複合養殖/魚菜共生/養耕
AQUAPONICS

方煒

台大生機系教授

AQUAPONICS

AQUACULTURE

HYDRO**PONICS**

甚麼是　複合養殖/魚菜共生/養耕?

- 結合水產養殖與水耕的一種複合人工養殖方式

- 水產養殖物提供植物所需之養份與CO_2，植物提供水產養殖物光合作用所需之O_2，
- 植物之根系更可對養殖水提供過濾、淨化之功能。

甚麼是 水耕/水培/無土/非土栽培

免翻地、免中耕、免除草、免水肥管理的
省工、省力、省水、省肥的一種以科學方式
管理的作物栽培系統

常見於溫室、垂直農場/植物工廠

Vertical Farm / Plant Factory

美國

- Is this the farm of the future
- **How Aerofarms' vertical farms grow produce**

日本

- 日本富士通植物工廠
- **Amazing Hydroponic farm Japan GRandpa Dome**

Aquaponics in Action

Nitrite is converted to Nitrate by beneficial bacteria Nitrobacter

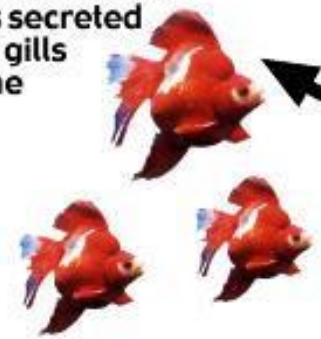
Nitrite

Nitrate

Nitrate is absorbed by the plants in the growth process

excess & unwanted vegetables are fed to the fish as feed to begin the whole cycle again

Fish waste in the form of Ammonia is secreted through the gills & in the urine



Ammonia

Ammonia is converted to Nitrite by beneficial bacteria Nitrosomonas

Major advantages of aquaponics over soil agriculture

1. no wasted fertilizer;
2. lower water use;
3. higher productivity/quality;
4. ability to utilize non-arable land; and
5. offset of tillage, weeding and other traditional agricultural tasks.

宣傳用 slogan

養魚不需換水

種菜不需施肥

Phytoremediation

使用植物淨化水質並進而清除污染的專業領域，在環保意識抬頭的今日正成熟穩定的成長。

太空農業

美國國家太空總署(NASA) 結合各大學：

- 「生態控制的維生系統」(Controlled Ecological Life Support System，CELSS)(1991 ~ 1995)
- 「控制的可生質再生的維生系統」(Controlled Bio-regenerative Life Support System，CBLSS)(1996 ~ 2000)

為太空農業發展的先驅計畫

養殖人員的難題

- 在找尋可以去除水中富於營養的魚類廢棄物的方法：
  - 固形物的去除為例行作業，通常拿去做堆肥，不會有太大困擾
  - 對於那些溶於水中的廢棄物才讓人頭大。

- 大約有70%的魚類廢棄物為水溶性，來自於魚類透過鰓做氣體交換所排出的氨態廢棄物，這是需要處理的。
- 想找一個方法可以去除養殖系統中的這類廢棄物。

- 目前的循環水養殖業者每天更換10%的養殖水來解決這個問題，這數字看來不大，但是對一個有100噸水體(規模不大)的養殖事業，代表每天要排放10噸的水並找新鮮水進來。
- 排放水還有環保法規需遵守。

- 養殖水中的可溶性廢棄物飽含氮與磷
- 這些是水耕栽培作物需要的大量元素
- 這些營養能否被植物吸收呢？

開始動手

- 由小的系統做起，做了12組完全相同的複合養殖系統。
- 每一組有100公升的養殖魚槽搭配生物濾床，後者在養殖上非常重要，主要功能在將有害的氨態氮轉換為無害的硝酸態氮。
- 養殖魚槽上方為水耕的栽培礫石植床，循環水用馬達由水槽打上植床，通過礫石回到水槽。既簡單又有效。

兩種型態的廢棄物

- 魚在養殖槽內產生兩種型態的廢棄物：。
  - 固態(排泄物)：透過定期的收集製造堆肥，
  - 水溶性：所含的氮與磷和水耕栽培業者使用無機鹽類調配的營養液的成分是相同的。
- 魚類廢棄物現在就成了植物的營養
- 養殖槽中的水體被輸送到水耕栽培的植床
- 氮與磷被植物吸收，乾淨的水體回到養殖槽，完成一個循環。

實驗設備

平衡

- 如果魚類廢棄物與植物所需要的營養能夠維持供需量的平衡，
- 基本上就建立了一個使用同一套水體就能持續養魚與栽培植物的系統，
- 除了補充蒸散失去的水分之外**不需補充其他的水**。

能否回答以下幾個問題

- 這種複合養殖系統真的能用嗎？
- 能養甚麼本土魚種？
- 需要多大的流量？
- 那一種水耕系統比較適合(礫石床、浮板，或是養液薄膜法)？
- 植物的營養是否會缺乏某幾樣？
- 這類系統是否可商品化？

這種複合養殖系統真的能用嗎？

- 養殖槽中放入1 公斤的魚，搭配20株的萵苣種苗。
- 魚類定期餵飼，系統監測中，期望一切順利。複合養殖系統允許每天觀察魚與植物，看著他們的成長真是美好的事。
- 三週後，收穫了120 克的萵苣(俗名：Green Oak Fancy Heads 綠橡木萵苣)，魚也成長了，
- 比起沒有植物搭配的養殖對照組，水中的營養鹽更是少了80%。

確定可行

- 魚看來很健康，成長速率與一般工業化養殖沒甚麼兩樣，也沒有不良的副作用。
- 事實上它們似乎更喜歡這樣經常維持水體乾淨的環境。
- 萵苣成長看來也頗健康，深綠色，看不出缺甚麼營養。

移植後第三天

移植後第三天的萵苣

多組複合養殖系統的全貌

傳統的水耕 VS. 複合養殖

- 傳統的水耕：
  建議應採間歇供水的方式而非連續流的方式，因為可以幫助在水體內加入氧氣，並將養液輸送至植物。
- 複合養殖：
  魚體需要的溶氧量至少要5 mg/L，對植物(萵苣2 mg/L)來說是充分足夠的。

礫石植床 VS. NFT 系統

- NFT的缺點
  - 植物栽培比較沒有效率 (採用礫石植床比NFT系統高出15-20%的產能)
  - 可溶性廢棄物去除效率較低
- NFT 的優點
  - 用水量較少
  - 整體系統較輕
  - 較便宜

連續流水式 VS. 間歇灌溉

- 採用連續流水式的礫石植床種的萵苣產能比間歇灌溉的系統高出20%

關鍵訊息

- 養殖物種：鱈魚，萵苣
- 當植物與養殖物達到正確的平衡，系統中的營養成分不會累積，植物也可得到所需的所有養分。
- 水體的電導度不累積也不下降，維持著**500 µS/cm**。這是由於每天餵魚3至4次，廢棄物不斷產生，就有足夠營養可不斷提供給植物。

