Aquaponics Training Booklet

Organic, Fresh, Healthy, Sustainable

Compiled For Training Purpose

By Dr, Allan Bachan

Foreword

We will face global challenges in the near future: namely that our finite natural resource base must sustain a growing population in a complex and changing world where agriculture faces an unprecedented confluence of pressures.

Our population continues to grow and are increasingly demanding more, better and affordable food. Many natural resources, including soil and freshwater, are already overexploited, and a changing climate will add further stress to this precarious situation.

Locally Climate Change and its impacts of increased temperature, frequent dry spells, dried up ponds in the early months of the year, proliferation of pests, loss of biodiversity, devastating floods and soil erosion have had negative impacts on productive farming. Within this context, we have complex social dynamics, institutional and governmental capacities that influence the long-term success and impact of development interventions.

In the future, the agriculture sector will need to produce more, with less. Following the principles of efficient resource use to increase the provision of goods and services from agriculture in a sustainable way, synergistic benefits need to be realized by integrating separate food production systems, and by reducing inputs, pollution, and waste, while increasing efficiency, earnings and sustainability. As one of these efficient and integrated techniques, aquaponics has the potential to support economic development and enhance food security and nutrition through efficient resource use, and it may well become one additional way of addressing the global challenge of food supply in a sustainable way.

Aquaponics has the potential for higher yields of vegetables and fish protein with less labour, less land, fewer chemicals, and a fraction of the water usage. Being a strictly controlled system, it combines a high level of biosecurity with a low risk of disease and external contamination, while producing high yields without the need for fertilizers and pesticides. Moreover, it is a potentially useful tool to overcome some of the challenges of traditional agriculture in the face of freshwater shortages, climate change and soil degradation.

Dr. Allan Bachan

Preface

As a boy growing up, agriculture was an integral part of rural community life, and for many years, local agriculture accounted for a lot of the food consumed in our household. As climate change disrupts the food supply and production in Trinidad and Tobago, we need to assist farmers in implementing new techniques to ensure sustainable livelihoods and food security for our local communities.

There is a growing interest in aquaponics in Trinidad and Tobago as more people turn to locally grown food produced in an environmentally friendly and sustainable way.

For anyone who has been curious about aquaponics or who is considering taking it up as a hobby or business, our training and this training package is the first step to learning more on the subject. While this training and the material in this guide is not exhaustive, it will serve as an introduction and a resource document providing supplementary knowledge in Aquaponics thereby instilling a heightened sense of self-confidence and awakening you to the possibilities.

This training manual does not provide a prescriptive approach to aquaponics instead, this is a resource paper and includes description and discussion of the major concepts needed for aquaponics.

After this you may decide that aquaponics is not for you; but some of you may take up aquaponics as an enjoyable way of growing their own food in simple backyard operations, while others may pursue aquaponics on the commercial scale as a primary or supplementary source of income.

But let’s do it right the first time if we can.

The trainer would like to acknowledge the Food and Agriculture Organization of the United Nations (FAO) as a major source for the material in this information Booklet. The views expressed in this information product are those of the author and do not necessarily reflect the views or policies of BHP, the Ministry of Agriculture, Turtle Village trust or the FAO.

Contents

Is Aquaponics Right for You?

Activity #1

The Quiz: Do You Have What It Takes?

Aquaponics Farming like most things in life is fraught with uncertainty and risk.

Take the Quiz in Attachment 1. The exercise is meant to be fun. The questions are not a judge of a person's actual ability to succeed in farming. However, the recommendations based on individual scores, are meant to be anecdotal, and to make participants think.

What would you like to know?

Activity #2

K-W-L Chart

Record Responses

Please use the Activity Worksheet in Attachment 2

Before Lesson:

Think about Aquaponics.

Write what you already know into the K box.

Write questions about what you would like to know in the W box.

During Lesson:

Make notes that will help you answer your questions.

After Lesson:

Write the answers to your questions in the L box.

Reread the text as needed

LESSON 1

INTRODUCTION TO AQUAPONICS

Climate Change and its impacts of higher temperature, water scarcity, severe weather, perianal flooding and pest and disease intensity coupled with the lack of available, arable land area and with a scarcity of resources are some of the current problems facing the agricultural sector here in Trinidad and Tobago.

