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(71) **Applicant: SIGNIFY HOLDING B.V.** [NL/NL]; High
Tech Campus 48, 5656 AE Eindhoven (NL).

(72) **Inventors: VAN DER MEER, Michiel;** c/o High Tech
Campus 7, 5656 AE Eindhoven (NL). **LIU, Liping;** c/o
High Tech Campus 7, 5656 AE Eindhoven (NL). **WANG,
Kui;** c/o High Tech Campus 7, 5656 AE Eindhoven (NL).

(74) **Agent: VAN EEUWIJK, Alexander, Henricus, Walterus**
et al.; Signify Netherlands B.V. - Intellectual Property, High
Tech Campus 7, 5656 AE Eindhoven (NL).

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(54) **Title:** CONTROL SYSTEM FOR USE IN FARMING FISH, LIGHTING SYSTEM, FISH FARMING SYSTEM, AND METHOD
FOR CONTROLLING LIGHT FOR USE IN FARMING FISH

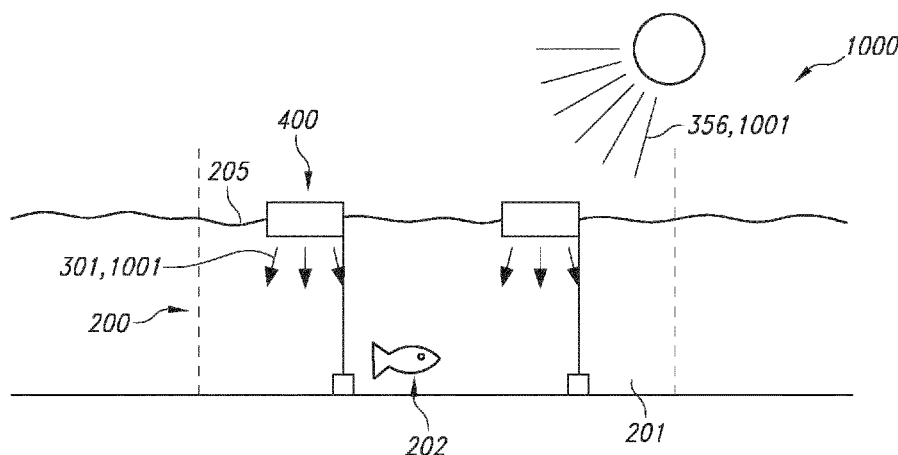


FIG. 1B

(57) **Abstract:** The invention provides a control system (100) for controlling one or more light parameters of light (1001) provided to an aqueous liquid in a containing element (200) for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid, wherein the control system (100) is configured to control one or more light parameters of the light (1001) for imposing a plurality of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP), wherein a duration of the light period (LP) is selected from the range of 12-20 h, and wherein a duration of the dark period (DP) is selected from the range of 4-12 hours, wherein the control system (100) is at least configured to control the illuminance of the light (1001) provided to the aqueous liquid with a first illuminance during the light period (LP) selected from the range of in average at least 1000 lux at a liquid surface of the aqueous liquid and a second illuminance during the dark period (DP) selected from the range of at maximum 400 lux at the liquid surface of the aqueous liquid.

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Control system for use in farming fish, lighting system, fish farming system, and method for controlling light for use in farming fish

FIELD OF THE INVENTION

The invention relates to a control system for controlling one or more light parameters of light provided to an aqueous liquid in a containing element for containing fish. The invention also relates to a lighting system that can be controlled by such control system.

- 5 Yet, the invention also relates to a farming system for farming fish. The invention also relates to a method for controlling one or more light parameters of light provided to an aqueous liquid in a containing element for containing fish. The invention also relates to computer program product that can be used for controlling such lighting system or farming system. Yet, the invention also relates to a use of the lighting system for providing light to an aqueous
10 liquid in a containing element for containing fish .

BACKGROUND OF THE INVENTION

- The use of lighting in fish farming is known in the art. US20160353716, for instance, describes a fish lighting system comprising: a lighting arrangement; an input
15 interface for receiving instructions representing a desired fish behavioral and/or physiological response, wherein the input interface is adapted: to receive instructions in the form of a set of at least two coordinate values (x,y,z,b,c,d,A) wherein a first coordinate value represents a visual response, and a second coordinate value represents a biorhythm response; or convert the instructions into a set of at least two coordinate values (x,y,z,b,c,d,A), wherein a first
20 coordinate value represents a visual response, and a second coordinate value represents a biorhythm response; and a conversion unit, for converting the coordinate values into a lighting control signal for driving the lighting arrangement, wherein the lighting control signal is adapted to select the intensity and color of the output from the lighting arrangement to obtain the desired fish behavioral and/or physiological response. In embodiments, the first
25 coordinate value represents a visual response during daylight, and the set of at least two coordinate values further comprises a third coordinate value which represents a visual response during the night.

SUMMARY OF THE INVENTION

Tilapia is one of the most widely cultured fish. The global tilapia production increased from 1.5 million tons to 3.2 million tons from the year 2003 to 2010. In Israel, the United States, and Europe, tilapia aquaculture is mostly carried out in recirculating aquaculture system (RAS). However, the reasonable light intensity and period had an important effect on the growth and physiological indexes of tilapia under the controllable condition of RAS.

In recent years, the requirements of food consumption are increasing, particularly in fish, fresh could not fulfill the requirement, consumers also ask for high-quality meat without off-flavor. It is necessary to keep fish in good welfare conditions to produce high-quality aquatic products, promote the development of aquaculture and provide health and sustainable food.

It is a desire to farm the fishes in such a way that growth is fast and/or stress of the fish is limited or essentially absent. This may however not always be possible with methods known in the art.

Hence, it is an aspect of the invention to provide an alternative controlling, method, lighting system, and farming system, which preferably further at least partly obviate one or more of above-described drawbacks. The present invention may have as object to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

When investigation the optimum growth conditions for tilapia, it surprisingly appeared that for best results in terms of weight gain, total weight, survival rate, use of electrical energy, and input in terms of manpower, there are optimum conditions. Amongst others, it appears that there should be a minimum light period but also a minimum dark period. Further, it appears that a minimum illuminance during the light period is especially at least 500 lux, even more especially at least 1000 lux. Such illuminances may be reached during the hours of daylight. However, the number of hours of daylight with at least 1000 lux may be smaller than the minimum light period. Hence, during those hours of the desired light period there is not enough illuminance, supplemental lighting may be used with an illuminance of is especially at least 500 lux, even more especially at least 1000 lux. However, it also surprisingly appears that illuminances over about 3000 lux have no (additional) beneficial effects. Hence, best results may be obtained wherein the illuminance of the (supplemental) light is at maximum about 2500 lux, such as at maximum about 2000 lux.

In a first aspect, the invention provides a control system for controlling one or more light parameters of light provided to an aqueous liquid in a containing element for containing fish, such as especially from the family of Cichlidae, like Tilapia, or a species from the family of the aquatic Arthropoda, in the aqueous liquid, wherein the control system is configured to control one or more light parameters of the light for imposing a plurality of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP), wherein the control system is especially at least configured to control the illuminance of the light provided to the aqueous liquid with a first illuminance during the light period (LP) and a second illuminance during the dark period (DP). The first illuminance is higher than the second illuminance. Especially, the first illuminance is selected from the range of in average at least 500 lux, such as especially in average 1000-2500 lux, at the liquid surface of the aqueous liquid (during the light period). Further, especially the second illuminance is selected from the range of 0-400 lux, especially 0-100 lux, at the liquid surface of the aqueous liquid during the dark period). Further, in specific embodiments the duration of the light period (LP) is selected from the range of 8-22 hours, especially 12-20 h. Further, especially the duration of the dark period (DP) is selected from the range of 2-16 hours, especially 4-12 hours. The choice of the light period and dark period, and the choice of the illuminance(s) related to these period(s) may herein also be indicated as “lighting scheme” or “fish lighting scheme”.

With such control system, a farming method can be executed, and a lighting system and/or light ingress control element can be controlled leading to an efficient growth of the fish. For instance, the growth efficiency and survival rate can be relatively high, higher than when e.g. conditions deviating from the above indicated (and further herein discussed) parameters concerning light and dark period and/or illuminance.

Herein, the invention is especially defined in relation to tilapia. However, wherever tilapia is mentioned, in an alternative embodiment a species from the family of the aquatic Arthropoda may be mentioned. The term “aquatic Arthropoda” refers to Arthropoda living in the water, such as crabs, lobsters, crayfish, shrimp, krill, woodlice, and barnacles. Hence, in embodiments instead of “tilapia”, also “shrimp” may be read.

Especially, the invention provides a control system for controlling one or more light parameters of light provided to an aqueous liquid in a containing element for containing fish from the family of Cichlidae (or a species from the family of the aquatic Arthropoda) in the aqueous liquid, wherein the control system is configured to control one or more light parameters of the light for imposing a plurality of diurnal cycles to the aqueous liquid with

each diurnal cycle having a light period (LP) and a dark period (DP), wherein a duration of the light period (LP) is selected from the range of 12-20 h, and wherein a duration of the dark period (DP) is selected from the range of 4-12 hours, wherein the control system is at least configured to control the illuminance of the light provided to the aqueous liquid with a first illuminance during the light period (LP) selected from the range of in average at least 1000 lux at a liquid surface of the aqueous liquid and a second illuminance during the dark period (DP) selected from the range of at maximum 400 lux at the liquid surface of the aqueous liquid.

As indicated above, the invention provides a control system for controlling one or more light parameters of light provided to an aqueous liquid in a containing element for containing fish. The containing element, the aqueous liquid, and the fish are not part of the control system. The containing element can be part of a larger system, such as a farming system.

The term “controlling” and similar terms especially refer at least to determining the behavior or supervising the running of an element. Hence, herein “controlling” and similar terms may e.g. refer to imposing behavior to the element (determining the behavior or supervising the running of an element), etc., such as e.g. measuring, displaying, actuating, opening, shifting, changing temperature, etc.. Beyond that, the term “controlling” and similar terms may additionally include monitoring. Hence, the term “controlling” and similar terms may include imposing behavior on an element and also imposing behavior on an element and monitoring the element. The controlling of the element can be done with a control system. The control system and the element may thus at least temporarily, or permanently, functionally be coupled. The element may comprise the control system. In embodiments, the control system and element may not be physically coupled. Control can be done via wired and/or wireless control. The term “control system” may also refer to a plurality of different control systems, which especially are functionally coupled, and of which e.g. one control system may be a master control system and one or more others may be slave control systems.

The control system may comprise a sensor or may be functionally coupled to a sensor, such as a light sensor. The light sensor may especially be configured to sense solar light. In an embodiment, a solar cell, especially a photovoltaic cell, is (also) configured as sensor. For instance, based on the electrical energy provided by the solar cell, the control system may determine whether or not the desired illuminance is received by other light, such as solar light. Would the illuminance lower than a predetermined value or would the

illuminance decrease with a predetermined value, then the control system may switch on a lighting system (see also below). The term “sensor” may also refer to a plurality of (different) sensors.

