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Review Article

Small Scale Fresh Water Aquaponics as Solution in Deserted and Arid Areas

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Abstract

The Aquaponics is start to be popular worldwide and a lot of people start established small or big farms. Aquaponics may be defined as an integrated quasi closed-loop multi-trophic food production system comprising a Recirculating Aquaculture System (RAS) and a hydroponic unit. This article is a guide for small Aquaponics farms and referred to United Arab Emirates environmental conditions. It is aiming to be a guide for any farmer to the region or in any other place with similar conditions. Similar systems could be established as small scale systems in most of cases with the potentiality to expand in commercial scale. In Aquaponics could be cultured successfully, most of vegetables and herbs without using any external chemical or other fertilizers or minerals, except the ones that will be produced from the fish wastes. A common and known difficulty is that in most cases in small to medium-sized Aquaponics farms, design and estimations between fish culture biomass and the culture surface are not followed. Additionally, the difficulty of achieving the ideal conditions for both fish and plants leads in many cases to a partial or a total failure of the system. The aim of this article is to participate in the development of a practical, easily applied hydroponics system, using the minimum energy and zero chemical. The data could be used as the basis for any future farmer and could scale up to commercial size.

Keywords: Aquaculture; Aquaponics; Fish; Integrated system; Nutrients; Oxygen; RAS; Temperature; Vegetables; Water consumption

Introduction

Due to the well-known problem of water scarcity, the necessity of innovated practices is a must wherever the water is going to be used. Humans, Animals and Plants we all need water in order to survive, Aquaponics could be a solution and a connection key element by using the water in an integrated way. Aquaponics is an integrated multi-trophic system that combines elements of recirculating aquaculture and hydroponics [1-3]. A lot of different sources of fresh water are available and each of them must be used on the most efficient way. Aquaponics is offers supportive and collaborative methods of vegetables and fish production and can grow substantial amounts of food in locations and situations where soil-based agriculture is difficult or impossible [4]. In most deserted countries such as United Arab Emirates most of the water is coming from desalination units or boreholes. Both sources have some limitations that must be overcome or eliminated in order to cover the needs as longer as could be. Successful cultivation practices such as Hydroponics or argillic clay and water recirculation are very promising but are not giving an integrated solution to this major problem.

A full integrated system based on aquaponics seems to be a solution

The creation of Aquaponics for agriculture purposes for both salt and fresh water and the reuse of the water as many times as could be is a must in any arid and deserted area, where the scarcity of water is the main issue that the farmers are facing down. The purpose of this article is to present a simplified and practically applicable model based on practical results collected by small and medium-sized farms in the Emirates region. Following simple measurement practices in collection of basic physio-chemical parameters, such as Oxygen, Temperature pH, Ammonia, Nitrite and Nitrate and applying the necessary adjustments, could be achieved a stable and productive from any prospective farmer Aquaponics system. According to the collected results, it is possible to obtain Aquaponics production of fish and vegetables, by following simple monitoring procedures that are feasible by any future farmer. Adjustment in the system as per the findings is essential and have to be followed on daily basis.

In the presented model has taken into account the minimization of water needs for an environmentally friendly cultivation system.

Objective and Scope

The scope of the article is to evaluate the possibility of producing sufficient quantity for a family, vegetables and herbs using only fish waste as fertilizer. In order to be build a model that could be established in similar conditions a control and monitoring system is necessary in order to control and supply the necessary conditions in both fish and plants and create a data base at the end of the season for any future needs. Not any external fertilizer, pesticide or mineral is necessary and the cultivation could took place by using only the waste of the Aquaculture part. The Recirculating Aquaculture System (RAS) as the most important component of the system, have to be designed very carefully and have to be sufficient to transform the waste of the fish in nutrients. From the efficiency of the RAS is depending the success of the hydroponic part. The system dynamics model of this study can be used to design and further optimize systems. The main objective of this paper is to present a theoretical design approach for a small Aquaponics farm. The model elaborated in this paper assesses the

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system's organic loading rates to achieve optimal conditions for both hydroponic and fish RAS under the UAE environmental conditions. There is also two medium scale aquaponics farms producing tilapia with vegetables in a symbiotic environment in Bani Yas and Al Faya. In addition, there are two small-scale tilapia farms; one in Al Ain and the other in Liwa [5].