As we consider how to feed our growing population in this prevailing climate we need to consider more sustainable alternative options for creating food while minimizing waste. Additionally, families and communities will need to find a way to produce food year-round especially with the scarcity of fresh produce and the rising food prices.

Aquaponics creates fresh, healthy food crops without soil in small spaces with significantly less water. Once you set up your system and get the chemistry right for your plants and fish, 95% of the work is automated. All you have to do is plant more seedlings after a plant has completed it's cycle. Can you imagine being able to go into your backyard and pick all the vegetables you want, or catch a fish whenever you want?

This is all possible because with aquaponics you are creating food in harmony with nature. Aquaponics is a compact but very real ecosystem that uses the same processes that Mother Nature uses to recycle something toxic into something useful. Aquaponics creates local resources for food, employment, community, and sustainable and profitable businesses.

The technology presented in this document provides a description of the concept of aquaponics and an overview of the three most common methods of aquaponics being utilized at present. In addition, the factors to consider when selecting a site for an aquaponic unit and the components essential for any method of aquaponics are described in detail in this document.

This Training Booklet is supplemented with a Practicum Booklet: **Aquaponics Systems Designing and Building.** This booklet gives step by step instructions on building the main components of your Aquaponics System.

WHAT IS AQUAPONICS?

It's a Cool way to grow fish and food

Aquaponics is a biologically integrated sustainable ecosystem for food production It is the integration of recirculating **Aqua**-culture, (raising aquatic animals such as fish), and Hydro-**ponics**, (growing plants without soil) in one production system.

So, in aquaponics, plants and fish are grown together in one integrated recirculation system. The waste products of fish serve as nutrients for our plants.

The aquaculture effluent is diverted through plant beds and not released to the environment, while at the same time the nutrients for the plants are supplied from a sustainable, cost-effective and nonchemical source. This integration removes some of the unsustainable factors of running aquaculture and hydroponic systems independently.

Water is conserved and re-used through biological filtration and recirculation. Aquaponics provides healthy foods and enhances the livelihood opportunities for rural communities.

WHY AQUAPONICS

Adaptative measure to the Impacts of Climate Change including a proliferation of pests, irregular rainfall, drought, flooding, degradation of fish spawning grounds, sea level rise causing salt water intrusion.

In 2050 the world will have 9.8 billion people to feed.

The capacity of our planet is limited.

Our Oceans are over fished.

Aquaponics could be one of the solutions to our future food problem.

WHY AQUAPONICS TRUMPS CONVENTIONAL GARDENING …

Benefits of Aquaponics

✓	**It is a complete system -** from technology to management, technical operation to markets.
✓	**Two agricultural products -** Fish and vegetables are produced from one nitrogen source (fish food).
✓	**Low Operation Costs -** Through an integrated pumping design, power cost is minimal. High feed conversion and year-round production without downtime plus low stock losses assure low overall production cost.
✓	**Virtually Hands Off & maintenance free -** Once you've set it up you can sit back while the fish provide nutrients, and the plants keep the water clean. The system is extremely simple to maintain making it perfect for the modern lifestyle.
✓	**No More Weeding -** Grow beds are placed up high off the ground where weeds can't spread and because of the nature of the media in the grow beds there's very little to allow new weeds to sprout.
✓	**No more watering!** - How's this for a bonus! You don't even have to water your aquaponics garden.
✓	**No More Dirt -** This means there is nothing to till, plow, hoe or rake. Happy days!
✓	**Produces premium quality fish.** It meets "sashimi" and "organic" specifications. They are free of pollution, chemicals and antibiotics.
✓	**More plants in less space -** Plant density (spacing) is very intensive, allowing more plants to be grown in a small space. Plants will also grow and develop quicker. .
✓	**Does not use fertilizers or chemical pesticides -** Because this system works without the use of soil there is no need to add fertilizer and reduces the costly mixing of inorganic nutrients because the fish do it automatically.