The control system may also comprise a timer or may be functionally coupled to a timer. The timer may be used to control the time of the light period (and of the dark period). For instance, the timer may be set on a predetermined light period. During that period, the (supplemental) light of a lighting system may be provided when during that predetermined light period the other light, such as solar light, is not able to reach the desired illuminance. Then, the control system can switch on (or increase) the lighting system light of a lighting system to obtain the desired illuminance, such as at least 500 lux, more especially at least 1000 lux. In this way, it may be possible to provide during the total light period light having a predetermined minimum illuminance, such as at least 500 lux, like at least 1000 lux, during a predetermined light period, based on lighting system light and/or solar light, especially based on solar light and lighting system light, wherein the latter may be used as supplemental lighting during light periods wherein the solar light does not provide the predetermined minimum illuminance, such as after sunset or before sunrise, or during a cloudy day (see also below).

Hence, in an aspect the control system is configured to control the lighting system (or the lighting system light) in dependence of a light sensor and in dependence of a timer. In embodiments, a photovoltaic cell may be used as light sensor. The control system may especially be configured to execute the herein described method, such as in embodiments provide the lighting system light as (supplemental) light during those periods within a predetermined light period that the illuminance of the solar light is lower than a predetermined minimum value, such as lower than 500 lux, or such as lower than 1000 lux, but not to provide such as (supplemental) light during the dark period, which may especially be in the order of 4-12 hours of a diurnal cycle.

Hence, based on the above (and further below) indicated conditions the weight increase efficiency appears to be optimal. In other words, taking into account the total weight or total weight increase and the total costs, which is herein also indicated as BCR (benefit cost ratio) above (and further below) indicated conditions appear to be optimal. Compared to the test conditions wherein only daylight was applied, the results under the herein defined conditions especially in terms of weight increase efficiency or benefit to cost ratio, appear to be better.

The control system can be comprised by or can be functionally coupled to e.g. a lighting system (see also below) or a fish farming system (see also below). This allows that

the aqueous liquid receives the right illuminance, and thus also the fish receive the desired illuminance.

A single control system may control a plurality of lighting systems, like a master control system. In other embodiments, each lighting system may include a control system (that may operate essentially independently of other lighting systems).

The invention may especially be of use for farming Cichlidae, such as Tilapia. Hence, the fish may especially be from the family of Cichlidae, like Tilapia. Cichlidae are fish from the family Cichlidae in the order Perciformes. Tilapia is the common name for nearly a plurality of species of cichlid fish from the tilapiine cichlid tribe. Tilapia are mainly freshwater fish inhabiting shallow streams, ponds, rivers and lakes and less commonly found living in brackish water.

The containing element can be any containing element that can be used to far Tilapia. The containing element can e.g. be a tank or a basin. The containing element can be tank or a containing element on land but may also be a containing element or tank in natural water like a stream, a pond, a river or a lake. For instance, with a net or gauze system may be arranged in natural water, wherein water may be in communication with surrounding water, but wherein the fish cannot escape from the containing element. The containing element may be configured in a closed unit, such as a shed, a factory, a greenhouse, etc.. In some embodiments, e.g. ambient light, especially solar light, may reach the aqueous liquid in the containing element. In embodiments, the closed unit does essentially not permit entrance of solar light, and the light is essentially only provided by artificial light, even more especially by essentially only the lighting system light. In embodiments, the containing element is configured outdoors, without essentially barrier for solar light to reach the liquid surface of the aqueous liquid. Hence, in embodiments the containing element may be an outdoor containing element, like a pond or basin configured outdoors, or configured in a stream, river, or lake. Instead of the term “containing element” also the term “container” may be used.

Therefore, in specific embodiments the containing element (of a farming system) may comprise an open water basin or a pond. For instance, in such embodiments the other light may (essentially) comprise solar light. This other light may be provided during at least part of the light period.

The aqueous liquid may especially comprise water, such as freshwater or brackish water, especially freshwater. Hence, the term “liquid surface” especially refer to the water surface of the freshwater or brackish water.

The containing element may be configured to receive solar light, or optionally other light. Hence, the containing element, i.e. the liquid in the containing element, may receive light from another light source, i.e. other than from the lighting system (when available). In other embodiments, the aqueous liquid essentially only receives light from the lighting system.

The control system is configured to control one or more light parameters of the light. There may be basically two series of embodiments, those where essentially all light provided to the aqueous liquid is provided by the lighting system and those where at least part of the light is provided by other light, especially ambient light, such as solar light.

Hence, in embodiments the fish can be farmed in a closed unit, where essentially all light provided to the aqueous liquid is from the lighting system, and ambient light in the closed unit is less than 5% of the total light (in Watt) provided to the aqueous liquid over time, such as less than 1%. The closed unit can be the containing element or may comprise the containing element, such as a shed or plant, enclosing the containing element.

In these embodiments, the control system is especially configured to control at least the lighting system (amongst other according to the herein indicated embodiments of the method).

The fish may also be farmed in (closed) units where ambient light from other light sources, such as ceiling lighting, and/or solar light, etc., may reach the aqueous liquid.

The (closed) unit can be the containing element or may comprise the containing element, such as a shed or plant, enclosing the containing element. In such systems it may be necessary to control the amount of other light, as it may be desirable to have a maximum illuminance during the lighting periods. During sunny days and e.g. dependent upon the construction and/or geographical location of the unit it may even be that light ingress may be controlled to limit the amount of other light reaching the aqueous liquid. However, it may be that the period that is chosen to provide the illuminance, i.e. the light period, may be longer than can be achieved with solar light. In such instance the lighting system may be used to supply additional light ("supplemental light") during those times that the other light cannot provide the desired illuminance. In these embodiments, the control system is especially configured to control one or more of the lighting systems and optionally a light ingress control element. Especially, in these embodiments the control system is especially configured to control the lighting system, and optionally also control a light ingress control element.

The light ingress control element may comprise a shutter, a blind, etc., or other element, which allows controlling ingress of light in the containing element. The light ingress

control element may comprise or be functionally coupled to an actuator. The actuator may configure the light ingress element in different configurations such that different amounts of light may reach the aqueous liquid in the containing element.

As indicated above, the control system is configured to control one or more light parameters of the light. Hence, the light may comprise in embodiments essentially only lighting system light and may comprise in other embodiments one or more of lighting system light and other light (from another light source, such as the sun). The one or more light parameters may especially refer to intensity of the power of the light. As further elucidated below, in embodiments the power of the light of the lighting system (see also below) may only be controlled to an on-state and an off-state (thus without intermediate. Hence, in such embodiments a fixed illuminance may be provided (in the on-state). The term “light” especially herein refers to visible light, i.e. light having one or more wavelengths selected from the range of 380-780 nm. When lighting system light is applied, the light may be white light but in other embodiments the lighting system light may be colored light, such as comprising at least one or more of blue and green, and with a low amount, or no, red light.

In specific embodiments, the light (i.e. especially thus the lighting system light) may white light. In the context of this description, color temperature of illumination or color temperature of a light emitting element is the temperature of an ideal black-body radiator that radiates light of a color comparable to that of the light emitting element. Color temperature is a characteristic of visible light and is most often associated with “white light”. White light is defined herein as light having chromaticity coordinates within seven or eight MacAdam ellipses from the black body locus (BBL). Color coordinates that lie on or near the BBL yield pleasing white light to a human observer. However, many artificial light emitting elements, such as fluorescent lamps or LEDs (light emitting diodes) emit light primarily by processes other than thermal radiation which means that the emitted radiation does not follow the black body locus spectrum. These sources are assigned what is known as a correlated color temperature CCT. CCT is the color temperature of a black body radiator which, to human color perception, most closely matches the light from the artificial light emitting element. General illumination generally has a (correlated) color temperature between 2000 K and 11000 K, with the majority of lighting emitting elements for general illumination being between 2700 K and 6500 K.

Hence, in embodiments the lighting system light has at least 70% of a spectral power distribution in the spectral wavelength range of 430-650 nm relative to the total spectral power distribution of the lighting system light in the range of 380-780 nm. Amongst

other, in this way in embodiments the light has at least 70% of a spectral power distribution in the spectral wavelength range of 430-650 nm relative to the total spectral power distribution of the light in the range of 380-780 nm. The light provided to the aqueous liquid may herein also be indicated as “fish light”.

5 In specific embodiment, the lighting system light or fish light has a spectral distribution essentially the same as depicted in the accompanying Fig. 1h.

Further, in specific embodiment, the lighting system light has a spectral distribution leading to a color point (CIE 1931) of $x=0.2662 \pm 10\%$ and $y=0.3305 \pm 10\%$, such as especially $x=0.2662 \pm 5\%$ and $y=0.3305 \pm 5\%$. Alternatively or additionally, in specific
10 embodiment, the lighting system light has a spectral distribution leading to a color point (CIE 1931) within 7 SDCM (standard deviation of color matching), even more especially within 5 SDCM of $x=0.2662$ and $y=0.3305$. Alternatively or additionally, in specific embodiment, the lighting system light has a spectral distribution leading to a correlated color temperature (CCT) selected from the range of 8500-10500 K, such as selected from the range of 9000-
15 9800 K, such as selected from the range of 9100-9700 K.

The one or more parameters that are controlled at least comprise the parameter of the intensity, as the light and dark period controlled by the control system, and as the light intensity during those periods may be controlled. However, in specific embodiments also the spectral distribution may be controlled. The spectral distribution of the light provided to the
20 aqueous liquid may e.g. depend upon the growth stage of the fish.

The control system is thus especially configured for imposing a plurality of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP). The term “diurnal cycle” especially refers to pattern that recurs every 24 hours as a result of a full rotation of the earth with respect to the sun. Herein, it especially
25 refers to a 24 hours period which may at least partly coincide with the natural diurnal cycle, such as in the case wherein also solar light may be applied. However, the diurnal cycle herein may also refer to a 24 hours period that may be essentially different from the natural diurnal cycle. However, the diurnal cycle herein is also a 24 hours period.

The control system imposes with the light the plurality of diurnal cycles to the
30 aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP), wherein the control system is at least configured to control the illuminance of the light provided to the aqueous liquid with a first illuminance during the light period (LP) and a second illuminance during the dark period (DP). As indicated above, in embodiments this may imply making use of the solar light during one or more hours of the light period and/or

may imply making use of the nocturnal dark times during one or more hours of the dark period. As also indicated above, this may in other embodiments imply providing essentially only lighting system light during the hours of the light period and providing less light, or essentially no light, during the hours of the dark period.

5 Hence, in specific embodiments the phrase “imposes with the light the plurality of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP)” and similar phrases may also imply providing essentially only lighting system light during the hours of the light period and providing less lighting system light (and also not other light), or essentially no lighting system light (and also not other
10 light), during the hours of the dark period.

Hence, the first illuminance is higher than the second illuminance. Especially, the difference is at least 500 lux, such as at least about 800 lux.

Especially, the first illuminance is selected from the range of in average at least 500 lux, such as especially in average 1000-2500 lux, like in the range of 1000-2000
15 lux, at the liquid surface of the aqueous liquid (during the light period). Further, especially the second illuminance is selected from the range of 0-400 lux, especially 0-100 lux, at the liquid surface of the aqueous liquid during the dark period).

Herein, the phrase “in average 1000-2500 lux” and similar phrases are applied, which may especially indicate that during the indicated period in average permanently the
20 indicated illuminance is applied. This may include embodiments wherein during a part of the period the illuminance is higher and during a part of the period the illuminance is lower. However, in average over the time the illuminance is permanently the indicate value. When a predetermined illuminance is chosen, the deviation thereof during the period may e.g. be 50% or less.