關鍵訊息

- 需要使用以磷和鈣為主的緩衝系統，
- 養魚者使用碳酸氫鈉或類似的基礎鹽類來確保水體的酸鹼度不會下降。
- 養魚的系統與水耕系統正好相反，當魚吃進飼料並進行新陳代謝之後，水體會變酸。
- 為了抵銷水體變酸，需要使用緩衝溶液來維持水體的PH接近7。
- 如果使用磷與鈣為基底的緩衝溶液，磷與鈣都可被植物利用來維持好的生長。

關鍵訊息

- 磷與鈣的組合用來提供PH的緩衝並供應其他植物需要的必要元素。
- 也添加一些螯合鐵，因為飼料中缺乏鐵元素，而這是植物葉綠體的必要成分。
- 整個系統中，就是每天加入魚的飼料與一點緩衝液，每週加入一點螯合鐵。
- 植物需要的所有微量元素在飼料中都包括了，所以不需添加其他的成分。

- 複合養殖系統的魚槽(有魚)與生物濾床

- 圖中顯示魚、被魚擋住的100 mm PVC水管，沈水馬達(輸送水至植床) 與由生物濾床流回來的水

複合養殖系統的優點

- 由於能夠平衡魚與植物對養分供需狀態，不需要換水，補充蒸散之消耗所做的補水量是很少的。
- 可以節省超過90%的循環水水量，所以用水非常環保，對環境的影響也最小，因為富含養分的廢水都沒有流失。

複合養殖系統的優點

- 非常優良的魚與植物的生長
- 對環境無危害
- 高效率的水體利用
- 產能與單獨的系統一樣
- 同時生產兩樣產品而只使用一種飼料

海水系統

- 魚/蝦/貝
- 藻類：海葡萄、海木耳
- 冰花

淡水系統

- 魚/蝦
- 葉菜：空心菜、萵苣
- 果菜：番茄

海洋农场科研与市场：海水电致淡水栽培延伸技术与市场长茎葡萄蕨藻。拉丁学名：Caulerpa lentillifera。别名：海葡萄、绿色鱼子酱、长寿藻。科属：蕨藻科蕨藻属。产地分布：原生于日本冲绳...

海木耳

半斤/包
120元/包

紅翎藻　半斤/包　120元/包

白蝦銷售

- 每包半斤 x 2 包

規格	重量	單價
40 ~ 50 尾/斤 (2 包)	600/40 or 50 = 12 ~ 15 g/尾	400 元/2 包
30 ~ 40 尾/斤	15 ~ 20 g/尾	450 元/2 包
25 ~ 30 尾/斤	20 ~ 24 g/尾	500 元/2 包
蝦仁 半斤	10 g/尾 約 30 尾	350 元/包

池邊價 250 元/斤，約 416 元/公斤
冷凍蝦進口價 200 元/公斤

- Plants require sunlight, air, water and nutrients to grow. Essential macronutrients include: nitrogen, phosphorus, potassium, calcium, magnesium and sulphur; Micronutrients include iron, zinc, boron, copper, manganese and molybdenum.
- Deficiencies need to be addressed by supplying the limiting nutrients with supplemental fertilizer.

- The most important water quality parameter for plants is pH because it affects the availability of essential nutrients.
- The suitable temperature range for most vegetables is 18–26 °C, although many vegetables are seasonal. Winter vegetables require temperatures of 8–20 °C, and summer vegetables require temperatures of 17–30 °C.

five key water quality parameters for aquaponics: dissolved oxygen (DO), pH, water temperature, total nitrogen concentrations and hardness (KH).

pH	6–7
water temperature	18–30 °C
DO	5–8 mg/litre
ammonia	0 mg/litre
nitrite	0 mg/litre
nitrate	5–150 mg/litre
KH	60–140 mg/litre

- Nitrate (NO_3^-) should be less than 400 mg/litre.
- Calcium carbonate from limestone, seashells or egg shells increases KH and buffers pH against the natural acidification.

- Leafy green herbs and vegetables do extremely well in aquaponics. Large fruiting vegetables are also applicable, including tomatoes, peppers, eggplant, and cucumbers, peas and beans. Root crops and tubers are less commonly grown and require special attention.
- Integrated production and pest/disease management uses physical, mechanical and cultural practices to minimize pests/pathogens, and then uses fish-safe chemical and biological treatment in targeted applications, when necessary.

- Intelligent planting design can maximize space, encourage beneficial insects and improve production.
- Staggered planting provides continual harvest as well as a constant nutrient uptake and more consistent water quality.

BALANCING THE FISH AND PLANTS: COMPONENT CALCULATIONS

The ratio estimates how much fish feed should be added each day to the system, and it is calculated based on the area available for plant growth. This ratio depends on the type of plant being grown; fruiting vegetables require about one-third more nutrients than leafy greens to support flowers and fruit development. The type of feed also influences the feed rate ratio, and all calculations provided here assume an industry standard fish feed with 32 percent protein. Lower-protein feeds can be fed at higher rates.

Leafy green plants	Fruiting vegetables
40–50 g of fish feed per square metre	50–80 g of fish feed per square metre

The recommended first step in the calculation is to determine how many plants are needed. Plants are most likely the most profitable part in small-scale aquaponics because of the high turnover rate. On average, plants can be grown at the following planting density. These figures are only averages, and many variables exist depending on plant type and harvest size, and therefore should only be used as guidelines.

Leafy green plants	Fruiting vegetables
20–25 plants per square metre	4 plants per square metre

Lettuce requires 4 weeks to grow once the seedlings are transplanted into the system, and 25 heads per week are harvested, therefore:

$$\text{25 heads/week} \times \text{4 weeks} = \text{100 heads in system}$$

Each 25 heads of lettuce require 1 m^2 of growing space, therefore:

$$\text{100 heads} \times \frac{1\ m^2}{\text{25 heads}} = 4\ m^2$$

Each square metre of growing space requires 50 g of fish feed per day, therefore:

$$4\ m^2 \times \frac{\text{50 grams feed/day}}{1\ m^2} = \text{200 grams feed/day}$$

The fish (biomass) in a system eats 1–2 percent of their body weight per day, therefore:

$$\text{200 grams feed/day} \times \frac{\text{100 grams fish}}{\text{1-2 grams feed/day}} = \text{10-20 kg of fish biomass}$$

Practical system design guide for small-scale aquaponic units

Fish tank volume (litre)	Max. fish biomass[1] (Kg)	Feed rate[2] (g/day)	Pump flow rate (litre/h)	Filters volume[3] (litre)	Min. volume of biofilter media[4] (litre)		Plant growing area[5] (m^2)
					Volcanic tuff	Bioballs®	
200	5	50	800	20	50	25	1
500	10	100	1 200	20–50	100	50	2
1 000	20	200	2 000	100–200	200	100	4
1 500	30	300	2 500	200–300	300	150	6
2 000	40	400	3 200	300–400	400	200	8
3 000	60	600	4 500	400–500	600	300	12

Notes:

