

**METHOD AND APPARATUS FOR
AERATING AQUACULTURAL SYSTEMS**

5 **FIELD OF THE INVENTION**

The present invention relates to a method for aerating fluids flowing through cultivation containers or ponds in aquacultural systems, particularly in hydroponic and fish farming systems. The apparatus for achieving this aeration method is also
10 described.

PRIOR ART

One of the major problem of both hydroponic cultivation and fish farming is the
15 need for aerating the nutrient liquid or liquid medium so that oxygen and other atmospheric gases are adequately dissolved in the liquid to reach the cultivated organisms. In hydroponic plants, oxygen is required to reach the roots of the plants. In a fish farm, oxygen is needed to sustain the fishes reared which, for economic reasons, are normally reared in a population density much higher than could be
20 found in their natural habitat. Many attempts have been made to solve this aeration problem but they are either ineffective, inadequate or too elaborate and expensive.

In hydroponics, the Nutrient Film Technique (NFT), started in the late 1960s, supplies plants with a continuously circulating film of liquid nutrient in elongated
25 hollow troughs as described in US-A-4,379,375 (Whittaker Corporation). The thin layer of liquid nutrient flowing through such troughs provides an air space on top of the nutrient solution inside the trough thus allowing some oxygen to reach the roots. However, maintenance of an adequate supply of oxygen to the roots becomes a problem when the roots proliferate during intermediate and later stages of growth
30 (Dudley Harris, *The Illustrated Guide to Hydroponics*, p.20).

In the 1970s, a hybrid between NFT and aggregate (such as gravel) sub-irrigation, called the Gravel Flow Technique or Deep Flow Technique (DFT) is developed. US-A-3,992,809 (C.E. Chew) is an example of a hydroponic system with a bed of

aggregate and means for delivering nutrient solutions to the bed. In a DFT system, nutrient solutions are delivered to the bottom of the bed of aggregate (normally water-absorbing material like leca, perlite, etc.). Aeration is achieved when the solution flows vertically upwards through the gravel, resulting in the "bubbling" effect. However, to achieve an adequate aeration, it is required that the amount of liquid supplied to each box has to correspond with the amount of dissolved air, particularly oxygen, the solution is able to carry. Thus, a relatively high volume of flow of the nutrient solution is required to be pumped through each cultivation unit or container.

In US-A-4,594,811 (Dainichi Sangyo K.K.) it is described a hydroponic system comprising hugh rotating cultivation towers formed by piling up a number of circular cultivation trays each with nozzles spraying nutrient liquid therein. Such spraying method, also known as **aeroponics**, (Harris, p.22) creates a mist of liquid nutrients and probably solves the aeration problem of hydroponic nutrient liquid but the capital outlay for such complicated towers is highly prohibitive.

In fish-farming, the aeration of the rearing pond is normally done by spraying water into the pond by sprinkler system or pumping air bubbles into the water using air pumps or combination of these two methods.

BRIEF DESCRIPTION OF THE INVENTION

The present invention attempts to solve the problem of aeration of liquid in aquacultural systems, such as hydroponic systems and fish farms, by introducing atmospheric air into the flow of liquid through the application of fluid dynamics principles thus resulting in an effective and economical way of aerating the liquid.

In one aspect of the present invention, the method for aerating the liquid flowing through one or more liquid container units wherein the liquid flows into the container via at least one inlet and overflows out of the container via at least one outlet, said method is essentially achieved by adapting the outlet to comprise an overflow aerating opening which has a cross-section large enough so that the rate of overflow

of the liquid does not overwhelmed the said opening and so that the said overflow substantially forms a vortex.

5 In another aspect of the present invention, Bernoulli's principle is employed to achieve a decrease in pressure near a jet of liquid flow, thus drawing air from the surrounding and admix it along with the liquid down-flow. In this method of aerating liquid flowing through an aquacultural system, for example one which comprises one or more liquid container units wherein the liquid flows into the container via at least one inlet conduit and overflows out of the container via at least
10 one outlet conduit, the method is characterised in that at least one of the conduit has one or more constriction along the passageway of the said conduit so as to increase the velocity of the liquid flowing out therefrom, or to create a jet-flow, thereby creating a decreasing air pressure effect around the jet-flow.

15 A second opening may be adapted to capture said jet-flow of liquid flowing out of the constricted tip, the said second opening disposed below the conduit at a distance sufficient for the liquid flow to create a drop in atmospheric pressure around the jet-flow. Both the conduit with constricted end and the second opening may be accommodated in a housing so as to contain the decreasing pressure effect. An air
20 intake passage is provided on the said housing to allow intake of air.