25 Herein, also the phrase “at the liquid surface of the aqueous liquid” is applied. In general, the illuminance is from over the surface of the aqueous liquid. However, alternatively or additionally light may also be provided from a side and/or with a light source within the aqueous liquid. Hence, an equivalent intensity to the herein indicated illuminance may be provided via one or more options including top lighting, side lighting, and lighting
30 with an at least partially immersed light source. Hence, the term “at the liquid surface” may especially indicate that the illuminance may be related to the surface area of the liquid, even when the light is escaping from a lighting system below the liquid surface. Hence, light may be provided from one or more of the top, the bottom, a side, and submerged. The term

“submerged” especially indicated that the window from which the light escapes is below the liquid surface (during generation of the light).

Especially, the first illuminance is at least 1500 lux.

Further, in specific embodiments the duration of the light period (LP) is
5 selected from the range of 8-22 hours, especially 12-20 h, even more especially 14-20 h, such as 16-20 h. Further, especially the duration of the dark period (DP) is selected from the range of 2-16 hours, especially 4-12 hours, like more especially 4-10 hours, even more especially 4-8 hours.

The light is especially provided during a substantial period during a phase
10 wherein the fish (or a species from the family of the aquatic Arthropoda) substantially growth. Hence, useful stages to apply the light are the juvenile stage. Especially, the control system is configured to provide at least 30 consecutive diurnal cycles with the light period (LP) and the dark period (DP). Even more especially, the diurnal cycles are applied during at least 60 days, especially at least 60 consecutive days, yet even more especially at least 90
15 days, such as especially at least 90 consecutive days, yet even more especially at least 120 days, such as especially at least 120 consecutive days.

Assuming e.g. an embodiment wherein a battery is applied, which is charged by solar light and discharged when the lighting system light is provided, it may sometimes be that during one or more days not the entire light period the control system or lighting system
20 can provide the light over the period of the light period the light is necessary. For instance, assume a day with very bad weather, an equivalent of only a few hours electrical energy may be generated during a period of e.g. 6 hours, wherein in the remaining hours the solar light is to such an extend absent, that the minimum illuminance is not reached, and thus the lighting system should provide the lighting system light. When only for a few hours lighting system
25 light can be generated, the predetermined light period with the predetermined illuminance may not be reached. In practices, especially in the geographical regions as indicted below, this may only be the case a limited number of days. Hence, in embodiments the control system may be configured to provide at least 20 diurnal cycles, such as at least 25 diurnal cycles, with the light period (LP) and the dark period (DP), during 30 consecutive diurnal
30 cycles. Even more especially, the control system may be configured to provide at least 50 diurnal cycles, such as at least 55 diurnal cycles, with the light period (LP) and the dark period (DP), during 60 consecutive diurnal cycles. Yet even more especially, the control system may be configured to provide at least 80 diurnal cycles, such as at least 85 diurnal cycles, with the light period (LP) and the dark period (DP), during 90 consecutive diurnal

cycles. Yet even more especially, the control system may be configured to provide at least 100 diurnal cycles, such as at least 110 diurnal cycles, with the light period (LP) and the dark period (DP), during 120 consecutive diurnal cycles. Hence, in embodiments during at least 90% , such as at least 95%, of the diurnal cycles out of a series of (at least 30, such as at least 60, like at least 90) consecutive diurnal cycles the light period with associated (minimum) illuminance and the dark period with associated maximum illuminance are realized.

In yet other embodiments, the batteries may be configured to store enough electrical energy to let the lighting system provide during one or more entire light periods, such as at least 1, like at least 2, such as up to 5 light periods, the lighting system light with at least 500 lux, such as at least 1000 lux, like at maximum 3000 lux, like at maximum 2500 lux, such as not more than about 2000 lux.

The chosen illuminance and/or the spectral distribution of the light may in embodiments also vary over time during such period of a plurality of diurnal cycles. For instance, the spectral distribution and/or the illuminance may be optimized to the stadium of growth, or may e.g. be adjusted when growth is less than desired or more than desired, or may be adjusted as function of the temperature of the aqueous liquid, etc. etc..

As indicated above, there may be basically two series of embodiments, those where essentially all light provided to the aqueous liquid is provided by the lighting system and those where at least part of the light is provided by other light, especially ambient light, such as solar light. Herein, the term “other light” may especially refer to other visible light, i.e. light within the range of 380-780 nm. It seems that light outside those ranges may not be of specific use for the fish.

Hence, in embodiments the control system is (further) configured to control a lighting system configured to provide lighting system light to provide at least part of the first illuminance during one or more diurnal cycles of the plurality of diurnal cycles.

In other embodiments (as also indicated above), also light from one or more other sources, such as the sun, may be used. In such embodiments, a sensor may be applied to measure the other light, and in dependence thereof, lighting system light may additionally be provided in those periods of the light period where the other light may not reach the desired illuminance. Therefore, in further embodiments the control system is further configured to be functionally coupled to a light sensor configured to sense other light reaching the aqueous liquid and not originating from the lighting system, wherein the control system is further configured to control the lighting system to provide the lighting system light to the aqueous liquid in dependence of a light sensor signal of the light sensor, to provide the first

illuminance provided by one or more of (a1) the lighting system light and (a2) the optional other light during the light period (LP). Hence, the first luminance may be provided by the lighting system light and/or the other light. For instance, during part of the light period of one or more diurnal cycles, the light may be provided by the other light, such as solar light.

- 5 However, the useful period of the other light may be shorter than the desired light period. Hence, for instance the day may be extended with the lighting system light, providing the required illuminance over the entire light period.

Hence, in embodiments a light period shorter than 12 hours provided by other light, such as especially (essentially) comprising solar light may be extended to e.g. at least
10 12 hours, i.e. a light period of at least 12 hours, by providing lighting system light (as supplemental light). Hence, in embodiments the control system may be configured to extend a light period shorter than 12 hours provided by other light (comprising solar light) to (a light period) of at least 12 hours by providing lighting system light.

When it would be desirable that the dark period is not entirely dark, for
15 instance, would it be considered to be desirable to provide some illuminance during the dark period, essentially the same may apply as above in the sense that the second luminance may be provided by the lighting system light and/or the other light. For instance, during part of the dark period of one or more diurnal cycles, the light may be provided by the other light, such as nocturnal light from the moon (and the stars). However, the intensity of the other light may
20 be lower than desired. Then, lighting system light may be applied.

Of course, would it be desirable that the dark period is essentially dark, but would other light have access to the aqueous liquid, then it may be desirable to include controllable light ingress elements to essentially exclude the other light, like light from the moon (and the stars), or optionally other light sources, such as background light.

25 As indicated above, the ingress of other light may be controlled. Therefore, in embodiments the control system may further configured to control the other light (from the optional other light source) reaching the aqueous liquid, by controlling a light ingress control element, wherein the light ingress control element is configured to control ingress in the containing element of the other light.

30 The control system may also be applied for other purposes. For instance, in embodiments the control system may further be configured to control one or more aqueous liquid parameters selected from the group comprising temperature of the aqueous liquid, oxygen content of the aqueous liquid, light transmission and/or light scattering of the aqueous liquid, and a flow speed and/or flow rate of the aqueous liquid.

The control system may in embodiments especially be configured to control the lighting system light. Therefore, the control system may in embodiments be configured to control the lighting system to provide the lighting system light (according to a desired lighting scheme, such as described herein).

5 In yet a further aspect, the invention also provides a lighting system that may e.g. comprise the herein described control system or that may be functionally coupled to such control system. Further, such lighting system may be used in the herein described method (see also below). Therefore, the invention also provides a lighting system that can be configured for lighting of fish from the family of Cichlidae (or a species from the family of
10 the aquatic Arthropoda) in the aqueous liquid of the containing element, wherein essentially no other light from another light source reaches the aqueous liquid and/or which can be configured for lighting of fish from the family of Cichlidae (or a species from the family of the aquatic Arthropoda) in the aqueous liquid of the containing element wherein other light may have access to the aqueous liquid, and wherein the lighting system may be configured
15 for providing additional light to reach the required illuminance according to the lighting scheme.

Hence, in an aspect the invention provides (also) a lighting system configured to provide lighting system light to an aqueous liquid in a containing element for containing fish from the family of Cichlidae (or a species from the family of the aquatic Arthropoda) in
20 the aqueous liquid, wherein the lighting system further comprises the control system for controlling one or more light parameters of light provided to the aqueous liquid in the containing element, wherein the light comprises one or more of the lighting system light and other (visible) light reaching the aqueous liquid and not originating from the lighting system.

When there is essentially no other light that can reach the aqueous liquid, the
25 light is essentially the lighting system light.

When however other light, like solar light may have access to the aqueous liquid, the lighting system may be configured to provide the lighting system light in dependence of the intensity (and optionally spectral power distribution) of the other light. Therefore, in yet further embodiments the lighting system may further comprise a light
30 sensor configured to sense other (visible) light reaching the aqueous liquid and not originating from the lighting system, wherein the control system is configured to control the lighting system to provide the lighting system light to the aqueous liquid in dependence of a light sensor signal of the light sensor to provide the first illuminance provided by one or more of (a1) the lighting system light and (a2) the optional other (visible) light during the light

period (LP), wherein the lighting system is configured to provide lighting system light to provide at least part of the first illuminance during one or more diurnal cycles of the plurality of diurnal cycles. As indicated above, when it would be desirable that the dark period is not entirely dark, for instance, would it be considered to be desirable to provide some
5 illuminance during the dark period, the second luminance may be provided by the lighting system light and/or the other light.

In specific embodiments, the power of the light of the lighting system (see also below) may only be controlled to an on-state and an off-state (thus without intermediate steps larger than zero power but smaller than at maximum power).

10 In embodiments, the lighting system may comprise a sensor or may be functionally coupled to a sensor, such as a light sensor. Such embodiments are also described in relation to the control system.

The lighting system may also comprise a timer or may be functionally coupled to a timer. Such embodiments are also described in relation to the control system.

15 In embodiments, the lighting system may comprise the above defined control system. In embodiments, the lighting system may comprise a lighting device. Further, in embodiments the lighting system may comprise a plurality of (different) lighting devices. In embodiments, the control system is configured to control one or more of the (one or more) lighting devices.

20 The lighting system may in embodiments essentially consist of a single lighting device. Herein, the lighting device is indicated with reference. Hence, in embodiments the lighting device is the lighting system. In yet other embodiments, the lighting system may e.g. comprise the lighting device and an external control system. In other embodiment, the lighting device may comprise the control system. The lighting device light
25 and the lighting system light may essentially be identical. For instance, in embodiments one or more lighting devices of a lighting system generate lighting device light; the lighting system light may essentially consist of the lighting device light. Unless indicated otherwise, the lighting device light has (essentially) the same optical properties in terms of spectral distribution, color point, color temperature, as the lighting system light.

30 Especially, the lighting device is configured to provide lighting device light have the spectral properties as defined in relation to the lighting system light. Hence, the lighting system light may essentially consist of lighting device light.

In embodiments, the lighting device may be configured to provide in the range of 500-300 lumen, such as in the range of 1000-3000 lumen, like in the range of 1000-2500

lumen, such as in the range of 1000-2000 lumen. In the containing system, the lighting system may be configured such, that the illuminance (by the lighting system) at the liquid surface is selected from the range of 500-3000 lux, such as in the range of 1000-3000 lux, like in the range of 1000-2500 lux, such as in the range of 1000-2000 lux.