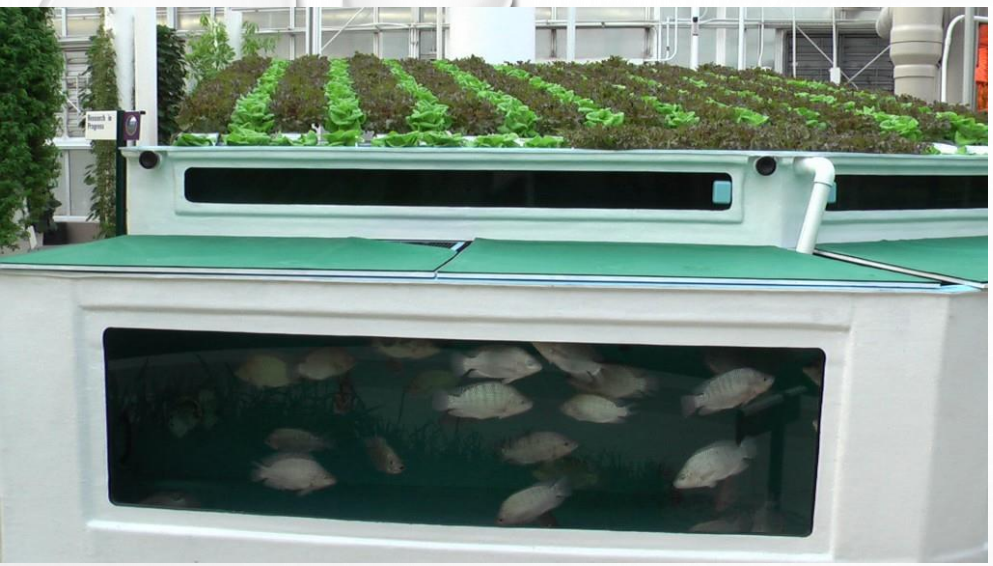
1. The recommended fish density is based on a maximum stocking density of 20 kg/1 000 litres. Higher densities are possible with further aeration and mechanical filtration, but this is not recommended for beginners.
2. The recommended feeding rate is 1 percent of body weight per day for fish of more than 100 g of body mass. The feeding rate ratio is: 40–50 g/m^2 for leafy greens; and 50–80 g/m^2 for fruiting vegetables.
3. The volumes for mechanical separator and biofilter should be 10–30 percent of total fish tank volume. In reality, the choice of containers depends on their size, cost and availability. Biofilters are only needed for NFT and DWC units; mechanical separators are applicable for NFT, DWC units and media bed units with a fish density of more than 20 kg/1 000 litres.
4. These figures assume the bacteria are in optimal conditions all the time. If not, for a certain period (winter), extra filtration media may need to be added as a buffer. Different values are provided for the two most common biofilter media based on their respective specific surface area.
5. Figures for plant growing space include only leafy greens. Fruiting vegetables would have a slightly lower area.

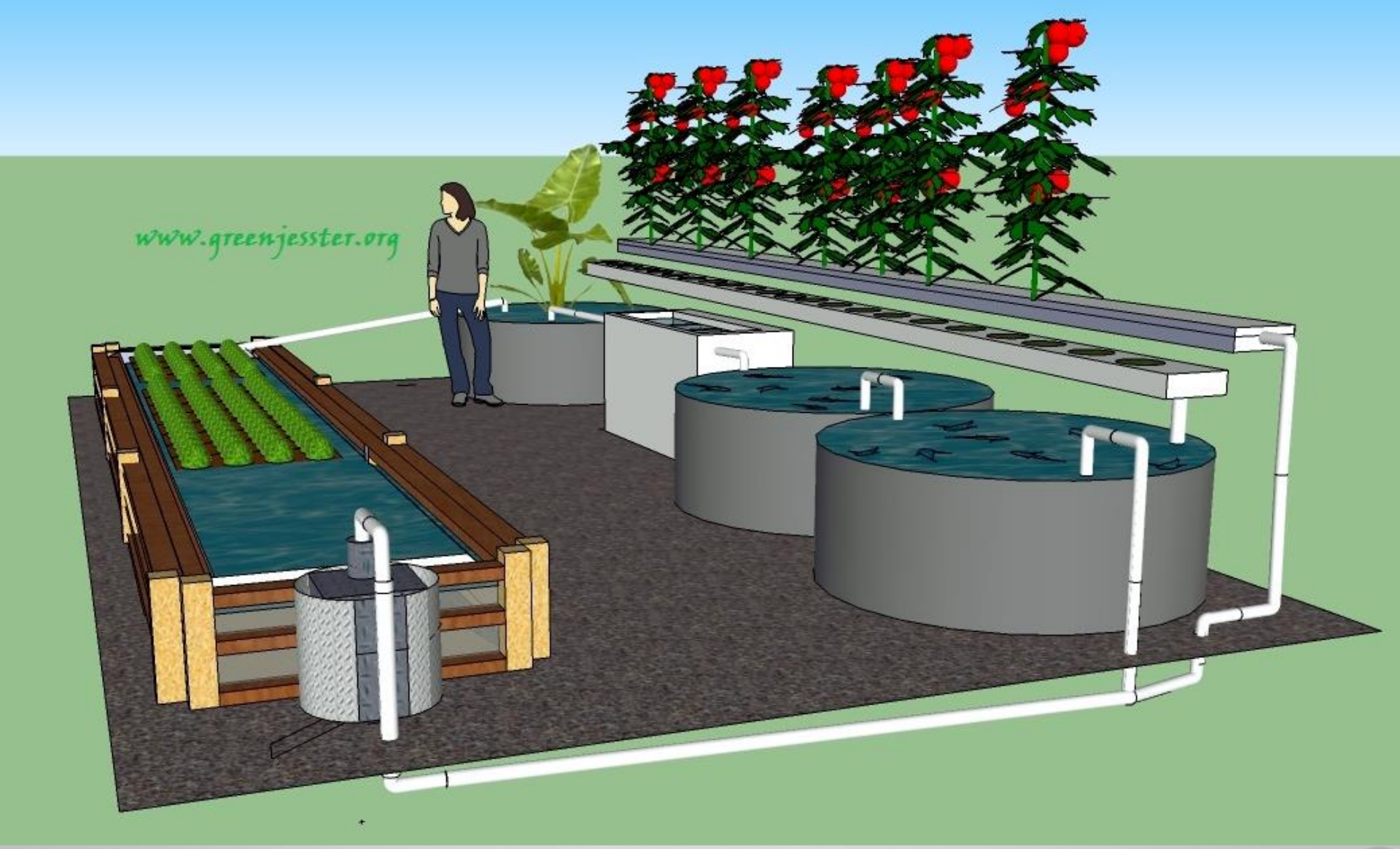
Ten key guidelines for successful aquaponics

1. Observe and monitor the system every day.
2. Ensure adequate aeration and water circulation with water pumps and air pumps.
3. Maintain good water quality: pH 6–7; DO > 5 mg/litre; TAN < 1 mg/litre; NO_2^- < 1 mg/litre; NO_3^- 5–150 mg/litre; temperature 18–30 °C.
4. Choose fish and plants according to seasonal climate.
5. Do not overcrowd the fish tanks (< 20 kg/1 000 litres).