DETAILED DESCRIPTION OF THE INVENTION

25 Various other features of the invention will now be set forth in the following detailed description and accompanying drawings.

- Figure 1 shows a cross-section of a typical cultivation container in hydroponic system wherein the outlet is adapted according to the present invention to an overflow aerating opening;
- 30 Figure 2 shows a series of variations of the said overflow aerating opening;
- Figure 3 shows the various dispositions of the aerating opening in relating to the cultivation container;
- Figure 4 shows the opening embodied separately as overflow chambers;

Figure 5 shows a housing wherein Bernoulli's effect is achieved with the jet-flow of liquid from a conduit;

Figure 6 shows an embodiment with a gradual reduction of diameters of pipes via a series of three tubes with the respective reducing diameters joined by reducing L-joints.

Figure 7 shows the application of the overflow vortex of the aerating opening in a deep-flow technique (DFT).

In a preferred embodiment of the present invention, as shown in Figure 1, a typical hydroponic system cultivation container (10) which may be a tray, trough, box, tank, vat, or specially constructed large-scale pond for the purpose of growing plants hydroponically or fish-farming to suit accordingly to the requirements of a hobbyist, home-grower or commercial set-up.

A typical cultivation container (10) comprises a lower part being a liquid-holding tray (11), and an upper part being a cover (12) which has a plurality of apertures (13) suitably spaced to accommodate the crown of plants as they grow, and has at least one inlet (14) whereby the liquid nutrient may flow into the said container.

Disposed on the bottom plane of the tray (11) is at least one outlet (15) comprised of an overflow aerating opening (16). The opening (16) has a cross-section that is large enough so as not to be overwhelmed or filled up by the rate of overflow of the liquid. When the cross-section of the aerating opening (16) is too large for the overflowing liquid to fill up, the liquid, upon reaching the level of the opening (16), will flow down into the said opening around the rims or edge of the said opening, leaving an air column at the centre of the vortex of liquid outflow. The flow of the liquid in this manner enables the air to be admixed at the bottom of the vortex.

Depending on the different construction of this aerating opening (16), as is shown in Figure 2, the downflow vortex can be of whirlpool-like shape, flowing down in a rotation about an axis (A), in concentric flows (B), radial flows (C) and the like. Hence, the word "vortex" is used herein to cover these variations of downward flow of liquid through the aerating opening.

In a preferred embodiment of the present invention, as shown in Figure 1A, the outlet (15) comprising the overflow aerating opening (16) is formed by an enclosed wall (17) projecting upwards from the bottom of the said container (10), the height of the wall enclosing the said opening (16) substantially defines the level of liquid held in the container before the liquid overflows down the said opening (16).

It will be appreciated that it is possible to have different embodiments of the opening (16) which may similarly achieve the vortex flow. Examples of such variation of the opening (16) are shown in Figure 2 wherein is shown outlets (15) of circular (2A), rectangular (2B) and hexagonal (2C) cross-sections, and with serrations (2D, 2E). It will be further appreciated that the level of liquid (h) held in container (10) before the liquid overflows down the opening (16) is defined by the minimum height (h) of the wall (17) taking into consideration the serrations or other adaptations on edges of the opening, thus the expression "substantially defines the level of fluid".

It will also be appreciated that the outlet (15) may be adapted to dispose on different parts of the container unit and adapted to different variations as shown in Figure 3. In Fig. 3A, it may be adapted to form on an elevated part (20) of the bottom of the container, the height of the said elevated part (20) defines the level of liquid held in the container before the liquid overflows down the said aerating opening (16) of the outlet (15). In Fig. 3B the outlet (15) is formed on the outside periphery (21) of the container.

In another preferred embodiment, as shown in Figure 4, the aerating opening (16) is embodied as an overflow chamber (30) separate from the container (10). The overflowing liquid from the container (10) may be channelled to the overflow chamber (30) via an inlet passage (31). It may be seen from Fig. 4B that such an overflow chamber need not have a depth (h_1) that corresponds with the depth (h_0) of container (10). In fact, the overflow chamber's (30) liquid-holding depth (h_1) may be less than that of the cultivation container (10) thus enabling the overflow chamber (30) to be designed as a relatively small and convenient piece of attachment, as shown in Figure 4C, for an aquacultural system. This is particularly advantageous in fish-rearing where an aerating opening (16) is constructed within the cultivation

container (10) may be dangerous as it may cause the fishes to be sucked into the vortex.