5 In an aspect, the invention is also related to the lighting device per se.

In an embodiment, the lighting system essentially consists of a single lighting device.

10 In embodiments, the lighting device is configured to be floating, with part of the lighting device below the liquid level and part of the lighting device configured above the liquid level.

In embodiments, the invention provides a lighting device configured to provide lighting device light, wherein the lighting device is configured to at least partly float on an aqueous liquid, and wherein the lighting devices comprises a light exit window from which lighting device light can escape from the lighting device, wherein the light exit window is configured below a liquid level of the aqueous liquid when the lighting device at least partly floats on the aqueous liquid.

In specific embodiments, the lighting device further comprises a solar cell configured to receive (solar) light and convert into electrical energy.

20 Yet, in further embodiments the lighting device comprises a battery configured to store at least part of the electrical energy.

In yet further specific embodiments, the lighting device may comprise a control system (such as described herein) especially configured to control an intensity of the lighting device light in dependence of a predefined daily time scheme and in dependence of a parameter related to the intensity of the (solar) light received.

25 In specific embodiments, the control system may thus comprise a timer (or be functionally coupled to a timer), wherein the timer is configured to define a maximum time for providing the lighting device light. For instance, in embodiments the control system may be configured to provide the lighting device light for at maximum 20 hours per day (see also above in relation to the desired light period).

30 Further, in specific embodiments the control system may be configured to control the intensity of the lighting device light in dependence of the intensity of the (solar) light received.

In embodiments, the control system may be configured to provide the lighting device only during a period when the parameter related to the intensity of the (solar) light

reaches a predetermined minimum amount (or reaches a predestined maximum reduction rate of the illuminance of the solar light.

Hence, in embodiments the solar cell, especially the photovoltaic cell, may also be used as sensor.

5 The control system and/or the lighting system may especially be functionally coupled to or be comprised by a farming system. Such farming system comprises further a containing element, wherein the fish may be farmed. The term “containing element” may also refer to a plurality of containing elements. As indicated above, such farming system may in embodiments comprise a closed unit, which may be the containing element or which may
10 comprise the containing element.

Hence, in yet a further aspect, the invention also provides a farming system for farming fish from the family of Cichlidae (or a species from the family of the aquatic Arthropoda), wherein the farming system comprises the control system as defined herein and a containing element for containing the fish (or a species from the family of the aquatic
15 Arthropoda), in an aqueous liquid. Hence, in an aspect the invention also provides a farming system for farming fish from the family of Cichlidae (or a species from the family of the aquatic Arthropoda), wherein the farming system comprises a containing element for containing the fish (or a species from the family of the aquatic Arthropoda), in an aqueous liquid and the lighting system as defined herein, wherein the farming system may further
20 comprise the control system as defined herein; the optional control system may be comprised by the lighting system or may be configured external thereof. Communication between an external control system and a lighting system may be executed via wires or wireless, as is known in the art. Therefore, in an aspect the invention also provides a farming system for farming fish from the family of Cichlidae or a species from the family of the aquatic
25 Arthropoda, wherein the farming system comprises a control system (such as defined herein), a containing element (for containing the fish or a species from the family of the aquatic Arthropoda in an aqueous liquid), and the lighting system (such as e.g. defined herein); in embodiments the lighting system may comprise the control system, wherein the control system is configured to control the lighting system (light).

30 The control system may in embodiments be configured to control one or more of a lighting system, such as described herein, and a light ingress element, such as described herein.

Hence, in embodiments the farming system further comprises the lighting system as defined herein. Alternatively or additionally, especially in specific embodiments

additionally, the farming system may further comprise a light ingress control element configured to control ingress in the containing element of other light reaching the aqueous liquid not originating from the lighting system, wherein the control system is further configured to control the light ingress control element as defined herein.

5 In an embodiment, a farming system as described above further comprises a recirculating aquaculture system, wherein the recirculating aquaculture system comprises the containing element and a recirculator for recirculating the aqueous liquid.

The term “fish” may especially refer to a plurality of fish. For instance, at least 100 fishes, or at least 1000 fishes, or even more, may be in the aqueous liquid in the
10 containing element. Further, the term “species” (in the phrase “species from the family of the aquatic Arthropoda”) may refer to over 1000, like over 10,000, such as over 100,000 of such species.

In yet a further aspect, the invention also provides a method of controlling the light provided to the aqueous liquid in a containing element for containing fish from the
15 family of Cichlidae (or a species from the family of the aquatic Arthropoda) in the aqueous liquid. Especially, the method may include controlling the lighting system light of a lighting system (or the lighting device of a lighting device). Even more especially, in embodiments the method may include controlling the lighting system light in dependence of other light, such as solar light, such that during a predefined light period, a minimum illuminance may be
20 maintained. Would e.g. during the predefined light period the other light reduce to a predetermined minimum level, the lighting system may be switched on to provide the lighting system light and provide a predetermined minimum illuminance, such as at least about 500 lux, such as at least about 1000 lux.

In an aspect, the invention provides (also) a method for controlling one or
25 more light parameters of light provided to an aqueous liquid in a containing element for containing fish from the family of Cichlidae (or a species from the family of the aquatic Arthropoda) in the aqueous liquid. In embodiments, the method may comprise imposing with the light a plurality of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP), wherein a duration of the light period (LP) is
30 selected from the range of 8-22 hours, especially 12-20 h, and wherein a duration of the dark period (DP) is selected from the range of 2-16 hours, especially 4-12 hours, the method further comprising controlling the illuminance of the light provided to the aqueous liquid with a first illuminance selected from the range of in average at least 500 lux, even more especially at least 1000 lux, such as in embodiments especially in average 1000-2500 lux at

the liquid surface of the aqueous liquid during the light period (LP) and a second illuminance selected from the range of at maximum 400 lux, such as in the range of 0-400 lux, especially 0-100 lux, at the liquid surface of the aqueous liquid during the dark period (DP).

In an embodiment the above described method, the method may further
5 comprises selecting the duration of the light period (LP) from the range of in average 12-20 h, such as 12-18 selecting the first illuminance from the range of – in embodiments – in average at least 1000 lux, such as in average 1000-2500 lux, like in average 1000-2000 lux, at the liquid surface of the aqueous liquid, selecting the second illuminance from the range of in average 0-50 lux at the liquid surface of the aqueous liquid. In specific embodiments, the
10 light has at least 70% of a spectral power distribution in the spectral wavelength range of 430-650 nm relative to the total spectral power distribution of the light in the range of 380-780 nm, providing at least 30 (consecutive) diurnal cycles with the light period (LP) and the dark period (DP)

In embodiments, the fish comprise Tilapia fish. In other embodiments, the
15 species from the family of the aquatic Arthropoda comprise shrimps.

In an embodiment the above described method may further comprise providing lighting system light with a lighting system configured to provide the lighting system light to the aqueous liquid, sensing with a light sensor other (visible) light, such as solar light, reaching the aqueous liquid and not originating from the lighting system to
20 provide a corresponding light sensor signal, wherein the method further comprises providing the lighting system light in dependence of the light sensor signal, to provide the first illuminance provided by one or more of (a1) the lighting system light and (a2) the optional other (visible) light during the light period (LP).

Hence, the first illuminance during part of the light period may be provided by
25 other light, such as solar light. Would however the solar light not provide the predetermined illuminance, the lighting system light may be provided as supplemental light, filling in time at least part of the light period with lighting system light having the predetermined illuminance.

In yet a further aspect, the invention also provides a computer program
30 product, that, when running on a computer which is functionally coupled to or comprised by the lighting system as described herein, or the farming system as described herein, is capable of bringing about the method as described herein.

In yet a further aspect, the invention also provides the use of the lighting system for providing lighting system light during periods of time of a diurnal cycle wherein

solar light cannot provide a predetermined illuminance, for instance, during part of the night and/or on days of bad weather.

The invention also provides the use of a lighting system configured to provide lighting system light to an aqueous liquid in a containing element for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda, especially Tilapia fish (in the aqueous liquid), wherein optionally together with other (visible) light reaching the aqueous liquid and not originating from the lighting system, a plurality of diurnal cycles are imposed to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP), wherein especially a duration of the light period (LP) is selected from the range of 8-22 hours, especially 12-20 hours, and wherein a duration of the dark period (DP) is selected from the range of 2-16 hours, especially 4-12 hours, with a first illuminance from one or more of the lighting system light and the other (visible) light selected from the range of in average at least 500 lux, especially at least 1000 lux, especially in average 1000-2500 lux at the liquid surface of the aqueous liquid during the light period (LP) and a second illuminance of one or more of the lighting system light and the other (visible) light selected from the range of at maximum 400 lux, such as selected from the range of 0-400 lux, especially selected from the range 0-100 at the liquid surface of the aqueous liquid during the dark period (DP), and wherein the plurality of the diurnal cycles are imposed, for promoting growth of the fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda, especially Tilapia fish.

During the light period, the predetermined illuminance may have a specific average value, such as at least 1000 lux, or selected from the range of 1000-2000 lux. In specific embodiments, during at least 50% of the light period, such as during at least 80% of the light period, the lighting system may provide the lighting system light with an illuminance that is essentially constant. As indicated above, in specific embodiments a fixed illuminance may be provided (in the on-state). Hence, as long as the lighting system provides the lighting system light, the illuminance is essentially constant.

In specific embodiments, the invention may especially be applied between the parallels at 45°, such as between the parallels at 40°, for instance between the parallels at 35°. In specific embodiments, the invention may be applied between the tropic of Cancer and the tropic of Capricorn.

Hence, the invention provides amongst others a control system for use in farming fish, lighting system, fish farming system, and a method for controlling light for use in farming fish.

The terms “upstream” and “downstream” relate to an arrangement of items or features relative to the propagation of the light from a light generating means (here the especially the light source), wherein relative to a first position within a beam of light from the light generating means, a second position in the beam of light closer to the light generating means is “upstream”, and a third position within the beam of light further away from the light generating means is “downstream”.

Aspects and embodiments are described in the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which Figs. 1a-1h schematically depict some aspects and embodiments. The schematic drawings are not necessarily to scale.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Below, experimental work and the results thereof are described.

Experimental fish and design

Male tilapias were purchased from Haikou City, Hainan Province in June 2016, with the average size 5 ± 0.9 g. After one-week temporary rearing in the recirculating aquaculture system (RAS) system, the healthy and lively tilapias were selected to conduct the experiment. Tilapias were randomly assigned to ten 1.5 m³-RAS tanks with 145 tilapias in each tank and rearing for continuous 160d.

A double-equation irrepetitive testing method was applied with light intensity A (1000lx, 2000lx, 3000lx) and light period B (12L: 12D, 18L: 6D, 24L: 0D) allocated and divided into groups: A₁B₁, A₁B₂, A₁B₃, A₂B₁, A₂B₂, A₂B₃, A₃B₁, A₃B₂, A₃B₃. The natural light intensity and light period group was set as a control group.

Here, 12 L and 12 D indicate 12 hours illuminated with the light with the indicated intensity and 12 hours no additional illumination with the light with the indicated intensity, i.e. “dark”.

In a total of ten tanks were included in the RAS system with a 1.5m³ volume of each tank, 30±2°C water temperature, 5mg/L dissolved oxygen by continuous inflation and 7.5-8.0 pH value. The fish feed was purchased from Tongwei (Wuxi) Co. with 3% BW (body

weight) as daily feeding amount at 9 am and 5 pm per day, the bait in the tank was removed in time and recorded.