Ten key guidelines for successful aquaponics

6. Avoid overfeeding, and remove any uneaten food after 30 minutes.
7. Remove solid wastes, and keep tanks clean and shaded.
8. Balance the number of plants, fish and size of biofilter.
9. Stagger harvesting and restocking/replanting to maintain balance.
10. Do not let pathogens enter the system from people or animals, and do not contaminate produce by letting system water wet the leaves.




www.greenjesster.org

better way to grow

aponics uses a recirculating process to grow and harvest plants, and farm fish. Fish waste works with the beneficial bacteria in el and plants, creating a recyclable, concentrated compost.

1
Wastewater is pumped from the fish run to the upper gravel bed, where the bacteria break down the impurities. What remains is nitrogen, an essential nutrient for plants. Watercress is planted in the gravel bed as a secondary method of filtering the fish-run water, as well as a variety of harvestable crops, including tomatoes and salad greens.

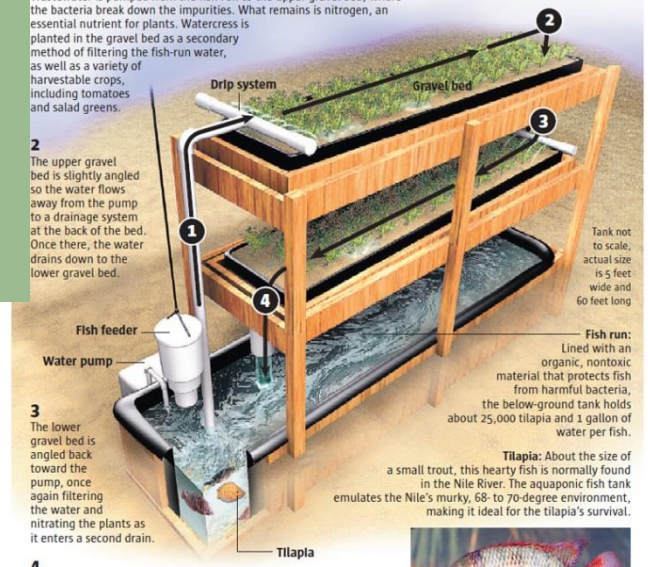
2
The upper gravel bed is slightly angled so the water flows away from the pump to a drainage system at the back of the bed. Once there, the water drains down to the lower gravel bed.

3
The lower gravel bed is angled back toward the pump, once again filtering the water and nitrating the plants as it enters a second drain.

4
The filtered water drains from the lower growing bed back into the fish run, and the cycle begins anew. Every nine months, the fish (tilapia and more recently yellow perch) are ready to be harvested.

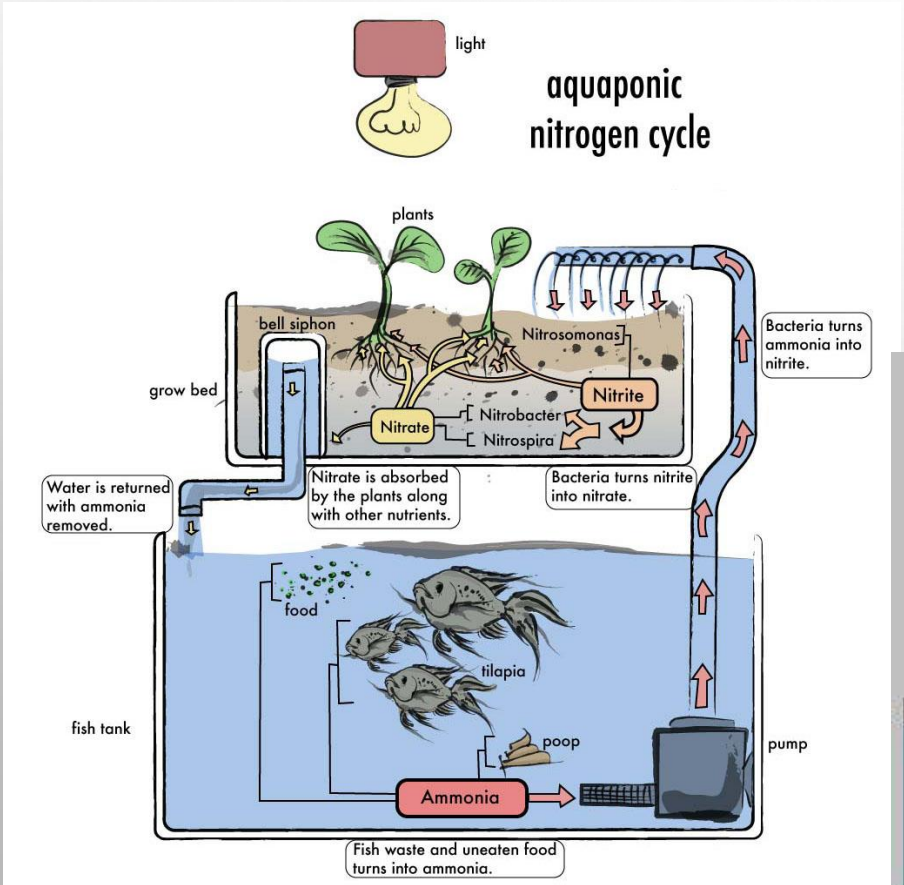
Additional text by Colleen O'Connor, The Denver Post

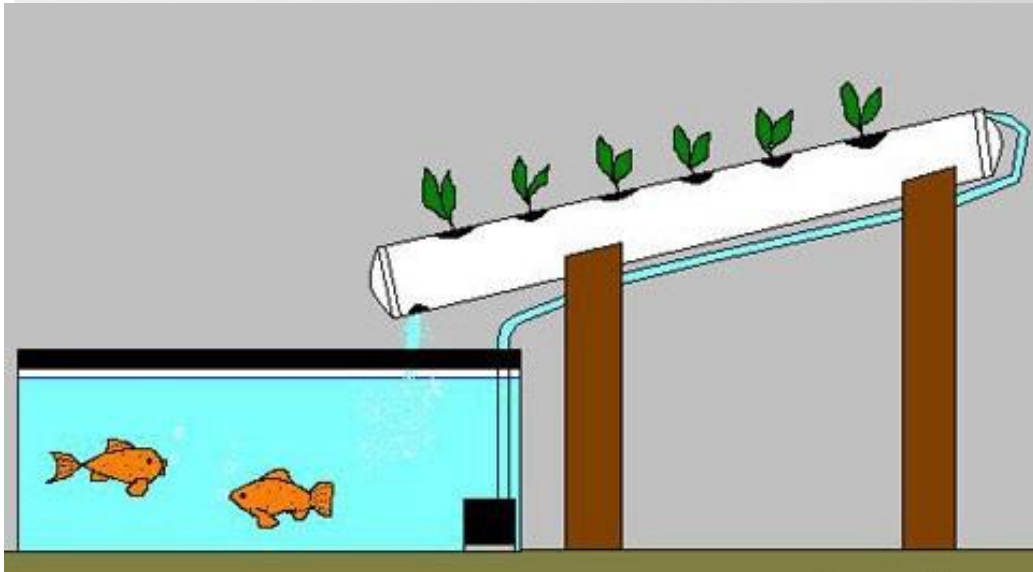
Source: Paul Tamburello, founder Urban Organics, Growing Power Inc.