5 In another aspect of the present invention, Bernoulli's principle is employed to achieve a decrease in pressure near a jet of liquid flow, thus drawing air from the surrounding and admix it along with the liquid down-flow. In this aerating method, the liquid flowing through an aquacultural system, for example, one which comprises one or more liquid container units wherein the liquid flows into the container via at least one inlet conduit and overflows out of the container via at least one outlet
10 conduit, is characterised in that at least one of the conduit has one or more constriction along said conduit so as to increase the velocity of the liquid flowing out therefrom, or to create a jet-flow, thereby creating a decreasing air pressure effect around the jet-flow.

15 It shall be understood that the constriction may be a gradual reduction of the diameter of the fluid passageway of the conduit. The constriction may also be disposed on any portion of the conduit but the preferred embodiment is to have the constriction disposed at the end tip (50) of the conduit as shown in Figure 5.

20 In preferred embodiment of this aspect of the invention, as shown in Fig. 5A, the jet-flow (51) of liquid created at the constricted end (50) of the first conduit (52) now flows into an opening (53) of a second conduit (54) disposed at a distance close enough from the tip of the first conduit (50) to create a decrease in air pressure around the jet-flow, said opening (53) adapted to capture said jet-flow of liquid
25 flowing out of the first conduit (52) and the liquid flows through the said opening (53) into the second conduit (54) forming the inlet conduit for the next container unit.

30 In yet another preferred embodiment, the constricted end of the first conduit and the opening of the second conduit is enclosed in a housing to contain the effect of decreasing pressure created around the jetflow and an opening is provided on the housing to allow air intake. Figure 5B shows an apparatus adapted for this method whereby the jet-flow of liquid may flow through a first or inlet conduit (52) and a

second or outlet conduit (54), said first conduit is constricted at the tip (50) to increase the velocity of the liquid flowing out therefrom, creating of jet-flow (51). An opening (53) of the second conduit (54) is adapted to capture said jet-flow of liquid (51) flowing out of the constricted tip (50), the said opening (53) disposed
5 below the constricted tip (50) at a distance sufficient for the liquid flow to create a drop in atmospheric pressure around the jet-flow (51). Both the first conduit (52) with constricted tip (50) and the opening (53) may be accommodated in a housing (60) so as to contain the decreasing pressure effect. An air intake passage (61) is provided on the said housing (60) to allow intake of air.

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In one embodiment of this aspect of the present invention, the conduit may be constricted gradually by having two or more tubes each having a diameter smaller than that of the previous tube. For example, the conduit may comprise three tubes with a series of decreasing diameters in the ratio ranges of (8 to 4):(5 to 3):(4 to 1).

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In a working example, as shown in Figure 6, using standard PVC pipes, a 30mm pipe (60) may be reduced to a 25mm pipe (62) with a 30x25 mm 'L' or elbow joint (61) and the 25mm pipe (62) may further be reduced to a 20mm pipe (64) with a 25x20 mm elbow joint (63). This example of 30mm:25mm:20mm reduction ratio works out to be a ratio of 5:4:3.

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Although the present invention was conducted mainly on deepwater NFT hydroponics systems, it is apparent that the vortex flow and the Bernoulli principles described above may equally be effective in the DFT systems as shown in Figure 6 wherein the cultivation tray (70) is filled with a bed or aggregate (71) of water-absorbing material like leca, perlite, etc. The conduit (72) for the inlet flow of
25 liquid nutrient is normally disposed in such way so that the nutrient liquid flows upwards through the bed of aggregate (71). A thin layer of liquid above the surface of the aggregate (71) is necessary so that the liquid may overflow down the aerating opening (73) in a vortex flow. Alternatively, the aggregate around the aerating opening (73) may be evacuated to create a pool of liquid (74) so that the overflow
30 of liquid down the aerating opening (73) in a vortex flow may be achieved. A porous retaining means (75) may be provided to prevent the aggregated from falling into the evacuated area (74).

It will be understood that the foregoing aeration method for aquacultural systems may be complemented by conventional aeration methods such as the fitting of sprinkler nozzles to the ends of the conduits, air pumps, water pumps etc. not specifically described herein. It will also be understood that the velocity of the liquid outflow from the conduits may be increased by increasing the height difference between the containers in series, i.e. by sheer reason of gravity.

The invention being thus described, it will be obvious that the specific procedures described herein may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention. There are described above novel features which the skilled person in the art will appreciate give rise to advantages. It is to be noted that in addition to the specific examples given above it is possible to used substitute configurations or designs which can be identified by simple experimentation to achieve the essence of this invention. These are each independent aspects of the present invention irrespective of whether or not they are included within the scope of the following claims.