✓	**No Soil-borne Pests or Diseases -** The need for dangerous pesticides and chemicals is eliminated again because there is no soil, and the grow beds are off the ground.
✓	**Environmentally friendly process that creates little waste,** Higher control on production leading to lower losses. All outputs are recycled.
✓	**Conserve Water! Extremely water efficient** - Aquaponics conserves water by using a fraction of the water utilized by traditional field production.
✓	**Reduced Carbon footprint**, food is grown and consumed locally. Trips to the market reduced.
✓	**Aquaponics decreases health concerns -** The closed-system food production technology that integrates recirculating aquaculture with hydroponics and provides a true organic nutrient for the plants makes chemical use unnecessary and the produce healthier and safer**.**
✓	**Food security and food independence.** By growing your own food, you can have food security and food independence
✓	**Livelihood opportunity:** An aquaponics system can be a source of income for you and your family if you grow commercially.

Weaknesses of Aquaponics

Major weaknesses of aquaponic food production:

- Expensive initial start-up costs compared with soil vegetable production or hydroponics.
- Knowledge of fish, bacteria and plant production is needed for each farmer to be successful.
- Fish and plant requirements do not always match perfectly.
- Mistakes or accidents can cause catastrophic collapse of system.
- Daily management is mandatory.
- Requires reliable access to electricity, fish seed and plant seeds.
- Alone, aquaponics will not provide a complete diet.

Why is Aquaponics Considered Sustainable?

Secret Word is Sustainability – **re-duce, - re-use, – re-cycle**

Aquaponics Sustainable Food Production Model

- The integration of fish and plants results in a polyculture that increases diversity and yields. Produces multiple products
- High yield, short cultivation time
- Biological control Less plant diseases
- No waste – hydroponics waste solution, aquaculture waste fish solids – aquaponics all waste is used.
- Waste from fish is diverted through plant beds used to feed the plants and not released to the environment. This nutrients for the plants are supplied from a sustainable, cost-effective and nonchemical source.
- Continuous organic fertilizer
- Local food production provides access to healthy foods
- This integration removes some of the unsustainable factors of running aquaculture and hydroponic systems independently.
- A lot of our material to build our systems are reused items; IBC, Barrels, fishnet, plastic bottles.

It is an adaptive response to Climate Impacts: Water footprint & Carbon footptint

- ✓ Water is re-used through biological filtration in the re-circulating system
- ✓ Water footprint – Circular water use, 90% less water use
- ✓ Local food production, enhances the local economy and reduces food transportation
- ✓ CO2 footprint – less transport – local for local – urban areas

Key learning points

Aquaponics is a production system that combines fish farming with soilless vegetable production in one recirculating system.

Aquaponics creates fresh, healthy food crops without soil in small spaces with significantly less water.

Aquaponics is sustainable and reduces our Water footprint & Carbon footptint

FYI

Did you know?

"research has shown that an aquaponic system uses about 1/10th of the water used to grow

NOTES:

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LESSON 1: Ask Question

Questions:

1. What TWO systems are combined to produce an aquaponics system?

____________________ ____________________

2. List TWO products farmers can obtain from an aquaponics system?

____________________ ____________________

LESSON 2

AQUAPONICS MECHANICS

What is Inside an Aquaponics System?

1. Plants

Growing plants organically is one reason many people want to set up their own aquaponics system. Plants also play an essential role in maintaining the aquaponics system's overall cycle by cleaning and oxygenating the water. Plants also filter the water and absorb the nitrates, thus cleaning it before recirculating back to the fish.

2. Fish

Fish are the power house of an aquaponics system, they provide the nutrients for the plants and if your growing edible fish, then they also provide protein for yourself. Fish play an essential role in an aquaponics system because their waste acts as a natural fertilizer for the plants.

3. Bacteria

Bacteria play a vital role in an aquaponics system because they convert fish wastes into nutrients absorbed by the plants.

Why Does Aquaponics Work?

When conducting training the participants being introduced to aquaponics often ask why Does Aquaponics Work? How come we are raising two separate things; plants and fish together and they seem to coexist in harmony?

Well one of the major factors for ensuring a happy fish and a thriving plant is their food. Look at the ingredients in a fish's diet and look at the ingredients in a plant's diet.

FISH	**PLANT**
Organic Protein	Nitrogen
Potasium	Potasium
Calcium	Calcium
Mahnesium	Mahnesium
Phosporus	Phosporus
Sulphur	Sulphur
Chlorine	Chlorine
Iron	Iron
Manganese	Manganese
Zink	Zink
Copper	Copper
Molybdenum	Molybdenum
Nickel	Nickel
Sodium, Iodine, Cobalt, Fluorine, Vanadium, Chromium, Selenium, Silicone	Boron

Essentially there is an 87% overlap in what the fish needs, and the plants need. Now that's a significantly high number and that's probably one of the main reasons why aquaponics works. Two crops being raised with very similar needs.