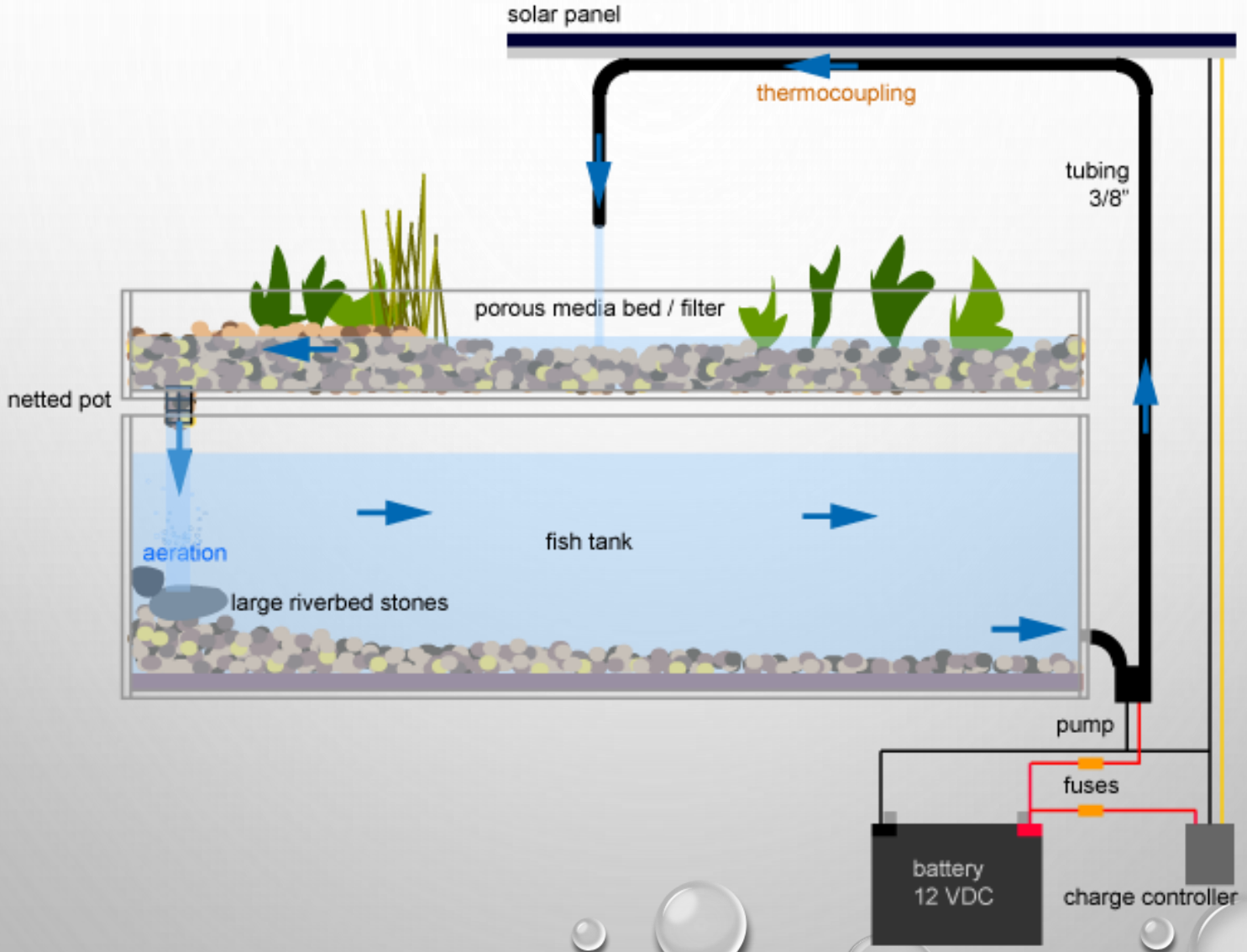


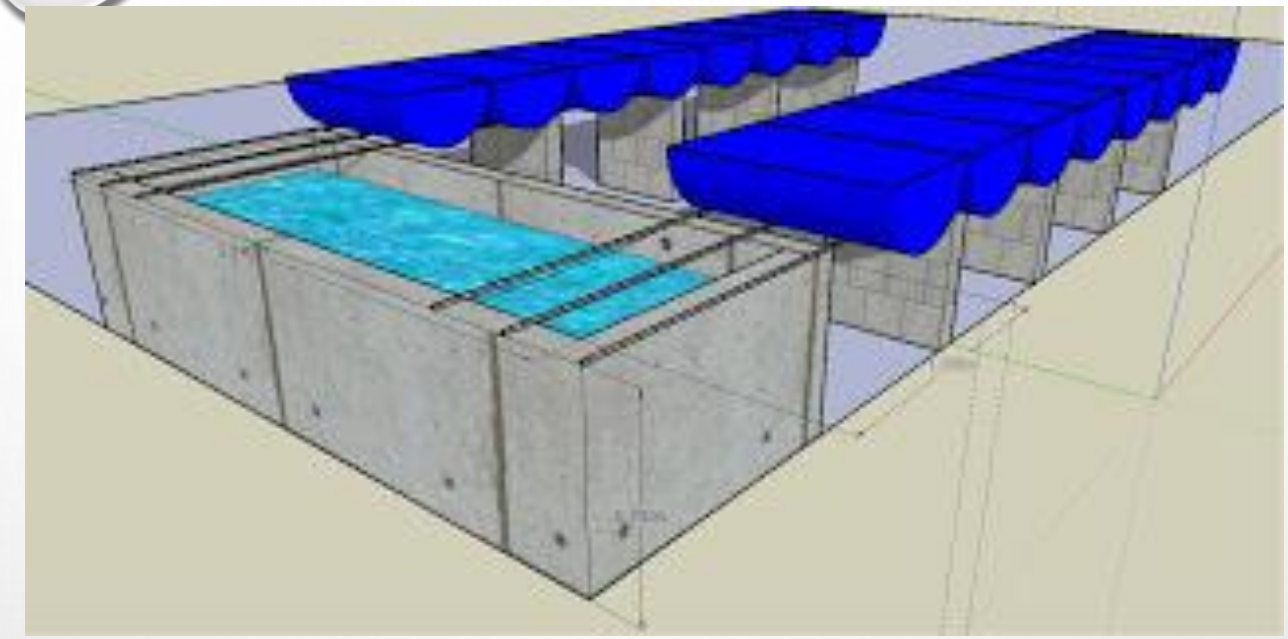
Associated Press photo, Moapa Valley National Wildlife Refuge

Jonathan Moreno, The Denver Post






solar panel
thermocoupling
tubing
3/8"
porous media bed / filter
netted pot
aeration
fish tank
large riverbed stones
pump
fuses
battery
12 VDC
charge controller



