 200 litres of water, activation of the transducer activation patterns A-1, O-1, C-1 and Z-1 caused the formation of different size holes by cavitation in the aluminium foil specimens in the ultrasonic cleaning tanks **14**. Each of the transducer activation patterns A-1, O-1, C-1 and Z-1 was tested using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz.

As illustrated in FIG 8, the cavitation caused by each of the transducer activation patterns A-1, O-1, C-1 and Z-1 punched holes in the aluminium foil specimens placed in the ultrasonic cleaning tanks **14**. The punched holes in the aluminium foil correspond to the holes that can be punched in pests (including eggs and larvae) and/or insects (including eggs and larvae) via the use of the transducer activation patterns A-1, O-1, C-1 and Z-1.

As illustrated in FIG 8, in comparison to the transducer activation patterns A-1, O-1 and C-1, both the first Z-1 transducer pattern and the second Z-1 transducer pattern exhibited the greatest coverage with ultrasonic waves of the volume of water in the ultrasonic cleaning tanks **14** as can be seen by the number, size, and distribution of cavitation holes made in the aluminium foil specimens at the lower level, middle level and upper level of the water in the ultrasonic cleaning tank **14** having a volume of 150 litres of water and in the ultrasonic cleaning tank **14** having a volume of 200 litres of water. The first Z-1 transducer pattern was applied independently or separately from the second Z-1 transducer pattern. The first Z-1 transducer pattern and the second Z-1 transducer pattern gave rise to the same results with respect to the number, size, and distribution of cavitation holes made in the aluminium foil specimens.

As illustrated in FIG 8, both the first Z-1 transducer pattern and the second Z-1 transducer pattern used on an ultrasonic cleaning tank **14** having a volume of 150 litres of water exhibited the best results for homogeneity or homogenous distribution of ultrasonic waves throughout the entire or substantially entire volume of 150 litres of water as can be seen by the number, size, and distribution of cavitation holes made in the aluminium foil specimens at the lower level, middle level and upper level of the water.

Example 2

As demonstrated in Tables 1 and 2, an embodiment of an ultrasonic cleaning and disinfecting device of the present disclosure (referred to as "Subject Device" in Table 1 and 2) was used to demonstrate the effectiveness of the ultrasonic cleaning and disinfecting device in maintaining the physical characteristics and/or physical integrity of vegetables (in this case Kale having thick skin) while cleaning and disinfecting the vegetables (in this case Kale having thick skin) using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz. The ultrasonic cleaning and disinfecting device of the present disclosure included an ultrasonic cleaning tank having a volume of water of 150 litres therein. The first Z-1 transducer pattern described above was used on the ultrasonic cleaning tank. The Kale was submerged and maintained below the surface of the water at all times during the ultrasonic cleaning.

As illustrated in Table 1 and 2, the effectiveness of the ultrasonic cleaning and disinfecting device of the present disclosure (referred to as "Subject Device" in Table 1) in maintaining the physical characteristics, physical integrity and/or physical structure of vegetables (in this case Kale having thick skin) while cleaning and disinfecting the vegetables (in this case Kale having thick skin) using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz was tested. Additionally, as illustrated in Table 1 and 2, the effectiveness of three other known ultrasonic cleaning devices (i.e., Retsch, Crest and Cavitator) in maintaining the physical characteristics, physical integrity and/or physical structure of Kale having thick skin while cleaning and disinfecting the Kale at other ultrasonic wave frequencies besides 60 kHz was tested.

As illustrated in Table 1 and 2, the ultrasonic cleaning and disinfecting device of the present disclosure (referred to as "Subject Device in Table 1) was tested using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz with electric power of 70 W and a voltage of 220 V / 50 Hz. The Retsch ultrasonic cleaning device (produced by Crest Ultrasonics) was tested using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 35 kHz with electric power of 240 W and a voltage of 220 V / 50 Hz. The Crest ultrasonic cleaning device (produced by Crest Ultrasonics) was tested using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 38.5 kHz with electric power of 240 W and a voltage of 220 V / 50 Hz. The Cavitator ultrasonic cleaning device (produced by Mettler Electronics Corp.) was tested using an ultrasonic vibration frequency and/or ultrasonic wave frequency of 67 kHz with electric power of 200 W and a voltage of 220 V / 50 Hz.

Table 1. Testing of Different Ultrasonic Cleaning Devices Using Different Ultrasonic Wave Frequencies

Characteristic	Retsch (Model UR1)	Crest (Model.960)	Subject Device	Cavitator (Serial.40B6481)
Frequency of Ultrasonic Wave	35 kHz	38.5 kHz	60 kHz	67 kHz
Electric Power	240 W	240 W	70 W	200 W
Voltage / frequency	220 V / 50 Hz	220 V / 50 Hz	220 V / 50 Hz	220 V/ 50 Hz

Results for Example 2

As shown in Table 2, the use of an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz resulted in the best performance results. In a surprising and unexpected finding, when an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz was used during the cleaning and disinfecting of the Kale, less than 5% bruising was observed on the cleaned and disinfected Kale. The use of an ultrasonic vibration frequency and/or ultrasonic wave frequency of 35 kHz and 67 kHz gave the poorest results.