Aquaponics Definition

Aquaponics is an integrated multi-trophic system that combines elements of recirculating aquaculture and hydroponics [6], on a simple words is an integration of Hydroponics and Aquaculture (fish or other aquatic animal farming) in order to produce plants and aquatic animals. Indoor fish production offers the advantage of optimal environmental and bio-safe conditions and has the potential to guarantee the supply of good quality fish, and vegetables, produced throughout the year.

By its nature RAS is flexible and adaptable to the local conditions related to the water source and water temperature and salinity and could implement in most of the cases successfully. The waste of the aquatic animals are converted by the bacteria who are built in the system, (Bio-filter) into nutrients, and will irrigate fresh water and salt water plants accordingly.

In case of desalination units two lines of fish production could be established, Fresh water and Salt water Aquaponics. Both systems could be run in RAS by using the minimum of new added into the systems water, just enough for the irrigation needs of the farm and cover of the evaporation. From the fresh water line could be irrigate vegetable and herbs cultures and from the salt water fish culture will be irrigated Halophytic cultures mostly Salicornia as it seems to be the most promising. If any excess water is existing could be collected from both systems and be used for irrigation in Palm trees or other semi-salt tolerant trees. The Aqua-ponically production idea could be work as home modular small farm enough to cover the needs of a family or as a commercial farm with production as per the requirement.

Small scale aquaponics farm

In the UAE, many local farmers implement small Aquaponics units using basic knowledge. This article aims to present a familiar home-based, fresh water Aquaponics model, using simple but high-level practice and reasonable equipment cost. At this small scale, the Aquaponics model could easily produce 150-200 kg of fish per season and a variety of vegetables, lettuce, cucumber, tomatoes and herbs up to 50 kg a month.

System Description

The Aquaponics unit could be established in a Net house or in a Green house. The Net house is proposed because of the lower operational cost and the absent of water cooling system which will consume additional water. Giving the current situation of water resources and energy aggravated by climate change in UAE as well as GCC countries, cooled greenhouse is not anymore a sustainable option for horticultural crops production. It was shown that this protected agriculture system consumes a considerable amount of water and energy in cooling process. However UAE climate allows to produce a large number of vegetables crops between October and May, that is a total of 8 months with a mild climate. During this period horticultural crops can be grown under nethouse even without cooling allowing, thus, increasing crop water productivity, energy saving and income improvement [7].

The necessary area for a small unit is about 400 m^2 covered by 60% shade in the plants cultivation area and 80-90% shaded above the Aquaculture part, including the fish tank and the treatment area. The farm will be capable to operate about 8 months a year, starting on September ending on May when the environmental temperature is relative low in UAE.

The system consist of

- Fish tank about 4 m^3 for the fish culture
- Sedimentation tank, as mechanical filtration and particle remover
- Bio-filter
- Aeration system, through an air blower (0.8-1.0KW) for the air supply
- Air diffusers in all the components, to maintain the oxygen level
- Culture beds

Schematically the water will be recirculating into the system as the following figure 1 layout.

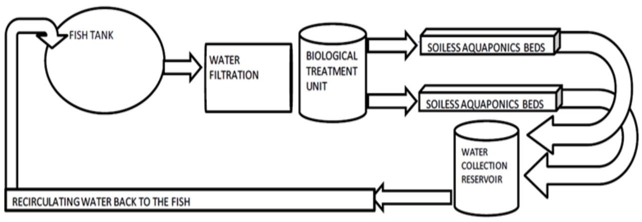

Figure 1: Layout the Aquaponics unit.

The chosen fish for this model is Tilapia spp because is a tolerant and easy cultured specie in both fresh and salty water. The species and hybrids of tilapia that are widely cultured can often survive and even thrive under environmental conditions that many other fishes would be unable to tolerate… are tolerances for low dissolved oxygen and a wide range of both salinity and temperatures. In the case of temperature, however, tilapia are tropical fishes, so they are susceptible to diseases and death at low temperatures. While most tilapia culture is conducted in tropical or subtropical regions, tilapia are also cultured in temperate regions where warm water is available [8]. Almost all the vegetables and herbs could be produced. The proposed for this system are leafy vegetables, Lettuce, Cucumber, Tomatoes, and herbs such as Basil, Coriander, Parsley, Mint.