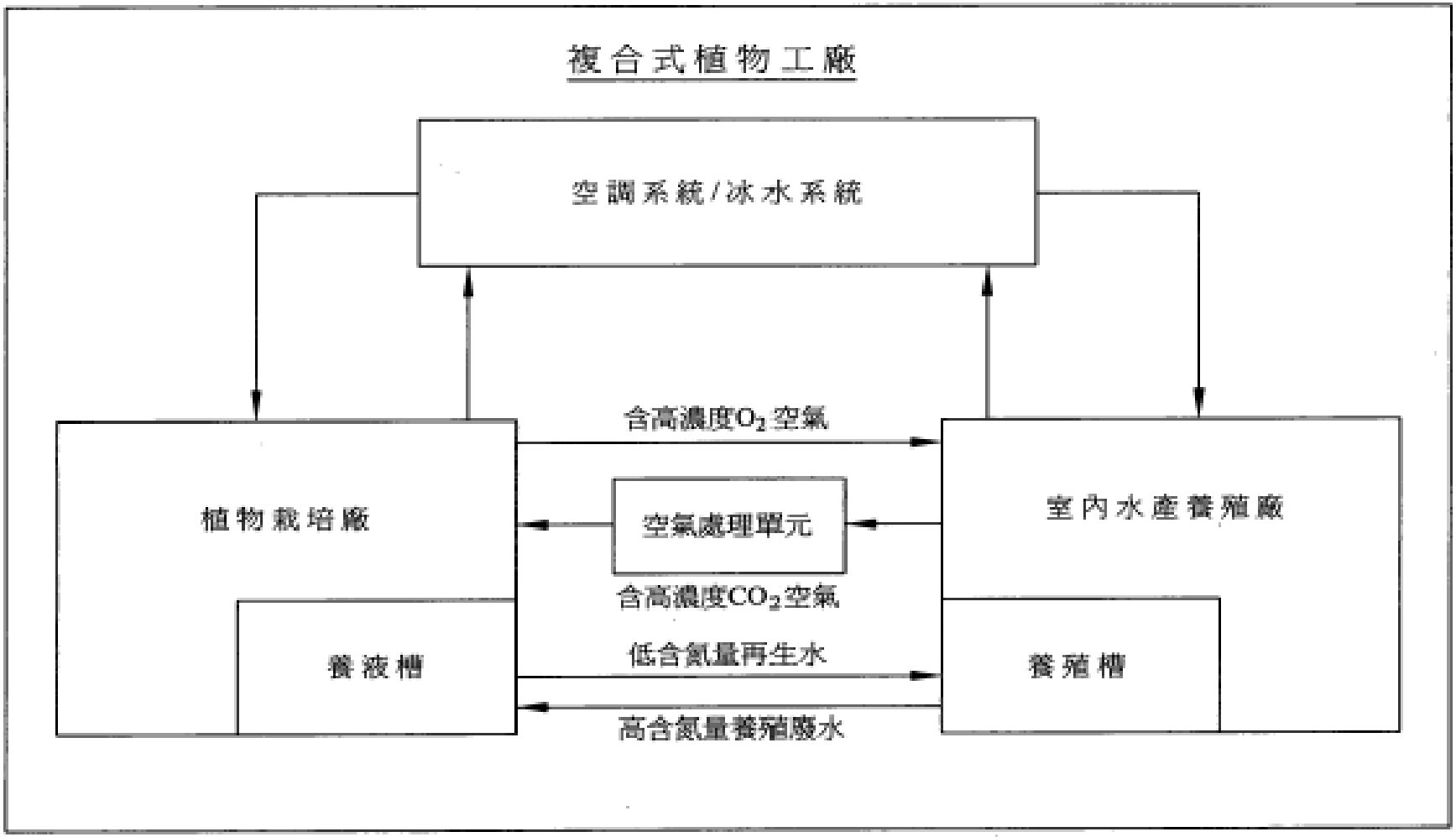

1
2
3
4


ILLUSTRATION: BRYAN CHRISTIE

VIDEO

- 魚菜共生 Aquaponics (中文)
- Farmedhere (Redefining Roots)
- Farmedhere openning
- JBA Aquaponics

台灣發明專利


複合式植物工廠
空調系統/冰水系統
含高濃度O_2空氣
植物栽培廠
空氣處理單元
室內水產養殖廠
含高濃度CO_2空氣
養液槽
低含氮量再生水
養殖槽
高含氮量養殖廢水