Table 2. Physical Characteristics of Kale (having thick skin) after Cleaning with the Different Ultrasonic Cleaning Devices at Different Frequencies

Frequency (kHz) and Cleaning Device	Temperature after cleaning (°C)	Physical characteristic of Kale	% bruising (by visual estimation)	Level of Bruising on scale of 1 to 5 (with 1 being the least amount of bruising and 5 being the most amount of bruising)
35 (Retsch)	33.5	Leaflets were seriously bruised and damaged; older leaves were covered in dot bruises	40	4
38.5 (Crest)	33	Relatively less bruises; distribution of some dot bruises on leaves	10	2
60 (Subject Device)	33	Few bruises	Less than 5	1
67 (Cavitator)	31	Leaflets were bruised; older leaves had bruises at the end of the leaf along with dot bruises	30	3

Example 3

As demonstrated in Table 3, an embodiment of an ultrasonic cleaning and disinfecting device of the present disclosure was used to demonstrate the effectiveness of the ultrasonic cleaning and disinfecting device for cleaning various vegetables using a an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz for 60 seconds. The ultrasonic cleaning and disinfecting device was used to clean basil, sweet basil, Chinese bitter, eggplant and Vietnamese Coriander. The ultrasonic cleaning and disinfecting device included an ultrasonic cleaning tank having a volume of water of 150 litres therein. The first Z-1 transducer pattern described above was used on the ultrasonic cleaning tank. The vegetables were submerged and maintained below the surface of the water at all times during the ultrasonic cleaning.

Results for Example 3

As demonstrated in Table 3, when an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz was used to clean and disinfect the vegetables for 60 seconds, the ultrasonic cleaning and disinfecting device effectively removed and eliminated insects (i.e., thrips and white fruit fly caterpillars) and insect eggs (i.e, white fruit fly eggs) without damaging the physical characteristics and/or physical integrity of the vegetables.

Table 3. Test Results for Cleaning Vegetables with Ultrasonic Waves for 60 Seconds

Type of Vegetable /Plant	Method/Time	% of Insects and/or Insect Eggs Removed from Vegetable/Plant
basil	Ultrasonic Waves for 60 seconds	- 87.49% removal of thrips
		- 33.33 % removal of white fruit fly eggs and white fruit fly caterpillars
sweet basil		- 100% removal of thrips
		- 100% removal of white fruit fly eggs and white fruit fly caterpillars
Chinese bitter		- 95% removal of thrips - No white fruit fly eggs or caterpillars were found on the Chinese bitter before the ultrasonic cleaning step
Eggplant		- 98% removal of thrips - No white fruit fly eggs or caterpillars were found on the Eggplant before the ultrasonic cleaning step
Vietnamese coriander		- 100% removal of white fruit fly caterpillars - 100% removal of white fruit fly eggs

Example 4

As demonstrated in Table 4, an embodiment of an ultrasonic cleaning and disinfecting device of the present disclosure was used to demonstrate the effectiveness of the ultrasonic cleaning and disinfecting device for cleaning vegetables (in this case Vietnamese Coriander) with an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz using different periods of time. The ultrasonic cleaning and disinfecting device included an ultrasonic cleaning tank having a volume of water of 150 litres therein. The first Z-1 transducer pattern described above was used on the ultrasonic cleaning tank. The Vietnamese coriander was submerged and maintained below the surface of the water at all times during the ultrasonic cleaning.

Results for Example 4

As demonstrated in Table 4, when an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz was used to clean and disinfect the vegetable (in this case Vietnamese Coriander) for 20 seconds, 30 seconds, 45 seconds and 60 seconds, the ultrasonic cleaning and disinfecting device effectively removed and eliminated insects (i.e., white fruit fly caterpillars) and insect eggs (i.e, white fruit fly eggs) without damaging the physical characteristics and/or physical integrity of the vegetable (in this case Vietnamese Coriander).

Table 4. Test Results for Cleaning Vietnamese Coriander with Ultrasonic Waves for Different Periods of Time

Type of Vegetable/Plant	Quantity (g)	Cleaning Time (seconds)	% of Insects and/or Insect Eggs Removed from Vegetable/Plant
Vietnamese coriander	100	20	- 89% removal of white fruit fly eggs - No white fruit fly caterpillars were found on the Vietnamese coriander before the ultrasonic cleaning step
		30	- 100% removal of white fruit fly caterpillars - 100% removal of white fruit fly eggs
		45	- 100% removal of white fruit fly caterpillars - 100% removal of white fruit fly's eggs
		60	- 100% removal of white fruit fly caterpillars - 100% removal of white fruit fly eggs

Example 5

As demonstrated in Table 5, an embodiment of an ultrasonic cleaning and disinfecting device of the present disclosure was used to demonstrate the effectiveness of the ultrasonic cleaning and disinfecting device for cleaning vegetables (in this case sweet basil) with an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz using different periods of time. The ultrasonic cleaning and disinfecting device included an ultrasonic cleaning tank having a volume of water of 150 litres therein. The first Z-1 transducer pattern described above was used on the ultrasonic cleaning tank. The sweet basil was submerged and maintained below the surface of the water at all times during the ultrasonic cleaning.