Objective and Scope

In most of the cases the small scale "home" Aquaponics farms are running with the minimum of knowledge and the control and monitoring practices are based on empirical observations and data that coming from different sources such as internet or neighboring farmers. Evaluation of RAS components of the system and data collection system related to the main components that could affect the productivity of both Fish and crops is giving the potentiality for further improvements. Collection of data related to the fish growth connected to vegetable productivity of the system it is a challenging aspect that any farmer could be have for its own farm. Sustainable practices such as small Aquaponics farms could be used not only to produce their own food but also to generate additional revenue.

Methodology and Data Collection System

A recording system is very important in order to collect the main data that are important for the welfare of both, fish and crops. A simple and efficient schedule have to be follow on daily basis is the measurements of the most important parameters. On daily basis twice a day, Oxygen, Temperature pH, Ammonia, Nitrite and Nitrate is necessary to be measured for both components Aquaculture and Vegetables culture area. Environmental temperature inside and outside of the culture areas it is also essential. Adjustments as per the findings of the measurements should be done whenever is needed. By following a program similar to the table 1 below, successful control and monitoring achieved by the author in small farms in Emirates.

Parameter	Inlet to the Fish Tank Water	Outlet of the Fish Tank Water	After the Biofilter	Outlet of the Culture Beds
Water Oxygen Level	✓	✓	✓	✓
Water Temperature	✓	✓	✓	✓
Water pH Level	✓	✓	✓	✓
Ammonia, Nitrite and Nitrate			✓	✓

Table 1: Daily measurements schedule.

According to the collected data at the above given check point it is easy to evaluate the productivity and the dynamic of the system and farther more to do the necessary adjustments. The monitoring equipment have to be easy to use and simple to their maintenance. It is proposed the oxygen-meter and the pH meter to be of high precision, from companies such as OxyGuard, Hanna, YSI, or others commonly used in Aquaculture. For the air temperature a minimum-maximum thermometer have to be placed inside and outside of the net-house. A simple on use Ammonia kit is enough to check the system in all the steps.

Special attention have to be given to the position of the thermometer, must be placed in a shaded place avoid the direct sunlight. The monitoring system and the collected data are giving the opportunity to adjust the parameters as per the needs on real time. They can also be used as reference by any prospective farmer in similar conditions.

Data Collection

Oxygen and pH

In Aquaponics the correlation between Oxygen and pH is an important factor. A strong aeration can increase the oxygen levels but is also increasing the pH, which is not desired for the vegetables. The oxygen levels have to be kept in the Fish tank and crops in a levels more than 4.0 ppm enough to cover the needs of both and keep the pH levels in the range of 6.2-7.2. A pH of 7.5 can lead to nutrient deficiencies of iron, phosphorus and manganese… Nitrifying bacteria experience difficult below a pH of 6, and the bacteria's capacity to convert ammonia into nitrate reduces in acidic, low pH conditions [4]. On daily basis Oxygen and pH have to be measured in a signed points twice a day. The points and the reason why we need these measurements are describing as bellow.

- Before fish tank (inlet water) in order to know what is the level of oxygen of the coming to the fish water. If this level is below 6.0 ppm we have to increase the aeration in the water collection tank
- After the fish tank (outlet water), in order to see the consumption of oxygen. If the level is bellow 4.0 ppm we have to increase the aeration in the fish tank
- After the Bio-filter, in order to see if the oxygen is enough to keep the bacteria in healthy conditions and also to know what is the oxygen in the water that goes into the culture beds. If the level is bellow 5.0 ppm we have to increase the aeration in the bio-filter
- Outlet of the beds, in order to see the consumption of the plants. At this point we have to keep a minimum of 5.0 ppm and according to the pH we can increase the aeration in the beds

According to FAO [4] the level of Oxygen and pH in warm water fish and the Aquaponics part have to be Oxygen 4.0-6.0 ppm with pH in range of 6.0-8.5 for the fish and biger than 3.0 ppm Oxygen and 5.5-7.5 pH for the plants. By using the aeration as a controller of both Oxygen and pH we can adjust the levels according to the needs.

Temperature

As the target is the system to work under the natural environmental conditions not any temperature control system is required.