HYDEAN
BIOTECH

迴圈水養殖系統

瀚頂生技利用物理過濾淨化系統、生物過濾系統及紫外線殺菌系統，讓水(海水)在系統中循環利用，減少水資源的損耗，也啟動科技養殖的藍色新革命。

有機廢物的蒐集利用

瀚頂對於養殖區、蔬菜區、海藻區產生的廢料也透過水處理系統直接蒐集到廢料槽，作為園區內的天然肥料，這是瀚頂對護土的堅持。

海水/淡水養耕系統

- 海水：石斑 + 海木耳 / 海葡萄
- 淡水：鰻魚 + 蔬菜

海木耳

海葡萄


安心 健康 自然
在南臺灣，熱情的陽光，湛藍的海水下，
一座生態漁場，一塊蔬果園，一份對人與自然的愛。

瀚頂生技建構魚藻共生 打造海洋生態陸地溫室

枋寮 蝦藻共生系統

7 m x 12 m 溫室
全部 12 棟
10 棟跑道式養殖系統

2棟桶槽式養耕系統

海膽 / 海葡萄

台灣　　影片

- 影片 1（媒體報導）
- 影片 2 （企業形象影片）

- 生態水培
- 生生不息

中國


中国水产科学研究院渔业机械仪器研究所
FISHERY MACHINERY AND INSTRUMENT RESEARCH INSTITUTE OF CHINESE ACADEMY OF FISHERY SCIENCES
鱼菜共生系统工程
FISH AND VEGETABLE SYMBIOSIS SYSTEM
鱼菜共生园
鱼菜共生系统是运用生物生态学原理及环境条件监控手段，融工厂化高密度养鱼与无土栽培植物为一体的现代农业新技术。该技术结合了水生动物养殖场、蔬菜作物种植园、花卉观赏园和水族馆诸特点，涉及设施装备、生命维护和仪表电子警卫系统、种养技术等多项专利技术。
上海市赤峰路63号 邮政编码：200092 No.63 Chi Feng Road, Shanghai 200092 China
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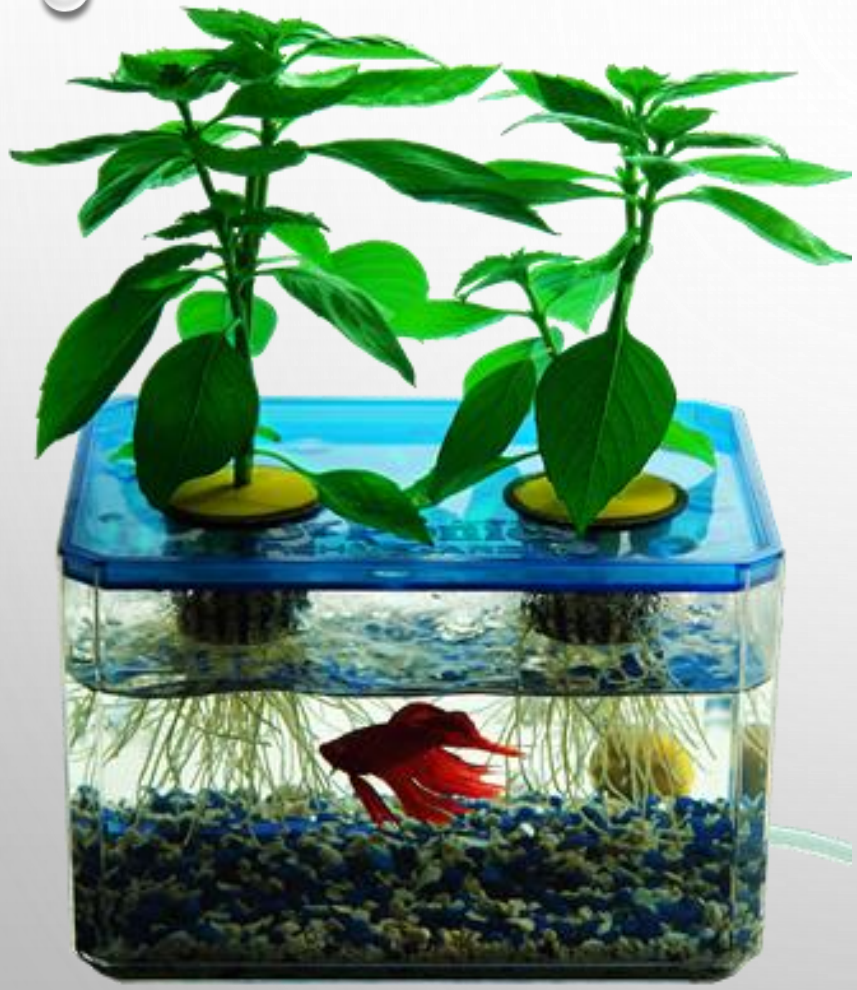
深池危险
请勿靠近


鱼菜共生生产系统

國內外養耕共生商品

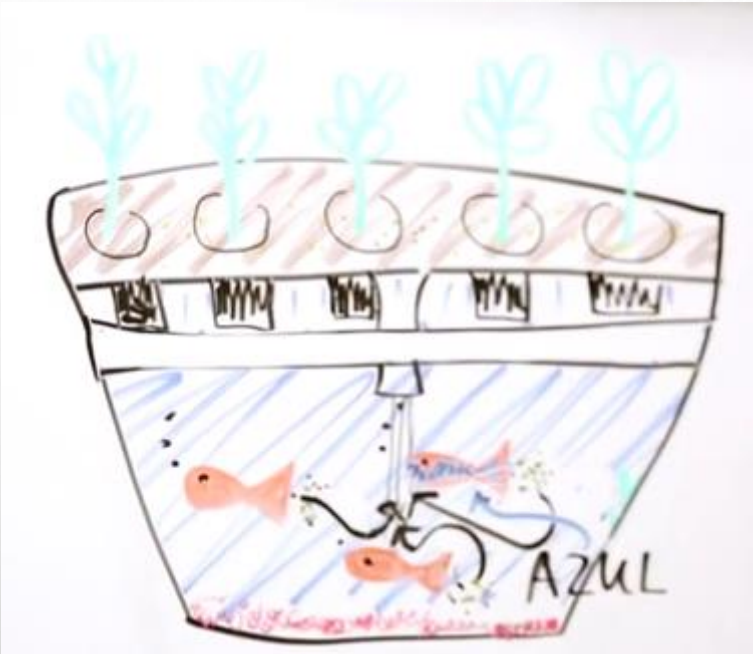
家用複合養殖設備

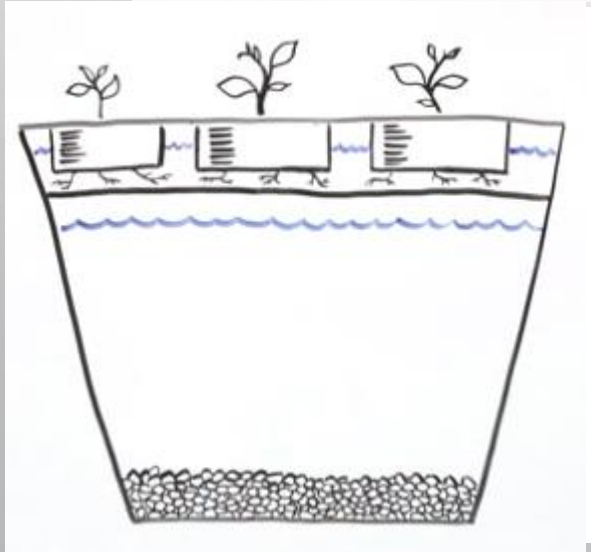


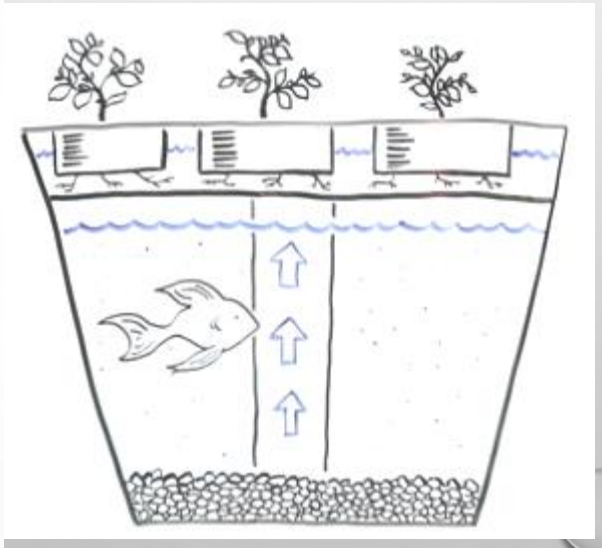
被動式

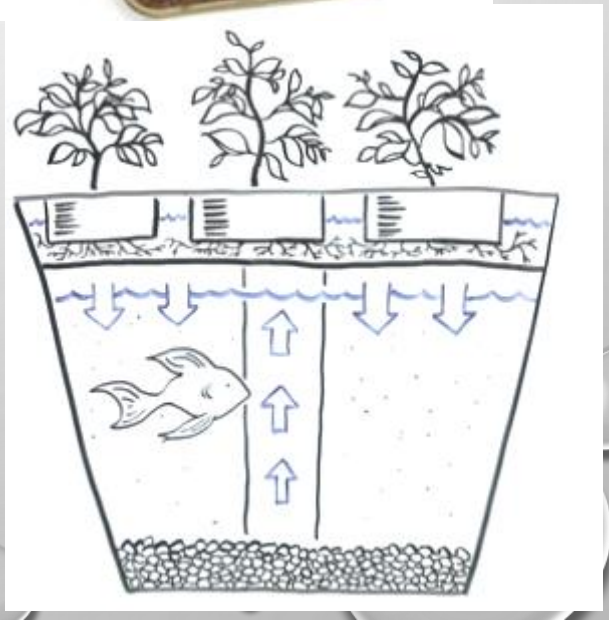
主動式

家用主動式複合養殖設備










AQUAFARM

Home Aquaponics Kit

Grow fresh produce right in the comfort of your own home - beans, basil, thyme, baby greens, oregano, mint, parsley, spinach and so many other delicious foods! This closed-loop ecosystem uses the fish waste to naturally fertilize the plants above. In turn, the plants clean the water for your pet fish.