Results for Example 5

As demonstrated in Table 5, when an ultrasonic vibration frequency and/or ultrasonic wave frequency of 60 kHz was used to clean and disinfect the vegetable (in this case sweet basil) for 20 seconds, 30 seconds, 45 seconds and 60 seconds, the ultrasonic cleaning and disinfecting device effectively removed and eliminated insects (i.e., thrips and common cutworm) and insect eggs (i.e, white fruit fly eggs) without damaging the physical characteristics and/or physical integrity of the vegetable (in this case sweet basil).

Table 5. Test Results for Cleaning Sweet Basil with Ultrasonic Waves for Different Periods of Time

Type of Vegetable/ Plant	Quantity (g)	Cleaning Time (seconds)	% of Insects and/or Insect Eggs Removed from Vegetable/Plant
Sweet basil	200	20	- 100% removal of thrips - 100% removal of white fruit fly eggs - No common cutworms were found on the sweet basil before the ultrasonic cleaning step
		30	- 93.3% removal of Thrips - 100% removal of common cutworms - 100% removal of white fruit fly eggs
		45	- 87.5 removal of thrips - 100% removal of common cutworms - 100% removal of white fruit fly eggs
		60	- 100% removal of common cutworms - 100% removal of white fruit fly eggs - No thrips were found on the sweet basil before the ultrasonic cleaning step

While various aspects and embodiments have been disclosed herein, it will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit of the invention being indicated by the appended claims.

CLAIMS

1. An ultrasonic cleaning device, comprising:

an ultrasonic cleaning tank, wherein the ultrasonic cleaning tank comprises a bottom closed base having an outer surface; and

a plurality of transducers installed on the outer surface of the bottom closed base, wherein the plurality of transducers emit ultrasonic waves having a frequency in the range of about 50 kHz to about 60 kHz.

2. The ultrasonic cleaning device of claim 1, further comprising a plurality of rows comprising:

a first row comprising four or more transducers;

a second row comprising four or more transducers, wherein the second row is parallel to the first row, wherein each of the four or more transducers of the second row is in positioned in staggered relation to each of the four or more transducers of the first row;

a third row comprising four or more transducers, wherein the third row is parallel to the first row and the second row, wherein each of the four or more transducers of the third row is positioned directly in line with each of the four or more transducers of the first row; and

a fourth row comprising four or more transducers, wherein the fourth row is parallel to the first row, the second row and the third row, wherein each of the four or more transducers of the fourth row is positioned directly in line with each of the four or more transducers of the second row;

wherein the second row is positioned between the first row and the third row,

wherein the third row is positioned between the second row and the fourth row.

3. The ultrasonic cleaning device of claim 1 or 2, wherein the plurality of transducers are arranged and activated according to a repeating pattern selected from the group consisting of a repeating pattern of at least two transducers on and at least two transducers off, a repeating pattern of at least two transducers off and at least two transducers on and a combination thereof.

4. The ultrasonic cleaning device of claim 2, wherein the plurality of transducers are arranged and activated according to a pattern selected from the group consisting of a repeating pattern of one row of transducers on and one row of transducers off, a repeating pattern of one row of transducers off and one row of transducers on, and a combination thereof.

5. The ultrasonic cleaning device of claim 2, wherein the plurality of transducers are arranged and activated according to a repeating pattern comprising one row of transducers on and two rows of transducers off.

6. The ultrasonic cleaning device of claim 2, wherein the plurality of transducers are arranged and activated according to a repeating pattern comprising one row of transducers off and two rows of transducers on.

7. A method of ultrasonically cleaning one or more articles, comprising:

providing the ultrasonic cleaning device of claim 1 or 2;

providing a volume of water in the ultrasonic cleaning tank;

providing the one or more articles;

immersing the one or more articles in the volume of water in the ultrasonic cleaning tank; and

ultrasonically cleaning the one or more articles.

8. The method of claim 7, comprising:

arranging and activating the plurality of transducers according to a repeating pattern selected from the group consisting of a repeating pattern of at least two transducers on and at least two transducers off, a repeating pattern of at least two transducers off and at least two transducers on and a combination thereof.

9. The method of claim 7, comprising:

arranging and activating the plurality of transducers according to a repeating pattern selected from the group consisting of a repeating pattern of one row of transducers on and one row of transducers off, a repeating pattern of one row of transducers off and one row of transducers on and a combination thereof.

10. The method of claim 7, comprising:

arranging and activating the plurality of transducers according to a repeating pattern comprising one row of transducers on and two rows of transducers off.

11. The method of claim 7, comprising:

arranging and activating the plurality of transducers according to a repeating pattern comprising one row of transducers off and two rows of transducers on.

12. The method of any one of claims 7-11, wherein the one or more articles are food articles.

13. The method of any of claims 7-12, wherein the one or more articles are non-food articles.

14. The method of claim 12, wherein the one or more food articles are selected from the group of food articles consisting of fruits, vegetables and a combination thereof.

15. The method of any one of claims 1-14, wherein the ultrasonic cleaning step comprises removing a contaminant selected from the group of contaminants consisting of dirt, oil, mold, chemical residue, pesticides, bacteria, microbes, microbial pathogens, pests including small pests, pest eggs, pest larvae, insects including small insects, insect eggs, insect larvae and a combination thereof.

16. The method of claim 15, wherein the ultrasonic cleaning step results in the removal of about 95% or more of insects, insect eggs, and insect larvae from the one or more food articles.