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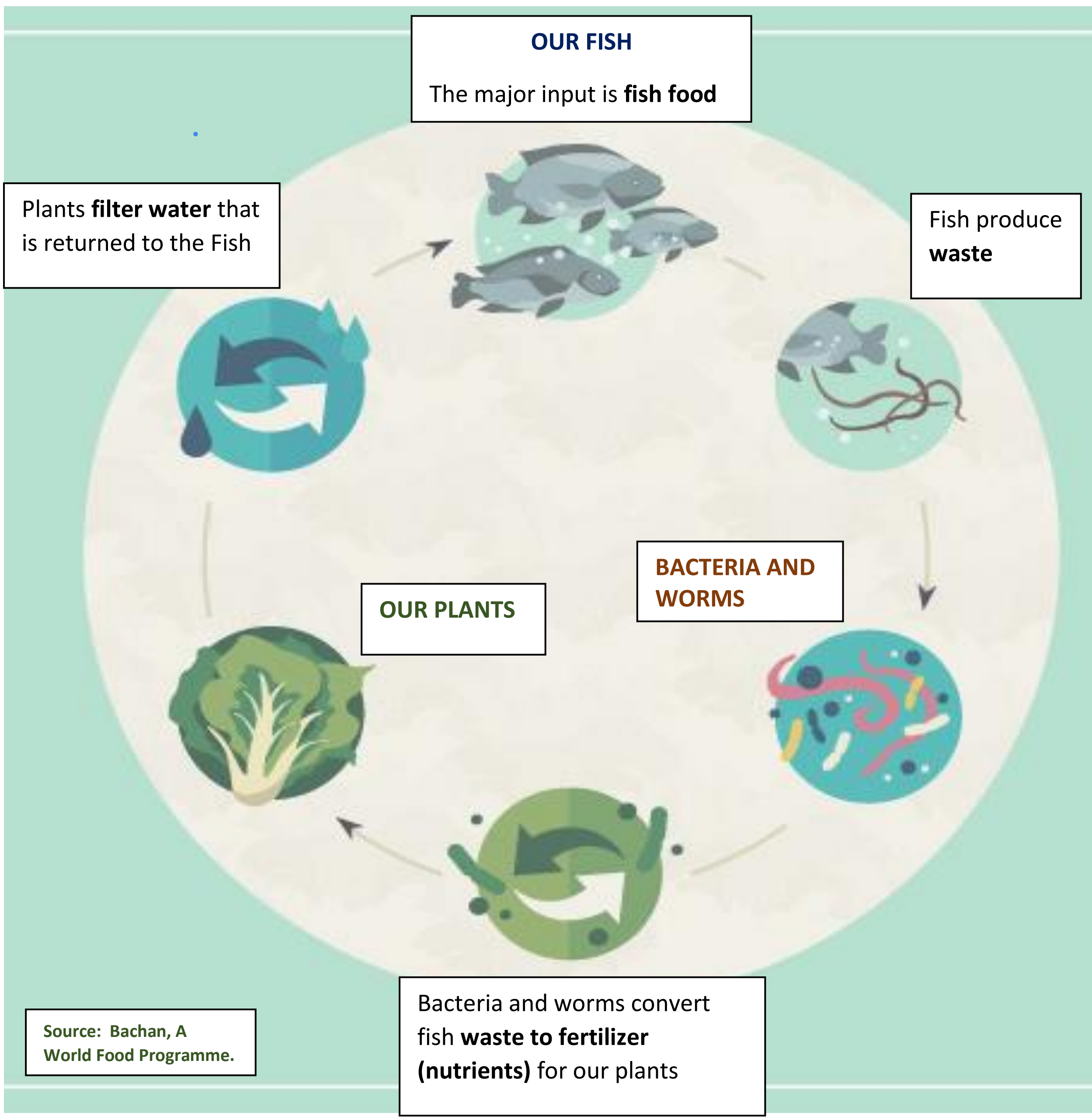
How Does Aquaponics Work?