Sample collection and growth index measurement

Every month, ten fish were randomly sampled from each tank after the 24-hours stop feeding. Then the fish were anesthetized with MS-222 for weighing and taking the blood sample. The blood sample was centrifuged for 15min at 3500r/min, and the serum was separated and stored at -80 °C for testing.

At the end of the experiment, the followed growth indexes were measured:

Survival rate (SR, %) = $m/n \times 100$

Daily weight gain (DWG, g/d) = $(W^t - W^0)/t$

Specific growth rate (SGR, %/d) = $(\ln W^t - \ln W^0)/t \times 100$

Growth efficiency (GE) = $[(W^t - W^0)/F] \times 100$

Feed coefficient (FCR) = $F/(W^t - W^0)$

m--fish number at the end of the experiment (ind); n--the fish number at the beginning of the experiment (ind); W^t --the average weight at the end of the experiment; W^0 --the average weight at the beginning of the experiment; t--the number of cultured days (d); F--the total food intake through the experiment.

Detection of blood samples

The levels of glucose (GLU), triglyceride (TG), total cholesterol (TC), low-density lipoprotein (LDL-C), high-density lipoprotein (HDL-C), total protein (TP), albumin (ALB), globulin (GLB), urea nitrogen (BUN), creatinine (SCR), aspartate aminotransferase (AST) in serum were measured by automatic biochemical analyzer BS-300 (Shenzhen Mindray Biomedical Electronics Co., Ltd.).

The activities of superoxide dismutase (SOD), malon dialdehyde (MDA) and catalase (CAT) in serum were analyzed by the kits produced by Nanjing Jiancheng Biology Engineering Institute. Serum cortisol (COR) was measured by ELISA method.

Economic analysis

An economic analysis was conducted to evaluate the net return and benefit cost ratio in the different treatments. The following formulas were used:

$R = TR - (FC + VC)$;

Benefit cost ratio (BCR, %) = $R/(FC + VC)$.

Where, R=total net return, TR=total revenue from tilapia sale that the price is 10 RMB/Kg, FC=fixed costs and VC=variable costs.

This analysis was based on farm-gate prices on December 10th 2016 for harvested tilapia. The electricity costs in these analyses were set on RMB 0.8 kwh⁻¹.

5

Statistical analysis

The effects of light intensity and light period to the fish growth indexes and blood physiological indexes were analyzed with Two-way ANOVA by SPSS19.0 software.

Single factor analysis of variance (One-way ANOVA) was used to determine the significance of differences among light intensity and light period, if $P < 0.05$, the Student-Neuman-Keuls multiple comparisons are used to analyze the difference among intensity and period index data.

Results

15 *Growth index*

The DWG, SGR, GE and FCR were significantly different in 2000lx group compare to 1000lx and 3000lx groups, moreover, tilapias in 2000lx group had higher weight gain, DWG, SGR and GE, and significant lower FCR than the other two groups (Table 1). There was no significant effect on the final weight, DG, SR, SGR, GE and FCR of tilapia among the different light period groups ($P > 0.05$, Table 2).

Table 1. The growth indicators in the different light intensity groups.

	1000lx	2000lx	3000lx
Final weight (g)	318.40±2.76 ^a	351.17±10.59 ^b	317.17±9.87 ^a
Daily weight growth (g)	1.96±0.17 ^a	2.16±0.67 ^b	1.95±0.61 ^a
Survival rate (%)	95.60±0.87 ^a	95.23±0.81 ^a	95.00±0.46 ^a
Special growth rate (%/d)	2.59±0.06 ^a	2.65±0.21 ^b	2.59±0.23 ^a
Growth efficiency	0.69±0.06 ^a	0.77±0.26 ^b	0.69±0.23 ^a
Feed conversion ratio	1.43±0.15 ^a	1.30±0.36 ^b	1.44±0.44 ^a

Table 2. The growth indicators in the different photoperiod groups.

	12L:12D	18L:6D	24L:0D
Final weight	325.36±15.17 ^a	330.27±28.3 ^a	331.10±16.35 ^a
Daily weight growth	2.00±0.97 ^a	2.04±0.10 ^a	2.03±0.12 ^a

	12L:12D	18L:6D	24L:0D
Survival rate	95.10±0.62 ^a	95.73±0.32 ^a	95.27±0.69 ^a
Special growth rate	2.60±0.03 ^a	2.62±0.06 ^a	2.62±0.03 ^a
Growth efficiency	0.71±0.04 ^a	0.72±0.07 ^a	0.72±0.04 ^a
Feed conversion ratio	1.40±0.07 ^a	1.39±0.11 ^a	1.38±0.07 ^a

Economic return

The total costs were higher in 3000lx groups which had higher lights investment as well as the followed electricity cost. However, the higher cost did not get a higher return: the 2000lx (12L, 18L and 24L) light groups received the highest total revenue than in other light intensity groups, which was similar to the total net return and benefit cost ratio.

This is also shown in table 3 (which is for the sake of readability divided over three subtables).

Table 3. Economic performance of different light intensity and light period groups in the experiment (Unit: RMB).

Table 3a

Parameters	1000lx, 12L	2000lx, 12L	3000lx, 12L
<i>Fixed costs</i>			
Lights depreciation	5	10	15
Electricity cost of water pump	60	60	60
Electricity cost of air pump	36.8	36.8	36.8
Electricity cost of lights	21	42	63
<i>Variable costs</i>			
Feed	181.5	170	186.6
Juveniles	78	78	78
Veterinary medicine	10	10	10
Total costs	392.3	406.8	449.4
Total revenue	466	496	453
Total net return	73.7	89.2	3.6

Parameters	1000lx, 12L	2000lx, 12L	3000lx, 12L
BCR (%)	19	22	1

Table 3b

Parameters	1000lx, 18L	2000LX, 18L	3000lx, 18L
<i>Fixed costs</i>			
Lights depreciation	8	15	23
Electricity cost of water pump	60	60	60
Electricity cost of air pump	36.8	36.8	36.8
Electricity cost of lights	31	63	95
<i>Variable costs</i>			
Feed	184.1	161.1	187.9
Juveniles	78	78	78
Veterinary medicine	10	10	10
Total costs	407.9	423.9	490.7
Total revenue	460	526	450
Total net return	52.1	102.1	-40.7
BCR (%)	13	24	-8

Table 3c

Parameters	1000lx, 24L	2000lx, 24L	3000lx, 24L	Control group
<i>Fixed costs</i>				
Lights depreciation	10	21	31	
Electricity cost of water pump	60	60	60	60
Electricity cost of air pump	36.8	36.8	36.8	36.8
Electricity cost of lights	42	85	127	
<i>Variable costs</i>				
Feed	185.4	167.5	177.7	198.2
Juveniles	78	78	78	78

Parameters	1000lx, 24L	2000lx, 24L	3000lx, 24L	Control group
Veterinary medicine	10	10	10	10
Total costs	422.2	458.3	520.5	383
Total revenue	458	505	476	427
Total net return	35.8	46.7	-44.5	44
BCR (%)	8	10	-9	11

Further, the weight increase efficiency was determined. The weight increase efficiency indicates the weight increase relative to the efforts that have to be done in terms of total costs:

5

Table 4a: weight increase efficiency at 1000 lx

Parameters	1000 lx, 12L	1000 lx, 18L	1000 lx, 24L	Control group
weight increase efficiency	173	118	73	100

Table 4b: weight increase efficiency at 2000 lx

Parameters	2000 lx, 12L	2000 lx, 18L	2000 lx, 24L	Control group
weight increase efficiency	200	218	91	100

10 Table 4c: weight increase efficiency at 3000 lx

Parameters	3000 lx, 12L	3000 lx, 18L	3000 lx, 24L	Control group
weight increase efficiency	9	n.r.	n.r.	100

n.r. indicates not relevant as the efforts are higher (in terms of total costs) than the weight increase (in terms of revenues).

Discussions

15 *Effects of light period and light intensity on tilapia growth*

This study shows for the first time that the growth indexes of the group (18L: 6D) are better than the other groups (12L: 12D and 24D). It confirms that prolonged illumination periods can promote the growth of fish, but sustained light may also have a negative impact on fish, especially on larvae fish.

5 These results showed no significant difference of survival rate among 1000lx, 2000lx and 3000lx group, which indicate that tilapia could grow healthy in the light intensity range. Additionally, 2000lx group has a better performance in final weight, DG, SGR, GR and FCR compares to groups 1000lx and 3000lx. The results showed that the light intensity had a significant effect on the growth of tilapia, and the FCR was the lowest under 2000lx
10 and the FCR was improved. From 1000lx to 3000lx, the growth performance of tilapia increased first and then decreased, which was similar to previous studies.

 Cholesterol content in 12L:12D group is higher than 24D group. Cholesterol content is an indicator of feeding and nutritional status, the lower the body cholesterol, the more healthy the body. But group 18L: 6D is between those two groups, it is likely to cause
15 malnutrition if the cholesterol content is too low in the appropriate range. Therefore, the 18L: 6D light period might be more suitable for the growth of tilapia.

 When the fish is affected by external environmental conditions, the hypothalamus - pituitary - renal tissue axis (HPI) is activated to promote the release of adrenocorticotrophic hormone (ACTH), causing cortisol hormone synthesis and release.

20 Changes in cortisol levels are one of the important indicators of the stress response. There was no significant difference in the content of cortisol from tilapia in the experiment. However, changes of the light period had a significant difference between the 12h light period and 18h, 24h. There was no significant difference between the photoperiod of 18h and the 24h light period. An appropriate extension of the light period is beneficial to reduce the
25 cortisol concentration of tilapia and improve the welfare conditions.

 The lights used in the RAS system require facility investment and electricity costs, therefore the 3000lx groups have the highest cost and the control group has the lowest. Without regard to the total cost, the 2000lx groups achieved the highest revenue, moreover, if take account the fixed costs and variable costs, the 2000lx intensity is still the most profitable
30 group that indicates the optimized light intensity is 2000lx, primarily due to the lower total cost and higher production.

 In contrast, all the experiment groups have higher tilapia production compared to the control group which implies that the extra illumination could promote tilapia growth. Within the 2000lx light intensity group, the different light periods may affect the biological

rhythm of tilapia, as well as the growth. Additionally, based on the current results, the future research could modify the lighting program such as using the natural light during the daytime and add extra illumination during the night or cloudy day to reduce the fixed cost and maximize the net revenue.

Hence, the aim of this work was to determine the effect of light intensity and light period on tilapia growth and serum physiological index in a recirculating aquaculture system. All tilapia fingerlings cultured in different light intensity and period by 160d and compared the growth target, blood physiological and biochemical parameters and plasma cortisol concentration. We used the double-equation irrepitive testing method in this study.

The light intensity denoted by A (1000lx, 2000lx, 3000lx), and the light period denoted by B (12L: 12D, 18L: 6D, 24L: 0D). So there were 9 groups, A₁B₁, A₁B₂, A₁B₃, A₂B₁, A₂B₂, A₂B₃, A₃B₁, A₃B₂, A₃B₃, and nature light intensity and the period were the control group. In 2000lx, the total weight, daily gain, special growth rate, and growth efficiency was higher than 1000lx and 3000lx.

Amongst others, it appears that the growth indexes and physiological state of tilapia could reach optimal performance in the state of light intensity of 2000lx and period of 18L: 6D, and improve the wealth fare and reduce the stress response of tilapia.