17. The method of claim 16, wherein the ultrasonic cleaning step results in the removal of about 99% or more of insects, insect eggs, and insect larvae from the one or more food articles.

18. The method of claim 17, wherein the ultrasonic cleaning step results in the removal of about 100% or more of insects, insect eggs, and insect larvae from the one or more food articles.

19. The method of any one of claims 16-18, wherein the ultrasonic cleaning step results in less than about 5% of bruising or damage to the physical structure of the one or more food articles.

20. The method of claim 15, wherein the method comprises pre-washing the one or more food articles in a pre-wash tank, and wherein the combination of the pre-washing step and the ultrasonic cleaning step results in the removal of about 95% or more of insects, insect eggs, and insect larvae from the one or more food articles.

21. The method of claim 20, wherein the combination of the pre-washing step and the ultrasonic cleaning step results in the removal of about 99% or more of insects, insect eggs, and insect larvae from the one or more food articles.

22. The method of claim 21, wherein the combination of the pre-washing step and the ultrasonic cleaning step results in the removal of about 100% or more of insects, insect eggs, and insect larvae from the one or more food articles.

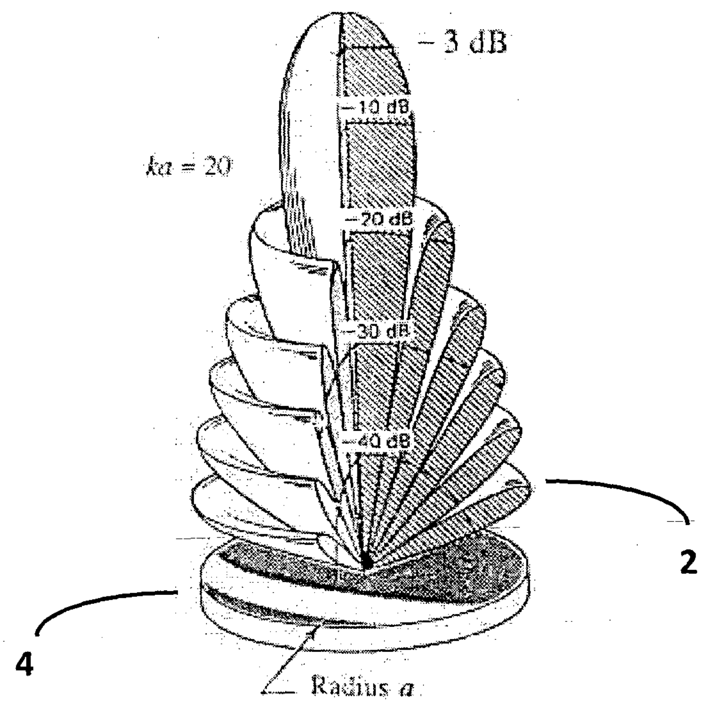


FIG 1

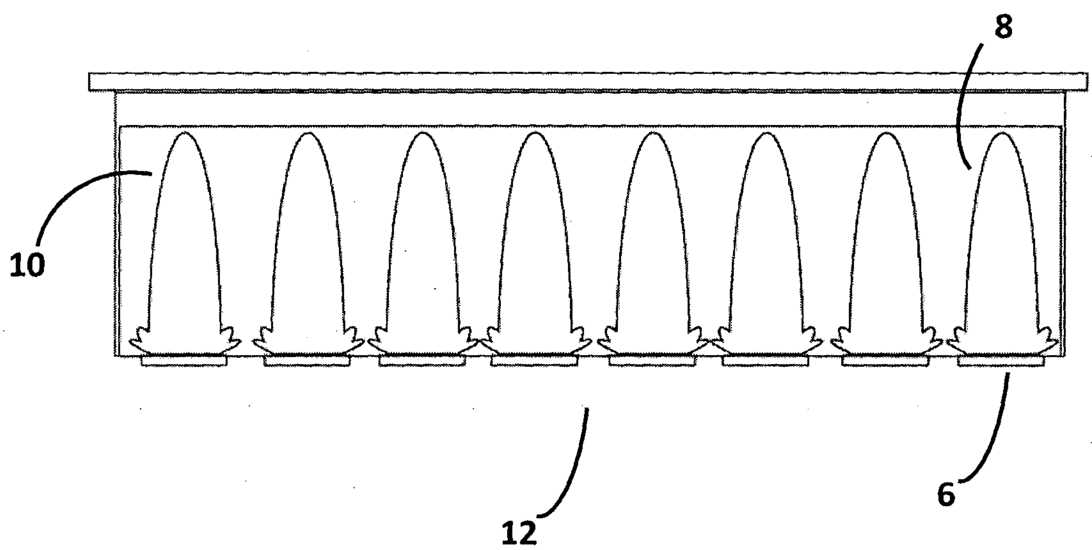


FIG 2

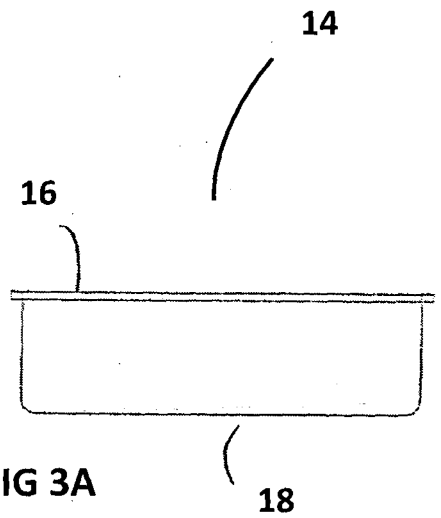


FIG 3A

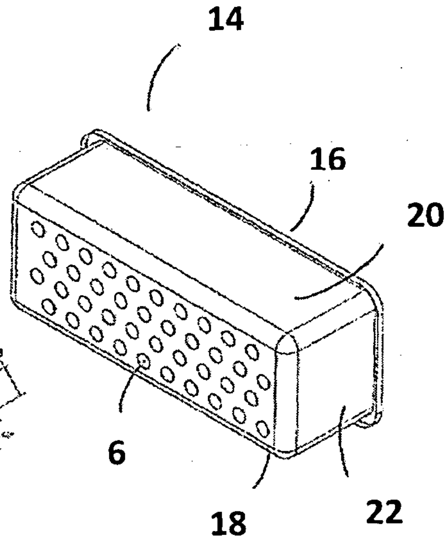


FIG 3B

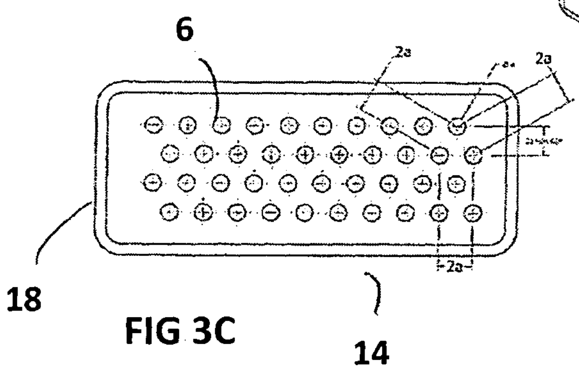


FIG 3C

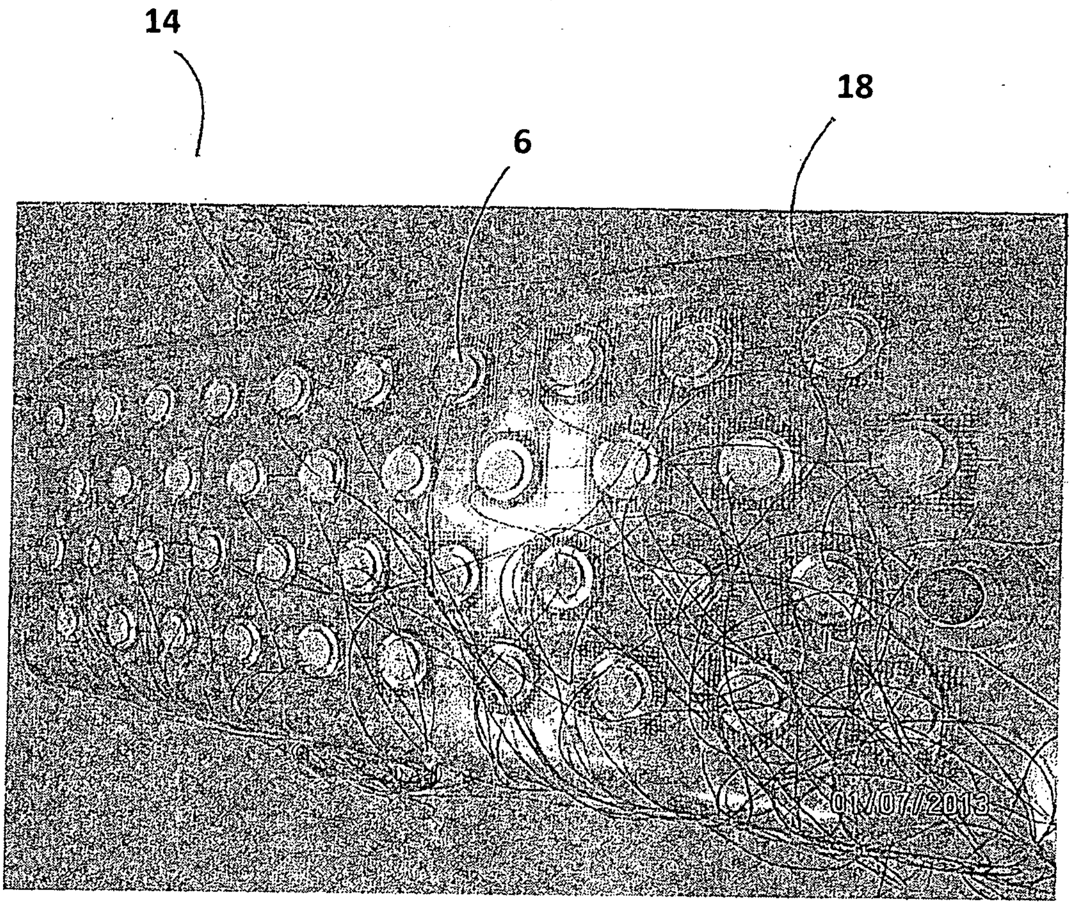


FIG 4

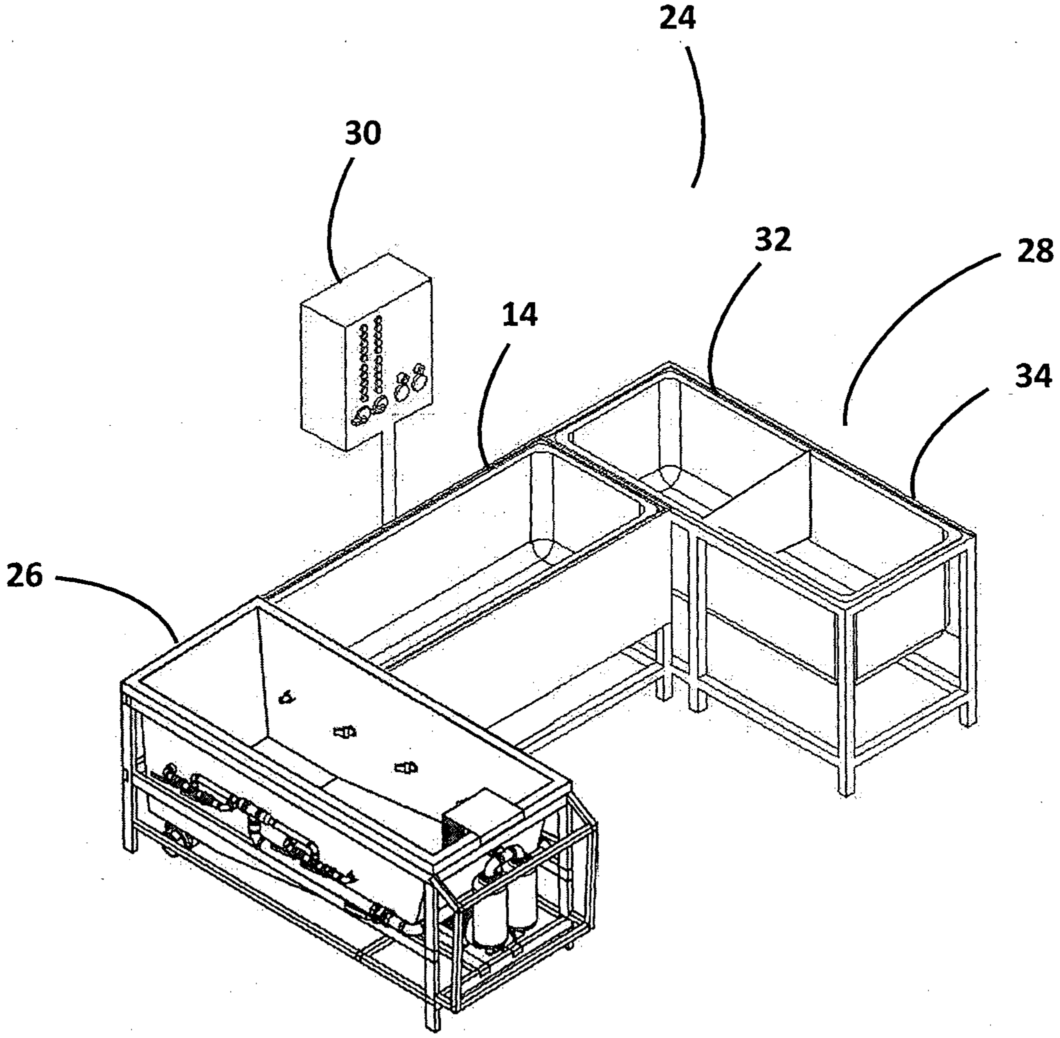


FIG 5

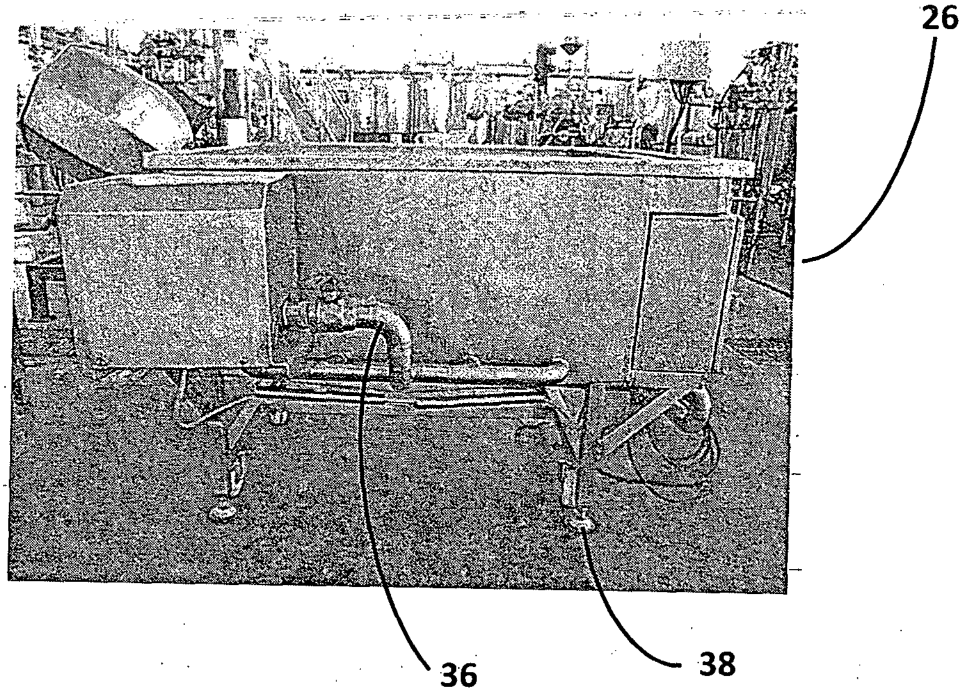


FIG 6A