The water temperature is related the most to the needs and the new added water, as the system is shaded and the water is recirculating 24/7 there is no significand fluctuations. The proposed for the Tilapia cultivation water temperature is about 22-32°C and for the plants 18-30°C [4]. The measurement of the water temperature is recommended to be done with the oxygen-meter (usually most of the oxygen-meters have temperature sensor also)

- Temperature
  - Inlet water to the fish tank, to know the temperature that is coming into the fish tank
  - Outlet of the beds, to check the efficiency of the shade and if the temperature is fluctuating a lot due to the weather temperature
  - Min max air temperature, it is important to know (especially in tropic climates) the daily fluctuation of the temperature. By recording the min & max temperature useful data for the effect of the environmental conditions will be collected

The minimum and maximum temperature fluctuation, inside the net house and outside of the net house has to be placed in a shaded point avoiding the direct sunlight into the instrument. In the table 2 below is presented the temperature fluctuation in Abu Dhabi UAE.

From the table 2 it is obvious, for the specific conditions, the duration of the cultivation period, starting during the end f September and lasting until the early of June.

As per some early data, collected from the author, the environmental temperature has not any significant difference inside the net house compared to the common in region temperature profile. More Data and replication of measurements per year is needed according to the specific environmental temperature in order the farm to have the unique for the area temperature profile.

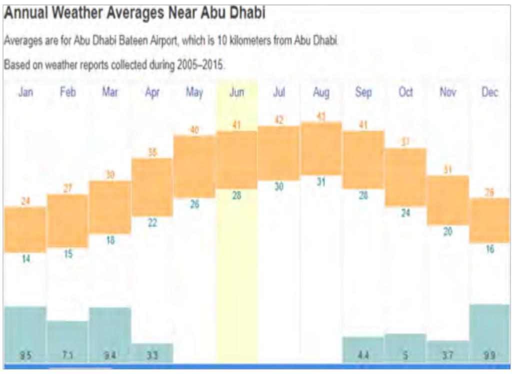

Table 2: Weather by CustomWeather, © 2019.

Nutrients

The waste of the fish after the decomposition through the bio-filtration procedure will provide to the plants the necessary for their growth nutrients. As the target is the creation of high levels of Nitrates (necessary and easy absorbed nutrients), enough to cover the needs of the crops, the biological filter is designed according to the maximum fish feed rate capable to transform the waste of the fish to useful nutrients for the plants. In the beginning of the season, during September the activation of the bio-filter is necessary to be done. A typical bio-filter activation needs up to forty days as the following figure 2 layout.

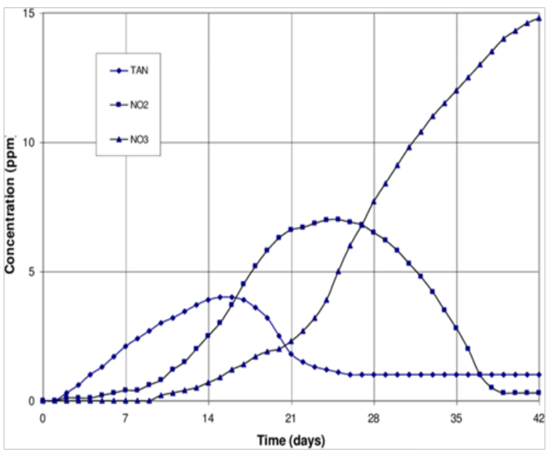

Figure 2: Typical startup curve for a Biological Filter showing time delays in establishing bacteria in bio-filters [9].

Instead of waiting up to forty days for the activation of the filter alive bacteria is proposed to be added to speed up the activation procedure. The expected levels of nutrients, as per some practical data that are collected from the author are presented in the following table 3.

By using alive bacteria from the beginning of the bio-filter's activation a similar to the above table 3, decompose of the waste elements will be figured up. The first twenty days slide high levels of Ammonia and Nitrite will be observed and after thirty days almost all the produced nutrients will be absorbed from the plants lasting to zero values when the hydroponic part will be in full capacity. Gradually, as the plants are growing and the Bio-filter is working on its full capacity all the produced nutrients is absorbed almost to zero levels.

	Ammonia	Nitrite	Nitrate	Nitrate in Beds
Month	(ppm)	(ppm)	(ppm)	(ppm)
September	1.0-2.0	1.0-0.5	80-40	40
October	0.5-1.0	0.8-0.4	60-40	30
November	0.4-0.6	0.2-0.0	40-20	20
December	0.4-0.6	0.2-0.0	<20	15
January	0.4-0.6	0.2-0.0	<20	10
February	0.4-0.6	0.2-0.0	<20	<10
March	0.4-0.6	0.2-0.0	<20	<10
April	0.4-0.6	0.2-0.0	<20	<10

Table 3: Average monthly fluctuation of Nutrients as values.