The control group was subjected to solar light, without additional lighting. Based on Table 4, it can be concluded that the light period may especially be in the range of at least 12 hours, but smaller than 20 hours. Further, it also appears that the illuminance is especially smaller than 3000 lux.

Figs. 1a and 1b schematically depict a non-limiting number of embodiments of e.g. a farming system 1000, which may be a closed or open tank, or which may be a pond, or which may be a for the fish or other species confined volume in a river, lake, etc.etc. Hence, the farming system 1000 comprises a containing element 200 for containing the fish and/or a species from the family of the aquatic Arthropoda. The dashed lines in Fig. 1b schematically depicts a barrier in the aqueous liquid, which is a barrier for the fish and/or a species from the family of the aquatic Arthropoda.

The farming system 1000 may thus especially be configured for farming fish from the family of Cichlidae and/or a species from the family of the aquatic Arthropoda, such as tilapia and shrimps respectively. Amongst others based on the above results, the inventors envision that the invention would also work for shrimps and other species grown in outdoor ponds and/or indoor tanks, etc..

Reference 201 indicates the aqueous liquid. Reference 205 indicates the liquid surface of the aqueous liquid 201. Reference 202 indicates schematically a fish, though other animals may also be farmed.

In embodiments, the farming system 1000 may comprise a control system 100 for controlling a lighting system 300. The control system may be comprised by the lighting system 300 or may be configured external thereof, which latter embodiment is schematically depicted in Fig. 1a.

Figs. 1a and 1b also schematically depict embodiments of a lighting system 300 configured to provide lighting system light 301 to an aqueous liquid in a containing element 200 for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid. In specific embodiments, the lighting system 300 may further comprises the control system 100 (see Fig. 1c) or may be configured external thereof (see Fig. 1a), for controlling one or more light parameters of light 1001 provided to the aqueous liquid in the containing element 200. The light 1001 comprises one or more of the lighting system light 301 and other light 356 reaching the aqueous liquid 201 and not originating from the lighting system 300.

By way of example, in Fig. 1a an embodiment is depicted where all light 1001 that is provided to the aqueous liquid is lighting system light 301. In Fig. 1b, an embodiment is schematically depicted wherein the light 1001 may comprise one or more of lighting system light 301 and other light 356 (especially solar light).

By way of example, Fig. 1a schematically depicts an embodiment wherein two lighting systems 300 are applied, or a single lighting system 300 with two lighting devices. The lighting system 300 is configured to generate lighting system light 301 (e.g. during part of the light period). One of the systems or devices is configured over the aqueous liquid 201, another one is schematically depicted at least partly submerged. This lighting system or lighting device may be floating. Such floating lighting system or lighting device may be anchored, such as schematically depicted in Fig. 1b.

The lighting system 300 may in embodiments essentially consist of a single lighting device. Herein, the lighting device is indicated with reference 400. Hence, in embodiments the lighting device is the lighting system. In yet other embodiments, the lighting system may e.g. comprise the lighting device 400 and an external control system 100. In other embodiment, the lighting device may comprise the control system 100. The lighting device light and the lighting system light may essentially be identical. For instance, in embodiments one or more lighting devices of a lighting system generate lighting device

light; the lighting system light may essentially consist of the lighting device light. Unless indicated otherwise, the lighting device light has (essentially) the same optical properties in terms of spectral distribution, color point, color temperature, as the lighting system light.

The lighting system (or lighting device) may provide the indicated
5 illuminance. The illuminance may be related to the area of the aqueous liquid in the containing element 200, even when the light is provide from over the liquid or in a submerged embodiment of the lighting system (or lighting device). Though not depicted, lighting system light 301 may also be provided from a side, or also from the bottom.

Fig. 1c schematically depicts an embodiment of a lighting device or of the
10 lighting system 300, wherein the lighting system in an embodiment may essentially consist of the lighting device. The lighting device may be configured to at least partly float on an aqueous liquid (see also Fig. 1b). The lighting device or of the lighting system 300 comprises a light exit window from which lighting system light 301 can escape from the lighting device or of the lighting system 300 (here, by way of example two of such windows are
15 schematically depicted). As schematically shown in Fig. 1b, the light exit window may be configured below a liquid level of the aqueous liquid when the lighting device (or of the lighting system 300) at least partly floats on the aqueous liquid; this may e.g. apply to the embodiment schematically depicted in Fig. 1c. The lighting device or of the lighting system 300 may further comprises a solar cell 380, especially a photovoltaic cell, configured to
20 receive (solar) light and convert into electrical energy. The lighting device or of the lighting system 300 may comprise a battery 370 configured to store at least part of the electrical energy. The lighting device or of the lighting system 300 may comprise a control system 100 (such as described herein) especially configured to control an intensity of the lighting device light in dependence of a predefined daily time scheme and in dependence of a parameter
25 related to the intensity of the (solar) light received. The control system 100 may comprises a timer or be functionally coupled to a timer (not shown). The timer may be configured to define a maximum time for providing the lighting device light. For instance, in embodiments the control system may be configured to provide the lighting device light for at maximum 20 hours per day (see also above in relation to the desired light period).

30 Hence, in embodiments the solar cell 380, especially the photovoltaic cell, may also be used as sensor. Alternatively, the lighting system 100 or lighting device may include a separate (light) sensor 350.

Further, in specific embodiments the control system may be configured to control the intensity of the lighting device light in dependence of the intensity of the (solar)

light received. In embodiments, the control system may be configured to provide the lighting device only during a period when the parameter related to the intensity of the (solar) light reaches a predetermined minimum amount (or reaches a predestined maximum reduction rate of the illuminance of the solar light.

5 Figs. 1a-1c also schematically depict embodiments of the control system 100 for controlling one or more light parameters of light 1001 provided to an aqueous liquid in a containing element 200 for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid, wherein the control system 100 may especially be configured to control one or more light parameters of the light 1001 for
10 imposing *a plurality* of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period LP and a dark period DP. In embodiments, a duration of the light period LP is selected from the range of 12-20 h, and a duration of the dark period DP is selected from the range of 4-12 hours. Further, in embodiments the control system 100 may at least configured to control the illuminance of the light 1001 provided to the aqueous liquid with a first
15 illuminance during the light period LP selected from the range of in average at least 500 lux, such as at least 1000 lux, at a liquid surface 205 of the aqueous liquid 201 and a second illuminance during the dark period DP selected from the range of at maximum 400 lux at the liquid surface 205 of the aqueous liquid 201. In embodiments, the latter period may be the night, or part of the night; the former period may be the day, part of the day, and optionally
20 part of the night. In closed systems, wherein the light 1001 is only provided as lighting system light 301, there is not necessarily a relation to the diurnal cycles in the closed system and the diurnal cycles provided by day light (though often this will be the case).

Fig. 1d schematically depicts an embodiment wherein the light 1001 may fully be provided by lighting system light 301. DP refers to dark period, and LP refers to light
25 period. The former may be defined by illuminances below I_2 above I_2 or by illuminances of a values of I_1 . On the x-axis the time, in a domain of 24 hours is depicted; on the y-axis the intensity.

Fig. 1e schematically depicts an embodiment wherein the other light 356, such as solar light, provides a illuminance well above the minimum level, and even well above the
30 desired maximum illuminance based on lighting system light 301 (or lighting device light). During the time a PV may receive solar light, a battery may be charged. When the illuminance drops with a predetermine rate and/or reaches a predetermine minimum level, such as below I_1 , the control system may switch on the lighting system (or lighting device), which light is indicated with reference 301. This light extends the light period LP. The total

illuminance of the light 1001 provided by other light 356 and lighting system light 301 (or lighting device light) may be a sum of those two curves. Hence, in embodiments a light period shorter than 12 hours provided by other light 356, such as especially (essentially) comprising solar light may be extended to e.g. at least 12 hours, such as at least 16 hours, i.e. a light period LP of at least 12 (or at least 16) hours, by providing lighting system light 301 (as supplemental light).

Fig. 1f schematically depicts an embodiment wherein over a complete time period, such as e.g. 90 days, for all consecutive diurnal cycles the light period with associated (minimum) illuminance and the dark period with associated maximum illuminance are realized. Fig. 1g schematically depicts an embodiment wherein a few days the desired entire light period may not be achieved. However, especially during at least 90% , such as at least 95%, of the diurnal cycles out of a series of (at least 30, such as at least 60, like at least 90) consecutive diurnal cycles the light period with associated (minimum) illuminance and the dark period with associated maximum illuminance are realized. Reference S indicates a lighting scheme, such as e.g. 30 or 60 or 90 diurnal cycles with the herein indicated light periods and dark periods with e.g. the herein indicated minimum illuminance for the light period.

Fig. 1h show the spectral distribution of an embodiment of the lighting system light 1001 (or device light), which may herein also be indicated as “fish light”, though this light may also be used for e.g. shrimp farming. On the y-axis, arbitrary units are used (though scaling with energy (like Watt)).

The term “plurality” refers to two or more.

The term “substantially” herein, such as in “substantially all light” or in “substantially consists”, will be understood by the person skilled in the art. The term “substantially” may also include embodiments with “entirely”, “completely”, “all”, etc. Hence, in embodiments the adjective substantially may also be removed. Where applicable, the term “substantially” may also relate to 90% or higher, such as 95% or higher, especially 99% or higher, even more especially 99.5% or higher, including 100%. The term “comprise” includes also embodiments wherein the term “comprises” means “consists of”. The term “and/or” especially relates to one or more of the items mentioned before and after “and/or”. For instance, a phrase “item 1 and/or item 2” and similar phrases may relate to one or more of item 1 and item 2. The term “comprising” may in an embodiment refer to “consisting of” but may in another embodiment also refer to “containing at least the defined species and optionally one or more other species”.

Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

The devices herein are amongst others described during operation. As will be clear to the person skilled in the art, the invention is not limited to methods of operation or devices in operation.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "to comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to". The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

The invention further applies to a device comprising one or more of the characterizing features described in the description and/or shown in the attached drawings. The invention further pertains to a method or process comprising one or more of the characterizing features described in the description and/or shown in the attached drawings.

The various aspects discussed in this patent can be combined in order to provide additional advantages. Further, the person skilled in the art will understand that embodiments can be combined, and that also more than two embodiments can be combined. Furthermore, some of the features can form the basis for one or more divisional applications.

CLAIMS:

1. A control system (100) for controlling one or more light parameters of light (1001) provided to an aqueous liquid in a containing element (200) for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid, wherein the control system (100) is configured to control one or more light parameters
5 of the light (1001) for imposing a plurality of diurnal cycles to the aqueous liquid with each diurnal cycle having a light period (LP) and a dark period (DP), wherein a duration of the light period (LP) is selected from the range of 12-20 h, and wherein a duration of the dark period (DP) is selected from the range of 4-12 hours, wherein the control system (100) is at least configured to control the illuminance of the light (1001) provided to the aqueous liquid
10 with a first illuminance during the light period (LP) selected from the range of in average at least 1000 lux at a liquid surface of the aqueous liquid and a second illuminance during the dark period (DP) selected from the range of at maximum 400 lux at the liquid surface of the aqueous liquid.

15 2. The control system (100) according to claim 1, wherein the light (1001) has at least 70% of a spectral power distribution in the spectral wavelength range of 430-650 nm relative to the total spectral power distribution of the light (1001) in the range of 380-780 nm, and wherein the control system (100) is configured to provide at least 30 consecutive diurnal cycles with the light period (LP) and the dark period (DP).