In aquaponics, fish, plants and bacteria work together to create a healthy growing environment for one another. Water is conserved and re-used through biological filtration and recirculation.



- First off, the major input is fish food. The fish eat their food and, after digestion, excrete organic waste matter in the form of urea, uric acid and fish poo. They also release ammonia as part of the gas exchange that occurs through respiration into the water.
- The water first passes through a mechanical filter that captures solid wastes
- It then passes through a biofilter which provides a habitat for bacteria to convert fish waste into accessible nutrients for plants.
- The water then travels through plant grow beds. These nutrients, which are dissolved in the water, are then absorbed by the plants. This process of nutrient removal cleans the water, preventing the water from becoming toxic with harmful forms of nitrogen (ammonia and nitrite),
- Finally, the water returns, purified, to the fish tank.

So this cyclic system allows the fish, plants, and bacteria to thrive symbiotically.

Food Conversion in Fish

The Feed Conversion Efficiency is how efficient the fish is in converting its feed into biomass. Tilapia Feed Conversion Efficiency Ratio = 0.55-0.60.

So, 55%- 60% of the feed input is going to be converted to fish biomass/ weight and the rest is extruded as waste.

Moreover, the converted fish waste provides all the fertilizer required by the plants.

FOOD

Feed Input 100%

100% Nitrogen

100% Phosphorus

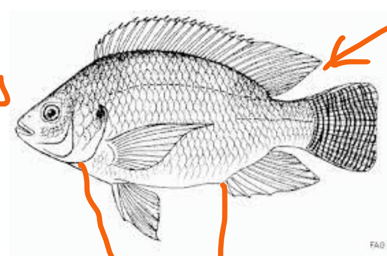
FISH

Feed efficiency 55-60%

Retained in Tissue

22% Nitrogen

28% Phosphorus



Effluent Solids

18% Nitrogen

60% Phosphorus

Effluent

78% Nitrogen

72% Phosphorus

Effluent Dissolved

60% Nitrogen

12% Phosphorus

(Characteristics of extruded waste and nutrient loading (%) per fish produced (adapted from Ali D, Bachan A, Brunt R (1997)

Bacteria and Our Plant's Food

There are two major categories of nutrientsthat plants require: **macronutrients** (nitrogen (N), phosphorous (P), potassium(K), calcium, magnesium and sulphur) **and micronutrients** (iron, zinc, boron, copper, manganese and molybdenum).

These nutrients are released through **The Nitrogen Cycle** and **the process of Mineralization.**

The Nitrogen Cycle

Bacteria are vital for the overall functioning of an aquaponic unit.

Two major groups of nitrifying bacteria are involved in the nitrification process: 1) the ammonia-oxidizing bacteria (Nitrosomonas bacteria), and 2) the nitrite-oxidizing bacteria (Nitrospira).

Nitrosomonas bacteria oxidise (metabolize) ammonia (NH^3) produced by fish and decomposing organic matter to Nitrite (NO^2-). Although it is less toxic than ammonia, elevated levels still present a threat to fish health. Prolonged exposure to low levels can lead to stress and is often associated with stress-related disease such as bacterial ulcers and fin-rot. As the ammonia levels dip, the nitrite levels increase.