Aquaculture components

The aim of the Aquaculture component as a part of the Aquaponics system is to provide the necessary wastes which furthermore will transform to nutrients for the plants cultivation.

Fish and fish tank

For the proposed model Tilapia (*Oreochromis niloticus)* is chosen as the cultivated fish, depending on the specific needs the weather conditions the water characteristics and the experience of the related people, other species could also been used.

Tilapia is proposed because of

- Is well known fish species with a wide local market
- Is tolerant in a wide range of environmental conditions
- It has very low water exchange needs
- Has good growth under culture conditions
- There are available juveniles in the local market
- Good quality Fish feed is also available and in the market

The fish will be cultured in a tank of 5.0 m^3 by using RAS technic, and then after wastes and waste water, will be used for the vegetables cultivation.

The fish tank could be any shape but circular tank is recommended as the most efficient from the self-cleaning point of you.

As per the study of James M. Ebeling &Michael B [9], Circular tanks are attractive for the following reasons:

- Simple to maintain
- Provide uniform water quality
- Allow operating over a wide range of rotational velocities to optimize fish health/condition
- Settle able solids can be rapidly flushed through the center drain
- Designs that allow for visual or automatic observation of waste feed to enable satiation feeding are possible [9]
- The oxygen level in the fish tank have to be above 4.0 ppm, this can be successfully achieved by using up to four air diffusers about one meter long and diameter 12 mm.

The air will be supplied 24/7 from air blower of 08-1.0 kw and through the daily measurements into the fish tank will be done the adjustments. The inlet water will be done from the top of the tank and the outlet from the bottom in order to be removed as many as could be solid wastes to the next step, mechanical remover part in our case sedimentation tank. For the model a number of 300 fish are enough to cover the needs of the proposed aquaponics components as the following table 4 layout.

Biological Data	
Initial fish number	300
Initial Av. weight (gm)	0.05
Initial biomass (kg)	15
Initial density (kg/m^3)	2.9
Survival (%)	90
Final fish number	270
Final Av. weight (gm)	500
Final density (kg/m^3)	26.5
Production period (months)	8.0-10
Final biomass (kg)	135

Table 4: Aquaculture component and biological data of the system.

RAS as a part of aquaponics

RAS is chosen as the most efficient system for arid areas where the water is limited and the discharge of the wastes difficult. Recirculating Aquaculture Systems (RAS) have been developed to overcome pollution concerns and stocking capacity limits of conventional terrestrial aquaculture facilities. RAS offer several advantages over traditional flow-through systems including: 90-99% reduced water consumption [10]. The Aquaculture part should be controlled and monitored on daily basis as described above in order to ensure the productivity of the system and the viability of the fish and plants. Special care is needed in the beginning when the first fish will be stocked.

In order to avoid any rapid increased of the Ammonia and or Nitrites level it is recommended the following steps to be followed

- Stocking of the half fish biomass until the system is ready
- Add alive bacteria by following the suppliers instruction
- By controlling the daily feed rate keep the levels of ammonia less than 2.0 ppm
- Follow up the results of the daily measurements and add into the fish tank the rest of the fish when the Nitrite start be less than 0.5 ppm
- Start the replantation when the first Nitrate are appeared and increase the cultures of the plants gradually by following the increasing of the Nitrates.

For our RAS model the necessary details are as describing in the following table 5.

A feeding program has been followed according to the needs and the results of the fish body weight and biomass estimation. The maximum, daily fish feed quantity, during the whole period for the model is up to 1.0 kg/day. By using a fish feed with about 32% protein the estimated volume of the bio-filter, (by using bio-media with surface of 600 m^2/m) is about 150 ltr. Three plastic containers of 1.0 m^3 are necessary for the RAS. One to host the bio-media. Second will be used as sedimentation tank and the third as water collector after the vegetable culture beds. The fish biomass and the growth has to be evaluated every end of the month and the feeding program have to be rescheduled accordingly. The feeding needs to be done according to the needs by using good quality extruded floated pellets containing 32% protein. The daily feed rate and the feed consumption presented in the below table 6.