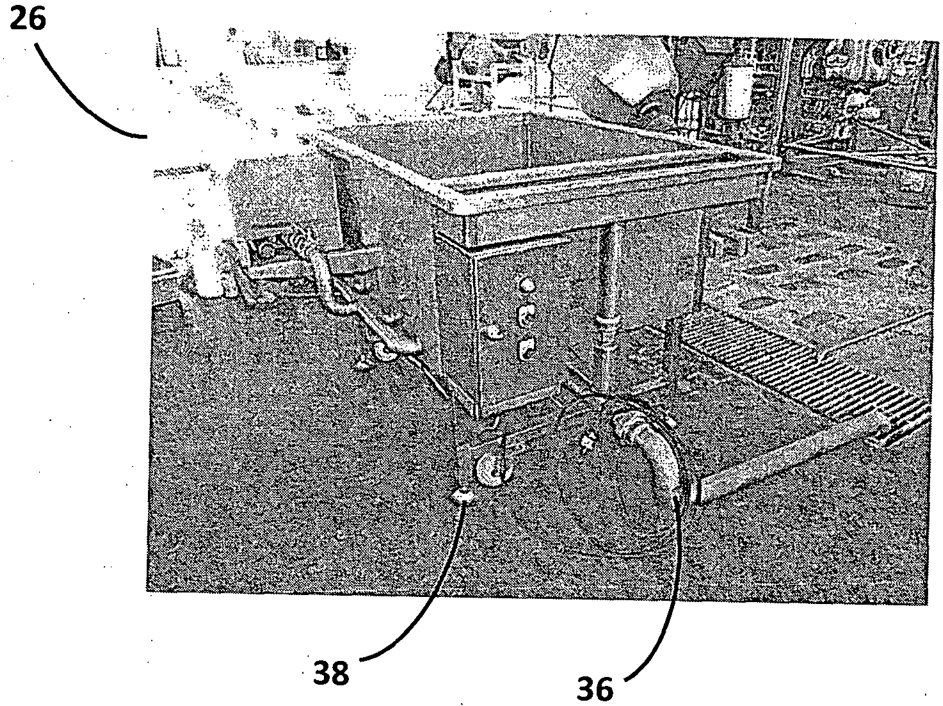


FIG 6B

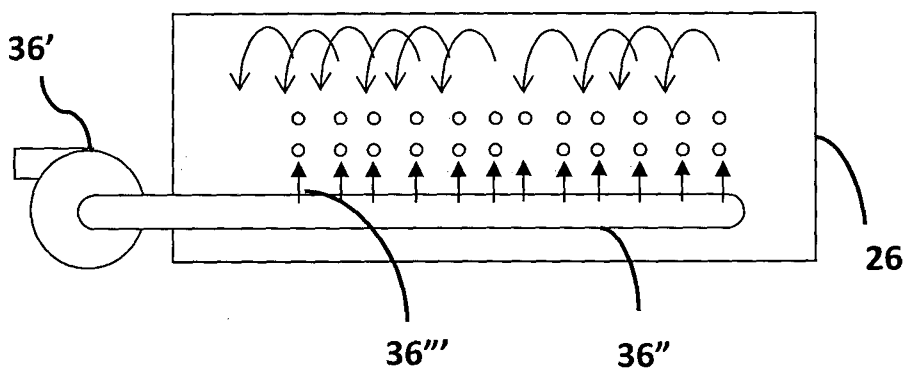


FIG 6C

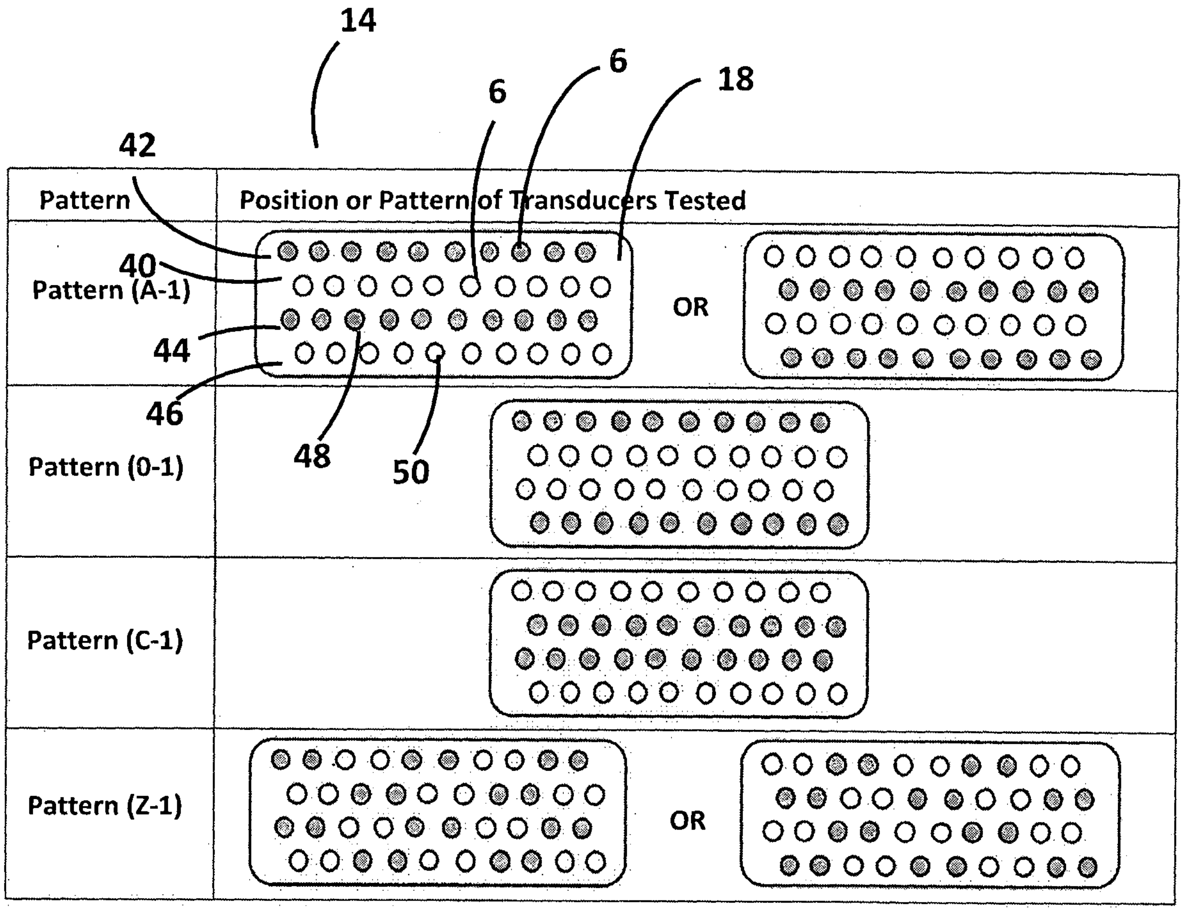

14
6
6
18
42
Pattern
Position or Pattern of Transducers Tested
40
Pattern (A-1)
OR
44
46
48
50
Pattern (0-1)
Pattern (C-1)
Pattern (Z-1)
OR

FIG 7

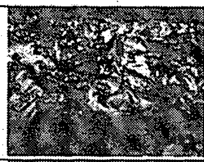
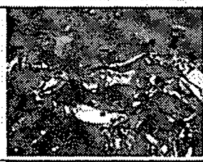
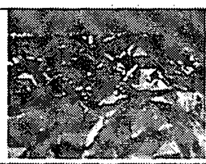
Pattern of Transducer		The number of holes					Appearance of Aluminium foil
		<1mm	1-2 mm	3-4 mm	5-10 mm	>10 mm	
150 litres Of H2O	(A-1)	174	384	128	111	-	
	(O-1)	304	292	57	18	-	
	(C-1)	-	5	-	3	-	
	(Z-1)	221	360	82	55	13	
200 litres Of H2O	(A-1)	301	276	143	30	-	
	(O-1)	340	102	1	-	1	
	(C-1)	306	12	-	-	-	
	(Z-1)	364	297	6	-	-	

FIG 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/TH2013/000024

A. CLASSIFICATION OF SUBJECT MATTER