our new product!
HOME AQUAPONICS KIT
Self-cleaning fish tank that grows food!
Give the gift of Aquaponics this Christmas!
Download holiday card after purchase.
Visit backtotheroots.com to purchase today.
Preorder yours now for 20% off + free shipping.
(expected delivery in march)

Home Aquaponics Garden - Preorder now for $60 + free shipping

JrPonics FishGarden

JrPonics FishGarden

Retail Price: $69.99

Sale Price : $64.95

Fountaine Domestic Pond

"Therapeutic objects, invisible design, ergonomics of desire..."

Mathieu Lehanneur

Liquid Garden by Benjamin Graindorge

Liquid Garden by Benjamin Graindorge

Castle Aquarium by Eric Jourdan

The GoldFish Garden


Wardley
Goldfish

香港家庭版菜魚共生系統

工具簡介

魚缸：大小無規定，唯要注意生物所須的活動空間。

菜盆：底部要有孔去水，深度須足夠植物根部生長。

水泵：家居用小魚缸，約 5W就足夠。

陶粒：表面有許多小孔、透水，微生物能在內生長並幫助分解養分。

1.

3.

外國的魚菜養耕比香港更早開始實行，有兩位法國設計師將藝術和環保結合，設計了一款名為 Local River的系統，希望取代傳統的純觀賞式水族箱。運作理論跟是次介紹的魚菜養耕大致相同，可種水耕菜，魚缸內也可養淡水魚、蝸牛、小龍蝦或河蝦等，不過是否完全有機養耕就沒有表明。

印象風綠繪 Impressionism Flower Frames

Size :

L300*W71*H300mm

Color :

印象風綠繪 Impressionism Flower Frames

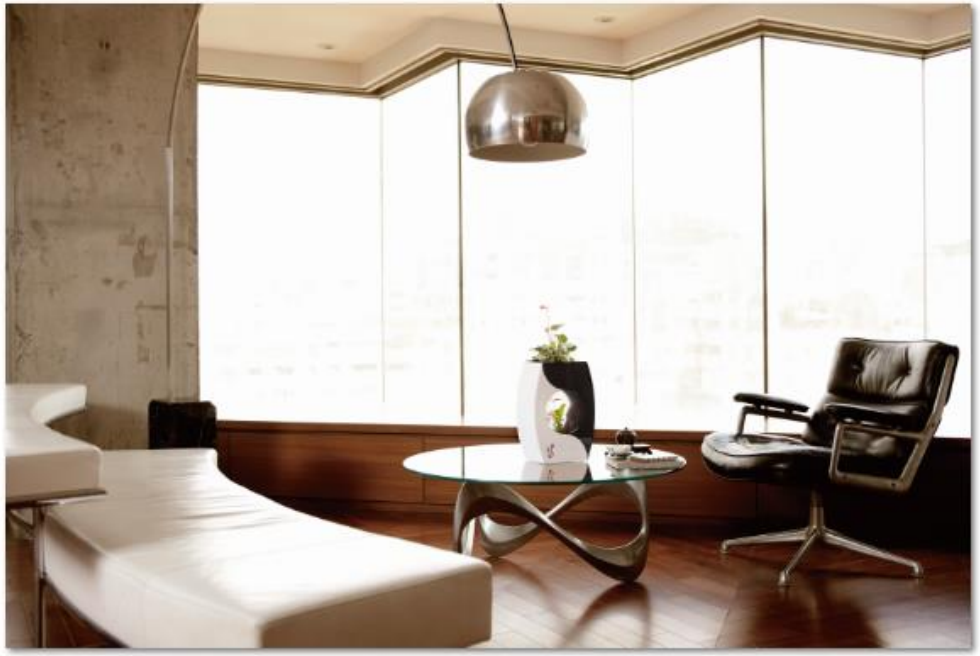
易 2 Yi 2

Size :

L213*W132*H324mm

Color :

易 2 Yi 2



易 1 Yi 1

Size :

L191*W191*H201mm

Color :

MOQ :

易 1 Yi 1

花妍巧魚 A Dialogue Between Flowers and Fish

Size :

L145*W145*H157mm

Color :

MOQ :

花妍巧魚 A Dialogue Between Flowers and Fish

積木花盒 Flower Blocks

Size :

L145*W145*H157mm

Color :

MOQ :

積木花盒 Flower Blocks

惑 Puzzle

Size :

L145*W145*H157mm

Color :

MOQ :

惑 Puzzle

惑 Puzzle

即興曲4/6 Impromptu 4/6

Size :

L140*W50*H90/120mm

Color :

MOQ :

即興曲4/6 Impromptu 4/6

即興曲5 Impromptu 5

Size :

L102*W102*H255mm

Color :

MOQ :

即興曲5 Impromptu 5

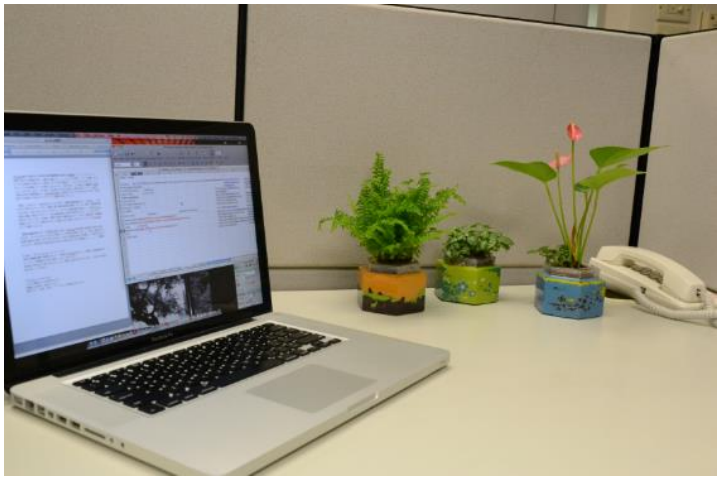
亞緹米斯一件式 Artemis with 1 pot

Size : L100*W88*H62mm

Color :

MOQ :

亞緹米斯一件式 Artemis with 1 pot



亞緹米斯三件式 Artemis with 3 pots

Size :

L280*W280*H62mm

Color :

MOQ :

亞緹米斯四件式 Artemis with 4 pots

Size :

L360*W120*H62mm

Color :

MOQ :