System Description		
Equipment	Details	Unit
Tanks	1	Nos
Dimensions	D:2.2 H:1.35	m
Volume per tank	5.1	m^3
Total volume	5.1	m^3
Water usage vol/tank	5.0	m^3
Total usage vol/unit	5.0	m^3
Water recycling %/tank	80%	
Water recycling (m^3/tank)	4.0	m^3
Turnover rate:	75	minutes
Total recycling water/unit	4.0	m^3/hour

Table 5: Aquaculture system description.

	Feeding Rate	Daily Feeding
Month	(% FR)	(kg)
Sep	2.50%	0.188
Oct	2.10%	0.548
Nov	1.80%	0.756
Dec	1.40%	0.973
Jan	1.20%	1.056
Feb	1.00%	1.037
Mar	0.90%	1.021
Apr	0.80%	1.08

Table 6: Feeding schedule and daily feeding rate (%FR).

The daily amount of fish feed is recommended to be split in two meals, the first about 10:00 and the second about to 14:00 in order the feeding to be take place during the maximum of Oxygen level. Six days a week with one starvation is a common practice and is recommended. The day after the starvation day is the most suitable for the necessary cleanings of the system or sampling of fish. It is essential at the beginning of the season to be count and weighed all the fish in order initial biomass to be estimated and accordingly the feeding program to be scheduled and applied in table 7.

To be accurate, the related to the fish biomass data, every end of the month a sampling of about 20% of the total number of fish need to be counted and weighted for the average fish body weight estimation. The average weight will be used for the estimation of biomass and the feeding schedule for the next month. At the end of the season a final count and weighed of all the fish have to be conducted in order to find out the growth performance. By following the monthly sampling and the above given table 7, can be easily figure out if any problem is disturbed the welfare of the fish and the necessary adjustments can be provided. A total biomass of about 135 kg (27.0 kg/m^3) had been produced in a period of 8 months in the proposed model. The FCR for Tilapia at these conditions was ranged from 1.3 to 1.6 in most of the farms where the model implemented.

Month	Fish (Nos)	Av.Weig (gm)	Biomass (kg)	Density (kg/m³)
Sep	150	50	7.5	1.5
Oct	290	90	26.1	5.2
Nov	280	150	42	8.4
Dec	278	250	69.5	13.9
Jan	275	320	88	17.6
Feb	273	380	103.7	20.7
Mar	270	420	113.4	22.7
Ap	270	500	135	27

Table 7: Fish biomass and density.

Vegetables Production Data

For the production of the vegetables is chosen and proposed soilless Aquaponics Deep Water Culture (DWC) technic. The DWC beds are giving the opportunity of culturing almost all kind of vegetables and herbs. The dimensions of culture beds for the proposed mode could be L: 8.0-10.0 m W: 1.5-1.2 m and H: 40-50 cm. It is recommended the above dimensions to be followed in order to be ensured the good circulation of the water and to be taken into account the relation 80 gm of fish feed per square meter of vegetable's culture surface. The depth of the beds it is also important to be at least 40 cm in order for the roots of the plants to have the necessary space to grow and at the same time make it easy to circulate water and oxygen. Furthermore, the depth will provide an additional settling area where some of the solids escaping from the aquaculture element will be settled down. The material of the beds could be fiberglass or plastic liner according to the desired design and the available budget. A small Nursery for the seeding is necessary to consider and placed in the most "cold" area of the Net house. The irrigation of nursery have to be done with water of the fish unit (after the bio-filter) twice a day or as the agronomist instructions cording to the plant specie. When the plants are ready for replantation to the main culture beds washing of roots with fresh water have to be done and put in the beds in a small pots. In the main culture beds foam panels with about 25 holes per square meter with about 6.0 cm diameter is common and enough to cover the needs for almost all of the plants. The concentration of each specie as FAO [4] recommendations and as per authors observations could be as below table 8.

Basil	25-30 per m²
Lettuce	25 per m²
Coriander	20-25 per m²
Okra	15-20 per m²
Parsley	12-15 per m²
Mint	12-15 per m²
Cucumber	6-8 per m²
Tomato	6-8 per m²

Table 8: Concentration of plants in culture beds (pcs/m² per vegetable specie).