A23N 12/02(2006.01)i, A23L 3/30(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A23N 12/02; B08B 3/10; A47J 43/24; A23B 7/158; H01L 41/09; B08B 3/12; A23L 3/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: ultrasonic, cleaning, tank, transducer, repeating pattern

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2005-0122003 A1 (GOODSON, J. MICHAEL) 9 June 2005 See abstract; paragraphs [0009], [0023]-[0024]; claim 1; and figure 1.	1-2,7 3-6,8-11
Y	US 4193818 A (YOUNG, JACK H. et al.) 18 March 1980 See column 3, lines 33-43; column 4, lines 40-53; column 7, line 62 - column 8, line 3; claims 1, 16; and figure 1.	3-6,8-11
A	US 6019852 A (PEDZIWIATR, MICHAEL P. et al.) 1 February 2000 See column 3, line 26 - column 4, line 30; and figures 1-2.	1-11
A	US 5113881 A (LIN, ISRAEL et al.) 19 May 1992 See column 3, lines 4-33, 54-64; column 5, lines 13-35; claims 1, 20; and figure 1.	1-11
A	EP 1943932 B1 (GIORGIA S.R.L.) 15 September 2010 See paragraphs [0042]-[0043]; claims 1, 7-8; and figure 3.	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 February 2014 (24.02.2014)	**24 February 2014 (24.02.2014)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/TH2013/000024

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 14-22
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 14, 16-18 and 20-22 are unclear because they directly or indirectly refer to one of claims which do not comply with PCT Rule 6.4(a) (PCT Article 6)./ Claim 15 is not clear, since it is concerned with "a method", but claims 1-6, to which claim 15 refers, are directed to "a device" (PCT Article 6). Claims 16-22 are also unclear since they ultimately refer to claim 15 (PCT Article 6).

3. ☒ Claims Nos.: 12-13, 15, 19
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/TH2013/000024

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