20 3. The control system (100) according to any one of the preceding claims, wherein the first illuminance during the light period (LP) is selected from the range of 1000-3000 lux, wherein the duration of the light period (LP) is selected from the range of 12-18 h, and wherein the duration of the dark period (DP) is selected from the range of 6-12 hours.

25 4. The control system (100) according to any one of the preceding claims, wherein the control system (100) is further configured to control a lighting system (300) configured to provide lighting system light (301) to provide at least part of the first illuminance during one or more diurnal cycles of the plurality of diurnal cycles.

5. The control system (100) according to claim 4, wherein the control system (100) is further configured to be functionally coupled to a light sensor (350) configured to sense other light (356) reaching the aqueous liquid and not originating from the lighting system (300), wherein the control system (100) is further configured to control the lighting system (300) to provide the lighting system light (301) to the aqueous liquid in dependence of a light sensor signal of the light sensor (350), to provide the first illuminance provided by one or more of (a1) the lighting system light (301) and (a2) the optional other light (356) during the light period (LP).

6. The control system (100) according to any one of the preceding claims 4-5, configured to extend a light period shorter than 12 hours provided by other light (356) comprising solar light to at least 12 hours by providing lighting system light (301).

7. A lighting system (300) configured to provide lighting system light (301) to an aqueous liquid in a containing element (200) for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid, wherein the lighting system (300) further comprises the control system (100) according to any one of the preceding claims, for controlling one or more light parameters of light (1001) provided to the aqueous liquid in the containing element (200), wherein the light (1001) comprises one or more of the lighting system light (301) and other light (356) reaching the aqueous liquid and not originating from the lighting system (300).

8. The lighting system (300) according to claim 7, further comprising a light sensor (350) configured to sense other light (356) reaching the aqueous liquid and not originating from the lighting system (300), wherein the control system (100) is configured to control the lighting system (300) to provide the lighting system light (301) to the aqueous liquid in dependence of a light sensor signal of the light sensor (350) to provide the first illuminance provided by one or more of (a1) the lighting system light (301) and (a2) the optional other light (356) during the light period (LP), wherein the lighting system (300) is configured to provide lighting system light (301) to provide at least part of the first illuminance during one or more diurnal cycles of the plurality of diurnal cycles.

9. A farming system (1000) for farming fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda, the farming system (1000) comprising the

control system (100) according to any one of the preceding claims 1-6, a containing element (200) for containing the fish or a species from the family of the aquatic Arthropoda, in an aqueous liquid, and the lighting system (300) according to any one of the preceding claims 7-8.

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10. The farming system (1000) according to claim 9, wherein the containing element (200) comprises an open water basin or pond, and wherein the other light (356) comprises solar light.

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11. A method for controlling one or more light parameters of light (1001) provided to an aqueous liquid (201) in a containing element (200) for containing fish (202) from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid (201), the method comprising imposing with the light (1001) a plurality of diurnal cycles to the aqueous liquid (201) with each diurnal cycle having a light period (LP) and a dark period (DP), wherein a duration of the light period (LP) is selected from the range 12-20 h, and wherein a duration of the dark period (DP) is selected from the range of 4-12 hours, the method further comprising controlling the illuminance of the light (1001) provided to the aqueous liquid (201) with a first illuminance during the light period (LP) selected from the range of in average at least 1000 lux at the liquid surface (205) of the aqueous liquid (201) and a second illuminance during the dark period (DP) selected from the range of at maximum 400 lux at the liquid surface (205) of the aqueous liquid (201).

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12. The method according to claim 11, selecting the duration of the light period (LP) from the range of in average 12-20 h, selecting the first illuminance from the range of in average 1000-2000 lux at the liquid surface of the aqueous liquid (201), selecting the second illuminance from the range of in average 0-50 lux at the liquid surface (205) of the aqueous liquid (201), wherein the light (1001) has at least 70% of a spectral power distribution in the spectral wavelength range of 430-650 nm relative to the total spectral power distribution of the light (1001) in the range of 380-780 nm, providing at least 30 consecutive diurnal cycles with the light period (LP) and the dark period (DP), and wherein the fish (202) comprise Tilapia fish.

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13. The method according to any one of the preceding claims 11-12, further comprising providing lighting system light (301) with a lighting system (300) configured to

provide the lighting system light (301) to the aqueous liquid (201), sensing with a light sensor other light (356) reaching the aqueous liquid and not originating from the lighting system (300) to provide a corresponding light sensor signal, wherein the method further comprises providing the lighting system light (301) in dependence of the light sensor signal, to provide the first illuminance provided by one or more of (a1) the lighting system light (301) and (a2) the optional other light (356) during the light period (LP).

14. A computer program product, when running on a computer which is functionally coupled to or comprised by the lighting system (300) according to any one of the preceding claims 7-8 or the farming system (1000) according to any one of the preceding claims 9-10, is capable of bringing about the method as described in any one of the preceding claims 11-13.

15. Use of a lighting system (300) configured to provide lighting system light (301) to an aqueous liquid (201) in a containing element (200) for containing fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda in the aqueous liquid (201), wherein optionally together with other light (356) reaching the aqueous liquid (201) and not originating from the lighting system (300), a plurality of diurnal cycles are imposed to the aqueous liquid (201) with each diurnal cycle having a light period (LP) and a dark period (DP), wherein a duration of the light period (LP) is selected from the range 12-20 hours, and wherein a duration of the dark period (DP) is selected from the range of 4-12 hours, with a first illuminance from one or more of the lighting system light (301) and the other light (356) selected from the range of in average at least 1000 lux at a liquid surface (206) of the aqueous liquid (201) during the light period (LP) and a second illuminance of one or more of the lighting system light (301) and the other light (356) selected from the range of at maximum 400 lux at the liquid surface (206) of the aqueous liquid (201) during the dark period (DP), and wherein the plurality of the diurnal cycles are imposed, for promoting growth of the fish from the family of Cichlidae or a species from the family of the aquatic Arthropoda.