During the cultivation period in order to avoid disease incident whenever a plant seems to be affected have to be remove from the system. By following this procedure not any significant problem will be detect and not will eliminate the usage of pesticides. Periodically check of the roots is needed and washing of the roots (if start to look brown) it is recommended in order to be clean white and healthy. The air diffusers is very important to be placed on a way to provide a good mixing of water and slight movement of the roots. In the proposed beds about four pieces of air diffusers, 80 cm long 8 mm diameter, are enough to provide the necessary oxygen in the plants. The supply of the aeration (through the diffusers) must be controlled by separate valves and according to the levels of oxygen and pH one or four can be in operation. For example, when the oxygen is lower than 3.0 ppm more diffusers must working and when the pH is higher than 7.2 less etc.

Water Consumption

The whole idea of the system is based on RAS in order to be run with the minimum of water exchange rates.

The system is supported with the minimum of equipment also

- Water recirculation pump of 4.0 m3/hour
- Air blower 1.0 kw

According to the above design (Figure 1 of the Aquaponics unit) the water is pumped from the water tank where all the beds are drained and led to the fish tank. The water moves gravitationally from the fish tank going into a sedimentation tank and a biopheresis system and gravitationally divided into the cultivation beds. The necessary amound of new water into the system, is used just to cover the evaporation and the absorption of the plants and is not more than 1.0-1.2% per day, of the volume of fish water tank. Not more than 50-70 ltrs per day, new fresh water, is needed to cover the needs of the system. From water consumption point of you the system can characterized as super intensive RAS as per FAO publication in 2015 [11] (Table 9).

The system can run with multispecies of vegetables and Herbs but for understating purposes is presented a monoculture production as a sample for the productivity of the system. With the hypothesis that the system will run as monoculture is capable to produce per month as per the following table 10.

The productivity refers to the real collected data and could be used as reference in case of similar units were monoculture will be applied.

Results and Observations

The idea of using in Aquaponicaly produced vegetable, as fertilizers only the wastes of the fish and not any additional fertilizers or minerals together with the minimum of supporting equipment (one air blower and one water pump) can be supported from the natural bio-decomposition of the fish waste, in this modular proposed idea. Tilapia as the most well known in region of UAE fish species is recommended as the most suitable for aquaponics purposes. The availability of Tilapia juveniles in local market and the existing consumption in UAE up to 310.000 tns yearly [5] supporting the idea of commercialization of the Aquaponics by using as fish this specie. Tilapia are a model species used by many in the aquaponics community because they have the advantage of being able to survive in poor water quality, handle well, and can grow to high density in confinement. Tilapia are also an omnivorous fish species, which can be viewed as an advantage for environmental sustainability [12].

Type of system	Consumption of new water per kg fish produced per year	Consumption of new water per cubic meter per hour	Consumption of new water per day of total system water volume	Degree of recirculation at system vol. recycled one time per hour
Flow- through	30 m^3	1 712 m^3/h	1 028%	0%
RAS low level	3 m^3	171 m^3/h	103%	95.90%
RAS intensive	1 m^3	57 m^3/h	34%	98.60%
RAS super intensive	0.3 m^3	17 m^3/h	6%	99.60%

Table 9: Comparison of degree of recirculation at different intensities compared also to other ways of measuring the rate of recirculation. The calculations are based on a theoretical example of a 500 tonnes/year system with a total water volume of 4 000 m^3, where 3 000 m^3 is fish tank volume.

Production Data as Monoculture				
		Lettuce	Cucumber	Cor-Prsley- Mint
Production per m^2	(min) kg/m^2	6.2	12	4
All farm (60 m^2)	(min) total kg/60 m^2	372	720	240

Table 10: Production capability of the system in case of monoculture.

In the model, as per the above description, successfully have been produced, up to 135.0 kg (27.0 kg/m^3) in a farm in Al Ain, Abu Dhabi. This model has the potentiality to maintain a continuously standard biomass of 150 kg (30 kg/m^3) enough to cover the monthly needs of a family if a proper fish harvesting program have been scheduled. The production of vegetables was also satisfactory and some of the vegetables produced were sold on the local market to cover some of the costs. Lettuce is the most suitable for this system by giving production of 20-25 pcs/m^2/month (6.2-7.0 kg/m^2/month). Cucumber can be also produced in a satisfied amounts giving a production of 12-16 kg/m^2. Coriander Parsley Basil and Mint are also suitable and the production as monoculture could extend up to 8.0-10 kg/m^2/month. It is very important the seeds to be suitable for Aquaponics and is not recommended to be used the ones which are for open field cultures. Instructions from agronomists have to be followed in order to be chosen the most appropriate seeds. In case of use open field seeds some problems related to the roots will be faced and the productivity will be lower compared to the ones which is suitable for soilless Aquaponics.