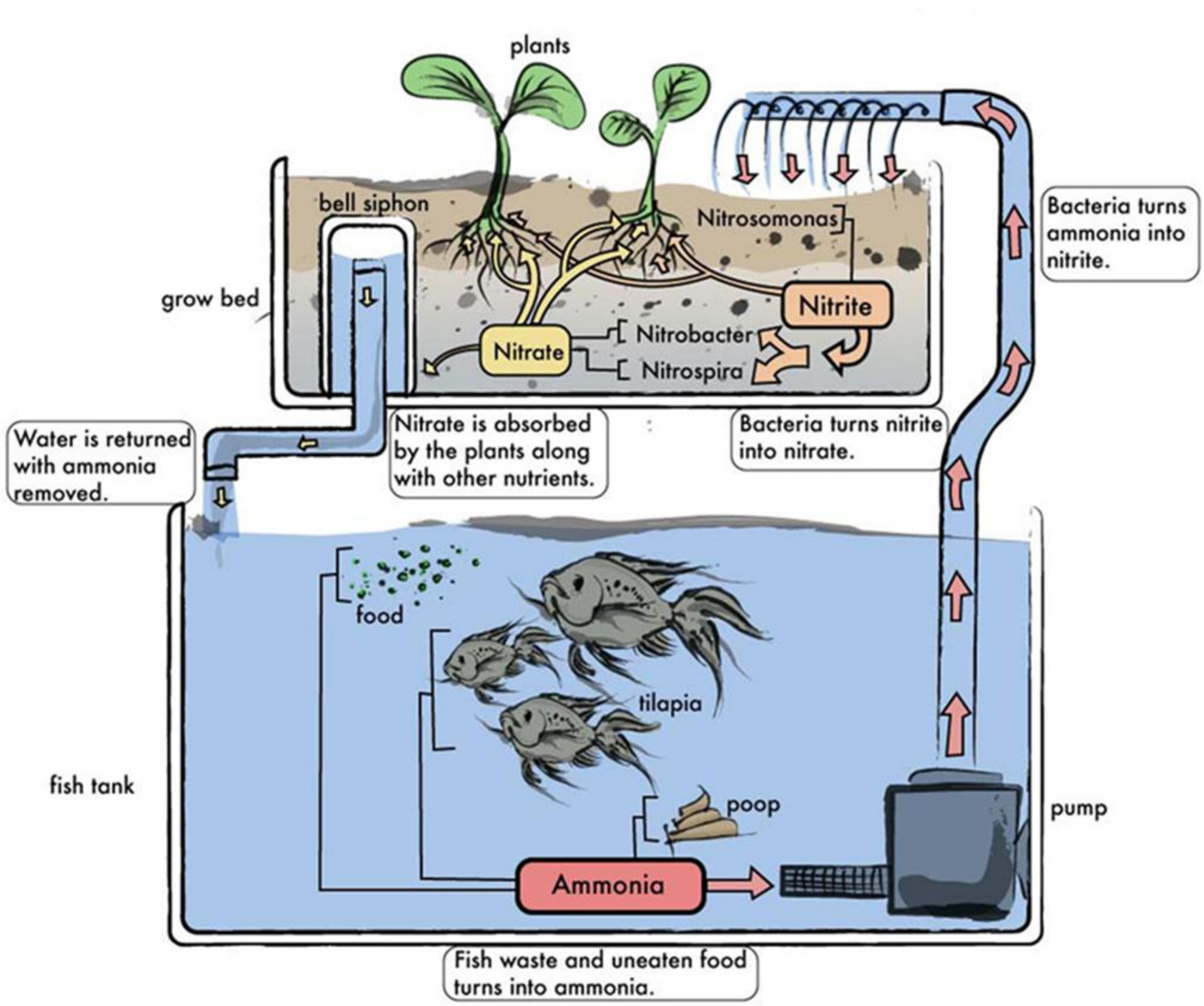
THE NITRITES (like ammonia) ARE TOXIC TO FISH! These nutrients from fish manure, algae, and decomposing fish feed are contaminants that would eventually build up to toxic levels in the fish tanks, but instead serve as liquid fertilizer to hydroponically grown plants.

The presence of nitrites attracts the bacteria, nitrospira (nitrite-oxidizing bacteria) which convert the nitrites (NO_2-) into nitrates (NO_3-), plant food!

Nitrates,are generally harmless to the fish and excellent food for your plants!

The plants consume the nitrates (and other compounds) and as they grow and are harvested, nitrogen is removed from the system. So, the plants clean and purify the water for the fish. Herbicides, pesticides or other harsh chemicals are not allowed in an aquaponic system, making the fish and plants healthful and safe to eat.

THE NITROGEN CYCLE



Source: http://www.palmspringsaquaponics.com/

Mineralization.

In addition to these basic requirements for nitrates, plants need a number of nutrients, also referred to as inorganic salts. These nutrients are required for the enzymes that facilitate photosynthesis, for growth and reproduction. In aquaponics, all of these essential nutrients come from the fish waste. Deficiencies in these nutrients are a result of the composition of the fish feed. There are two major categories of nutrients: macronutrients (nitrogen (N), phosphorous (P), potassium(K), calcium, magnesium and sulphur) and micronutrients (iron, zinc, boron, copper, manganese and molybdenum). These nutrients are released through the process of **Mineralization.**

Mineralization is the decomposition by microbiota such as fungi and bacteria along with worms of the chemical compounds in organic matter, by which the nutrients in those compounds are released in soluble inorganic forms that may be available to plants.