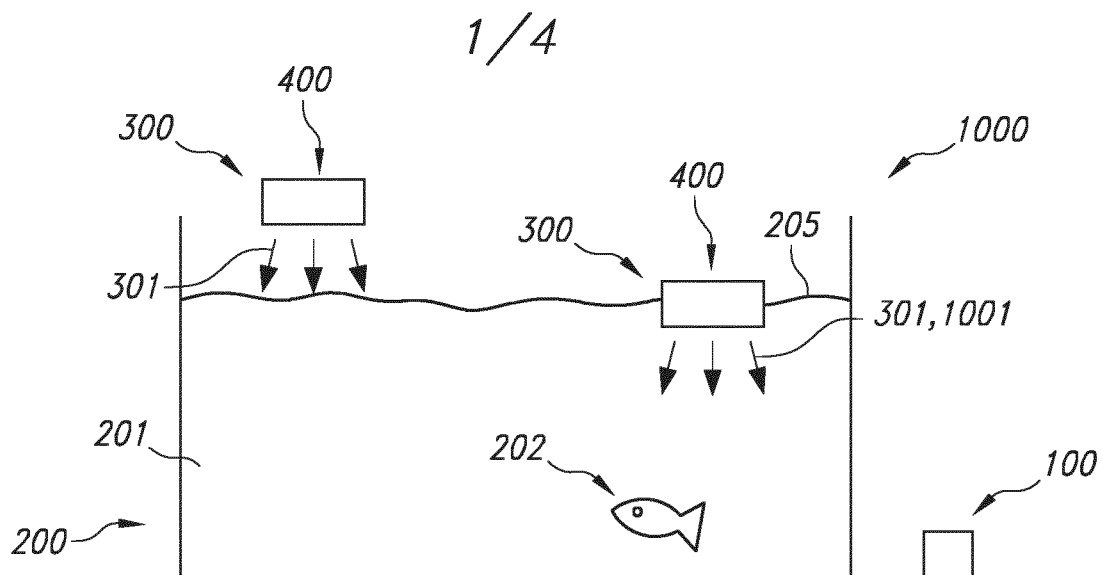


FIG. 1A

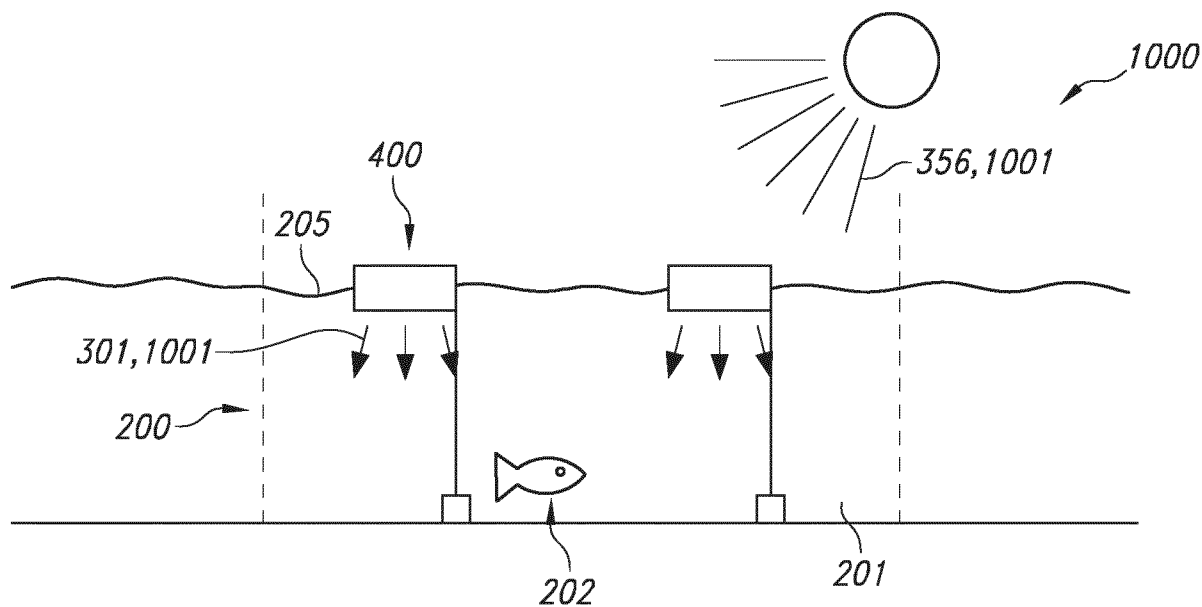


FIG. 1B

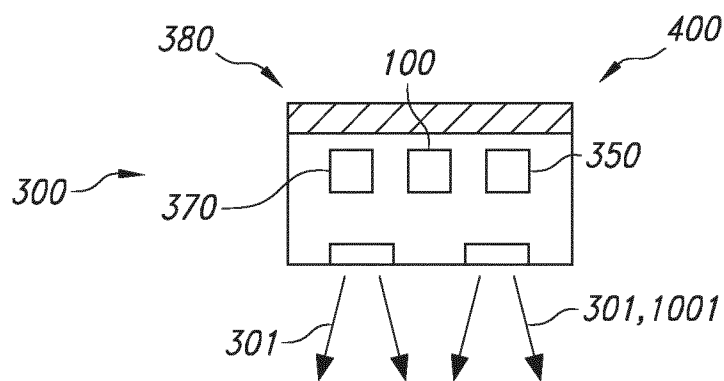


FIG. 1C

2/4

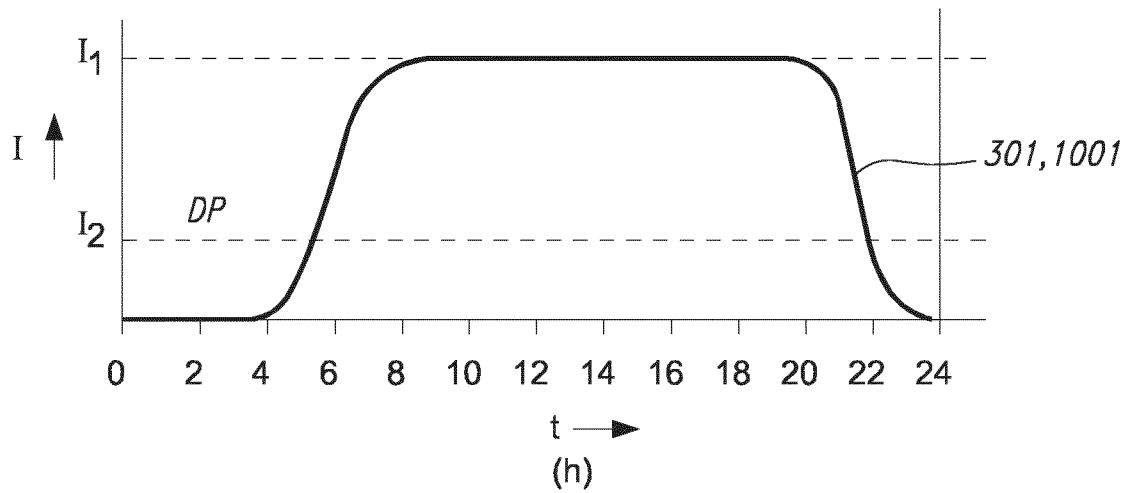


FIG. 1D

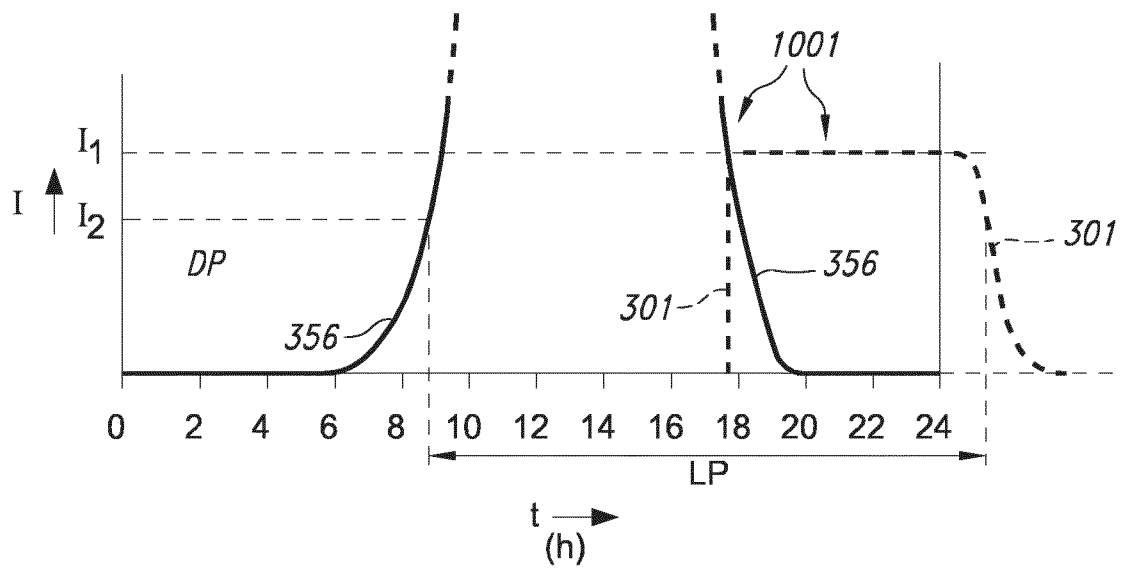


FIG. 1E

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FIG. 1F

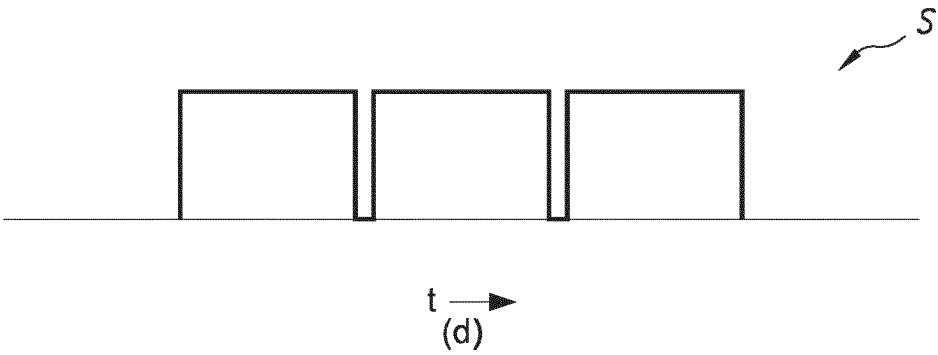


FIG. 1G

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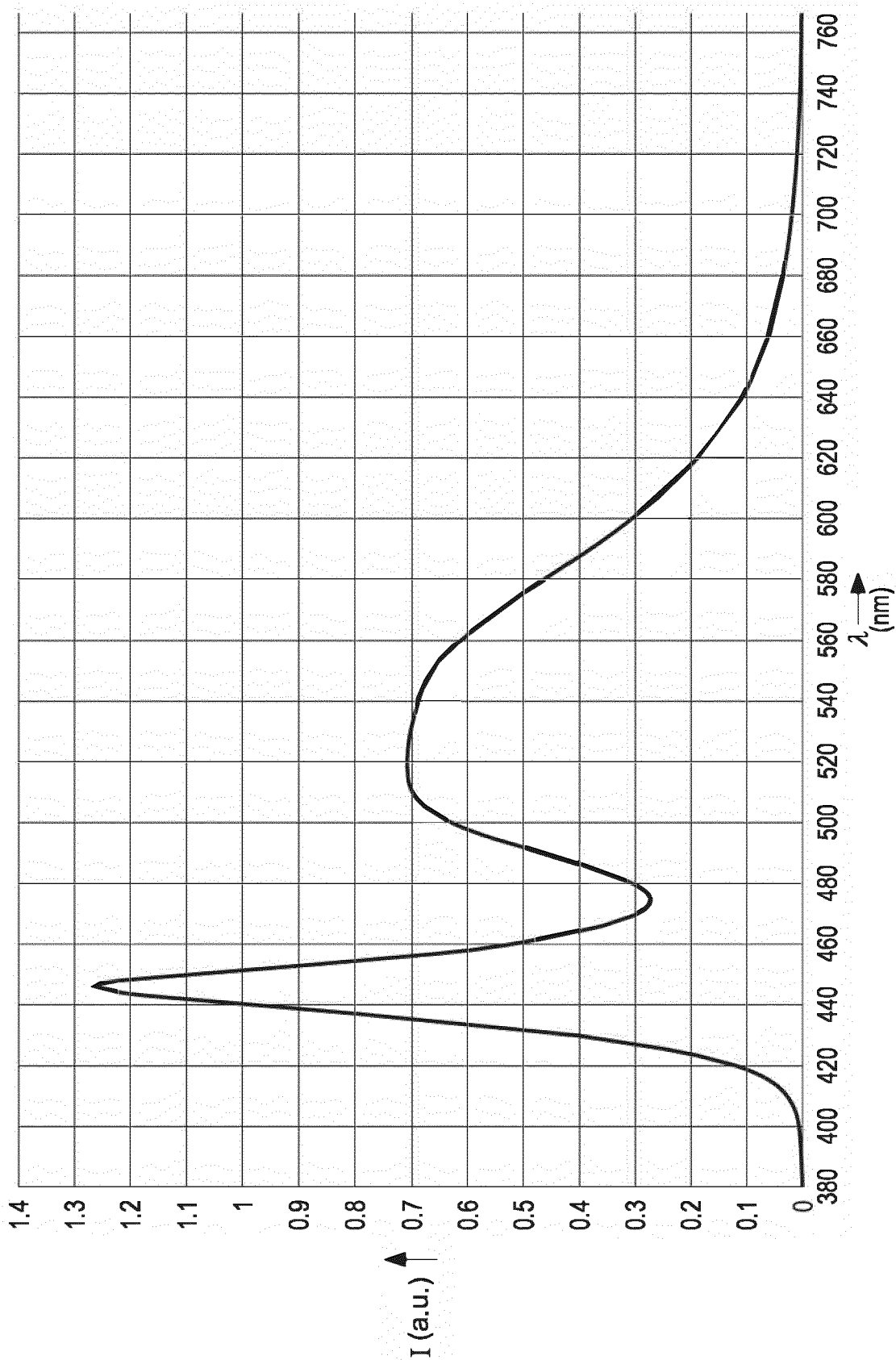


FIG. 1H

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/080418

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B37/02 A01K63/06
ADD.

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)
H05B A01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ABDEL-FATTAH M EL-SAYED ET AL: "Effects of photoperiod on the performance of farmed Nile tilapia <i>Oreochromis niloticus</i> : I. Growth, feed utilization efficiency and survival of fry and fingerlings", AQUACULTURE, vol. 231, no. 1-4, 31 March 2004 (2004-03-31), pages 393-402, XP055535513, Amsterdam, NL ISSN: 0044-8486, DOI: 10.1016/j.aquaculture.2003.11.012	1,3,4,7, 9-11,14, 15
Y	the whole document ----- -/--	1-15



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

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"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

7 January 2019

Date of mailing of the international search report

14/01/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Schwarzenberger, T

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2018/080418

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	M T RIDHA ET AL: "Effect of light intensity and photoperiod on Nile tilapia <i>Oreochromis niloticus</i> L. seed production", AQUACULTURE RESEARCH, vol. 31, no. 7, 30 July 2000 (2000-07-30), pages 609-617, XP055537903, GB ISSN: 1355-557X, DOI: 10.1046/j.1365-2109.2000.00481.x	1,3,4,7,9-11,14,15
Y	the whole document	1-15
Y	----- US 2016/353716 A1 (TANASE CRISTINA [NL] ET AL) 8 December 2016 (2016-12-08) cited in the application the whole document	1-15
Y	----- WO 2013/096840 A1 (DELABBIO JULIETTE [US]) 27 June 2013 (2013-06-27) figure 1 paragraphs [0022] - [0028], [0040] - [0043]	1-15
Y	----- US 2017/166929 A1 (SOWERS KEVIN R [US]) 15 June 2017 (2017-06-15) paragraphs [0079], [0080], [0083], [0106], [0107]	1-5,7-15
Y	----- Atef Elsbaay ET AL: "Effects of Photoperiod and Different Artificial Light Colors on Nile Tilapia Growth Rate", IOSR Journal of Agriculture and Veterinary Science, vol. 3, no. 3 31 January 2013 (2013-01-31), pages 5-12, XP055535537, DOI: 10.9790/2380-0330512 Retrieved from the Internet: URL: http://www.iosrjournals.org/iosr-javs/papers/vol3-issue3/B0330512.pdf [retrieved on 2019-01-03] the whole document	2,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/080418

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