Discussion

The main objective of this work is to highlight the importance of a simple but properly structured system of measurements and controls in small and intermediate Aquaponics farms based on real been collected data from small farms in United Arab Emirates. Significant findings from the early days of the system underline the importance of a planned daily check. In order to maintain the pH and oxygen levels, so as to be compatible with both aquaculture and vegetable cultivation, initially (at the beginning of the vegetable season), installed plastic tubes with holes up to one millimetre instead of very small pores air diffusers. By following this practice the oxygen levels remained in all the parts above 4,0 mg/ltr and the pH in a range of 6.8 to 7.2. About a month after, the plastic hoses replaced with air diffusers. Trials that implemented in Abu Dhabi region, was following the environmental temperature under Net house, (common in region shade leve, 20-30%) and not any temperature control applied. The effect of temperature and direct sunlight on the vegetables was observed (as expected) to had a negative effect on the growth of vegetables but did not affect the herbs. Despite the fact that initially both lettuce and cucumbers had slow growth when the temperature started decreasing, about the mind of November, they recovered. The Tomatoes seems to be more sensitive, they began grow well and giving fruits during the middle of winter with the maximum productivity January to March. The Nutrients (NH_3, NO_2 and NO_3), dramatically reduced during the winder period but not any negative effect is observed related to the vegetables grow and productivity.This fact consolidates the position that by using Aquaponics can provide a viable and complete solution to the use of the Aquaculture wastes. The control of the Aquaculture component, as a supporting element to the Agricultural part, is giving the advantage of further control of the vegetable cultivation surface. The monthly sampling of fish and the reschedule of the feeding program is a key element to estimate the correct for each period vegetable cultivation surface.

Conclusion

In general Fresh water Aquaponics seems to be an easy matter and in most of the cases failures are observed after few months (as per author survey in UAE farms).

The reason why, is coming from two sides. The appropriate design and the correct calculations of RAS that will support the system and the luck of cultivation knowledge. The luck of data collection system is also a big disadvantage in small farms. It is essential and highly recommended before any trial been done, advices to be taken from specialists in each field. It is also essential and is recommended to any prospective small or big scale farm the establishment of standard procedures and recording system. In the Appendix A are presented samples of spreadsheets which could be used for data recording. Targeting to a sustainable and integrate usage of the available fresh water, the concept of an aquaponics system which is utilizing the water on efficient way, seems to be the most suitable, affordable and profitable solution, for the arid areas of the region. The system could be characterized totally integrated and could be used as prototype to the existing or new, commercial Aquaculture farms by giving the potentiality of additional income from the vegetable cultures and better control of the available water.

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Appendix A

Samples of records and spreadsheets for data collection.

CROPS HARVESTING RECORD				
Date	**Number of Bed**			
Specie	Cucumber	Lettuce	Lettuce	Tommato
Starting Date				
Pcs				
01-Jan				
02-Jan				
03-Jan				
04-Jan				
05-Jan				
06-Jan				
07-Jan				
08-Jan				
09-Jan				
10-Jan				
11-Jan				
12-Jan				
13-Jan				
14-Jan				
15-Jan				

FISH MONITORING RECORD								
Date	**Type of food**	**Kg of food**	**Mortality**	**New Water**	**Oxygen**	**pH**	**Temperatur**	**Observations**
01-Nov								
02-Nov								
03-Nov								
04-Nov								
05-Nov								
06-Nov								
07-Nov								
08-Nov								
09-Nov								
10-Nov								
11-Nov								
12-Nov								
13-Nov								
14-Nov								
15-Nov								

Daily Measurements Record																		
Date	**Oxygen**			**Ammonia**			**Nitrite**			**Nitrate**			**Temperature**			**pH**		
	Before	**After**	**Outlet of**	**Before**	**After**	**Outlet of bed**	**Before**	**After**	**Outlet of bed**	**Before**	**After BF**	**Outlet of bed**	**Before**	**After**	**Outlet of bed**	**Before**	**After**	**Outlet of bed**
1-Jan																		
2-Jan																		
3-Jan																		
4-Jan																		
5-Jan																		
6-Jan																		
7-Jan																		
8-Jan																		
9-Jan																		
10-Jan																		
11-Jan																		
12-Jan																		
13-Jan																		
14-Jan																		
15-Jan																		