Balancing The Aquaponic Ecosystem

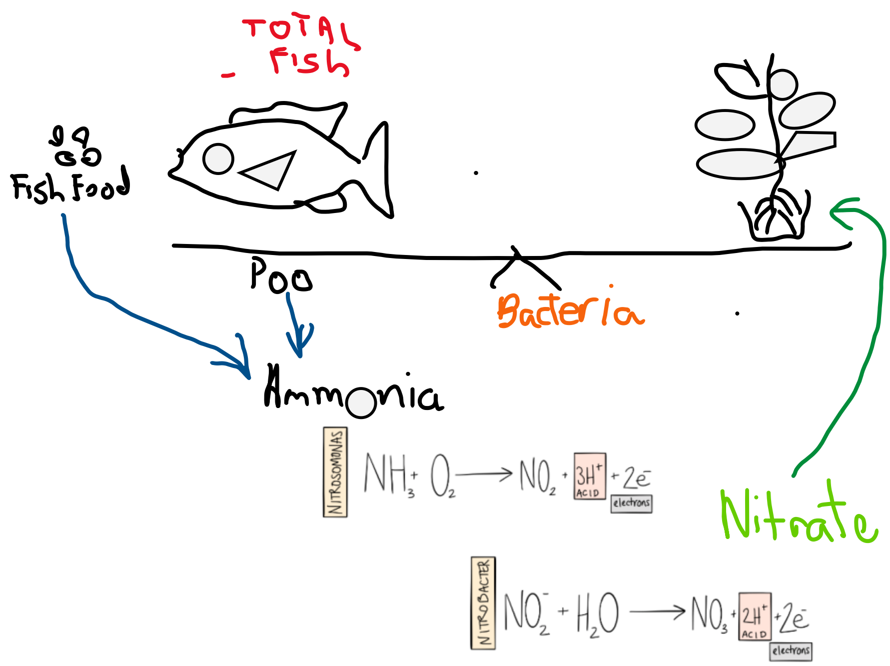
BALANCING THE FISH AND PLANTS:

The term balancing is used to describe all the measures you must take to ensure that the ecosystem of fish, plants and bacteria is at a dynamic equilibrium. It cannot be overstated that successful aquaponics is primarily about maintaining a balanced ecosystem.

What does this mean?

The fish (and thus, fish feed) need to supply adequate nutrients to the plants; the number of plants should be adequate to use all the nutrients released, but not in excess to prevent any risk of deficiencies. The biofilter (which really means the amount of bacteria) needs to be large enough to process all of the fish wastes, and enough water volume is needed to circulate this system.

Simply put, this means that there is a balance between the number of fish, the amount of plants and the size of the biofilter.



Nitrate balance: The equilibrium in an aquaponic system can be compared with a balancing scale where fish and plants are the weights standing at opposite arms. The balance's arms are made of nitrifying bacteria. It is thus fundamental that the biofiltration is robust enough to support the fish and plants.

Hopefully, that wasn't confusing at all!

Understanding the need for balance and placing this as the basis of all your thinking will greatly benefit you in the long run.

For example,it will help you remember to scoop out uneaten food so that that food will not sink to the bottom, turn into large amounts of ammonia and poison your fish.

It will remind you to be careful when you harvest lots of plants at once so you don't kick your entire system out of balance.

It will also helps you keep your eye on LARGE water changes. (It is best instead to top your tanks off with a little bit of water every other day than to introduce gallons of new water when it's too late!).

Just as easily, remember this: "Balance is important and Water in an established, balanced Aquaponics system is nature working in symbiotic harmony."

Health check of fish and plants

When the plants are well watered and well fed in a balanced aquaponics system, they will often grow twice as fast as those grown in soil. And because we're not using soil, the roots don't need to dig very deep to find water and plants can be grown close together using much less space.

***Health check of fish and plants*:** Unhealthy fish or plants are often a warning that the system is out of balance. Symptoms of deficiencies on the plants usually indicate that not enough nutrients from fish waste are being produced. Nutrient deficiencies often manifest as poor growth, yellow leaves and poor root development. In this case, the fish stocking density, feed (if eaten by fish) and biofilter can be increased, or plants can be removed.