CLAIMS

1. A method for aerating liquid flowing through an aquacultural system comprising one or more liquid container units wherein the liquid flows into the container via at least one inlet and flows out of the container via at least one outlet
5 characterised in that

the outlet comprises an overflow aerating opening having a cross-section large enough so that the rate of overflow of the liquid does not overwhelmed the said opening and so that the said overflow substantially forms a vortex.

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2. A method according to Claim 1 wherein the said outlet is formed by an enclosed wall projecting upwards from the bottom of the said container, and the height of the wall enclosing the said opening substantially defines the level of liquid held in the container before the liquid overflows down the said opening.

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3. A method according to any one of Claims 1 and 2 wherein the said outlet is formed on an elevated part of the bottom of the container, the height of the elevated part defines the level of liquid held in the container before the liquid overflows down the said outlet.

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4. A method according to Claim 1 wherein the said outlet comprises an overflow chamber separate from the container, said chamber comprises at least one inlet passage for liquid overflowing out of the container and at least one aerating opening.

25 5. A method according to Claim 1 wherein the said outlet is formed on the outer periphery of the container.

6. A method according to any one of Claims 1 to 5 wherein the fluid overflows through the outlet into a conduit extending substantially downwards from the aerating opening.

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7. A method according to Claim 6 wherein the diameter of the conduit's passageway proximate to the aerating opening is larger than diameter of the



passageway's distal end so that the narrowing of passageway of the fluid flowing through the conduit creates a jet flow when the liquid flows out of the said conduit.

8. A method according to Claim 7 wherein the conduit comprises two or more
5 tubes each having a diameter smaller than that of the previous tube.

9. A method according to Claim 8 wherein the conduit comprises three tubes with a series of decreasing diameters in the ratio ranges of (8 to 4):(5 to 3):(4 to 1).

10 10. A method according to Claim 9 wherein the ratio is 5:4:3.

11. A container for use in aerating liquid flow in an aquacultural system wherein the container has at least one inlet for liquid in-flow and at least one outlet for the outflow of the liquid characterised in that
15 the outlet comprises an overflow aerating opening having a cross-section large enough so that the rate of overflow of the liquid does not overwhelmed the said opening and so that the said overflow substantially forms a vortex.

12. A container according to Claim 11 wherein the said outlet is formed by an
20 enclosed wall projecting upwards from the bottom of the said container, and the height of the wall enclosing the said opening substantially defines the level of liquid held in the container before the liquid overflows down the said opening.

13. A container according to Claim 11 wherein the said outlet is formed on an
25 elevated part of the bottom of the container, the height of the elevated part defines the level of liquid held in the container before the liquid overflows down the said outlet.

14. An apparatus for use in accordance with the method of Claim 4 comprising
30 an overflow chamber separate from the container, said chamber comprises at least one inlet passage for liquid overflowing out of the container and at least one aerating opening.



15. A container according to Claim 11 wherein the said outlet is formed on the outer periphery of the container.

16. A conduit for use in accordance with any of the methods of Claims 6 to 10.

17. A method according to any of one Claims 6 to 10 wherein distal end of the conduit is fitted with sprinkler nozzles.

18. A method of aerating liquid flowing through an aquacultural system comprising one or more liquid container units wherein the liquid flows into the container via at least one inlet conduit and overflows out of the container via at least one outlet conduit characterised in that

at least one of the conduit has one or more constriction along said conduit so as to increase the velocity of the liquid flowing out therefrom, or to create a jet-flow, thereby creating a decreasing air pressure effect around the jet-flow.

19. A method according to Claim 18 wherein the constriction is disposed at the end tip of the conduit.

20. A method according to any one of Claims 18 and 19 wherein the jet-flow of liquid from the end of a first conduit flows into an opening of a second conduit disposed at a distance close enough from the tip of the first conduit to create a decrease in air pressure around the jet-flow, said opening adapted to capture said jet-flow of liquid flowing out of the first conduit and the liquid flows through the said opening into the second conduit forming the inlet conduit for the next container unit.

21. A method according to any one Claims 18 to 20 wherein the constricted end of the first conduit and the opening of the second conduit is enclosed in a housing to contain the effect of decreasing pressure created around the jetflow and an opening is provided on the housing to allow air intake.

22. An apparatus for use in accordance with any one of the methods of Claims 18 to 21.