Similarly, if fish exhibit signs of stress, such as gasping at the surface, rubbing on the sides of the tank, or showing red areas around the fins, eyes and gills, or in extreme cases dying, it is often because of a buildup of toxic ammonia or nitrite levels. This often happens when there is too much dissolved waste for the biofilter component to process. Any of these symptoms in the fish or plants indicates that you need to actively investigate and rectify the cause.

Key learning points

The same nitrogen cycle that happens in soil also happens in the aquaponic system. Nitrifying bacteria convert fish waste (ammonia) into plant food (nitrate).

Bacteria are vital for the overall functioning of an aquaponic unit: Ammonia (NH^3) produced by fish and decomposing organic matter is oxidise (metabolize) to Nitrite (NO^2-).The nitrites (NO_2-) are then converted into nitrates (NO_3-), plant food!

Note: THE NITRITES (like ammonia) ARE TOXIC TO FISH!

Plants need other nutrients: macronutrients (nitrogen, phosphorous, potassium, calcium, magnesium and sulphur) and micronutrients (iron, zinc, boron, copper, manganese and molybdenum). These nutrients are derived from fish poo and released through the process of Mineralization.

The key factors for maintaining healthy bacteria are water temperature, pH, dissolved oxygen and adequate surface area on which the bacteria can grow.

Successful aquaponic systems are balanced. The *feed rate ratio* is the main guideline to balance the amount of fish feed to plant growing area.

Daily health monitoring of the fish and the plants will provide feedback on the balance of the system. Disease, nutritional deficiencies, and death are symptoms of an unbalanced system.

NOTES:

LESSON 2: Ask Question

Question:

1. What is a balanced system?
2. What happens when Fish biomass exceeds the biofilter carrying capacity?
3. What happens Fish and biofilter are correctly sized, but the system is unbalanced with too few plants?
4. What happens Fish and biofilter are correctly sized, but the system is unbalanced with too many plants?
5. Describe how the bacteria and plants purify the water in an aquaponics system

Answer

1. A balanced system where fish, plants and bacteria are in dynamic equilibrium.
2. Fish biomass exceeding the biofilter carrying capacity and therefore an accumulation of toxic ammonia and nitrite occurs.
3. Fish and biofilter are correctly sized, but the system is unbalanced with too few plants and therefore too much nitrate.
4. Fish and biofilter are correctly sized, but the system is unbalanced with too many plants and therefore insufficient nitrate
5. Bacteria remove ammonia from the wastewater by converting it to nitrate, which is then used by the plants. This is one way of cleaning the water. 2. Plants use the nitrates in the water for growth, thereby removing the nitrates from the water and in so doing, clean up the water in which the fish live.

LESSON 3

WATER IS LIFE

Water Quality Management

Water is the lifeblood of an aquaponic system. It is the medium through which plants receive their nutrients and the fish receive their oxygen. It is very important to understand water quality and basic water chemistry in order to properly manage aquaponics.

Because the system combines plants with animal production, it has a special set of water chemistry requirements, and optimal water quality is essential to a healthy, balanced, functioning system.

So what are the most important water quality parameters that affect the health and productivity of aquaponics systems? A good understanding of how these parameters interact with each other is necessary in order to maintain a balanced system.

Never leave uneaten fish feed in the aquaculture tank, so increasing the stocking density of the fish may be necessary. Alternatively, plants can be removed so that there are enough nutrients for those that remain.

Source Water

Selecting the source of water used in an aquaponics system can greatly influence the water quality and is an important first consideration. Potential sources include well water, municipal water, and surface water.

Water Quality Parameters

Compromises are made for some water quality parameters to meet the needs of each organism in aquaponics.

The following are the Main Water Quality Parameters and the target ranges for each parameter:

- Water Temperature: 21–30°C
- Dissolved oxygen (DO): 5 ppm or 5–8 mg/litre
- pH. 6.8–7.4
- Ammonia 0 mg/litre
- Total Ammonia Nitrogen (TAN): <1 ppm
- Nitrite (NO2): 0 mg/litre
- Carbon Dioxide: < 15 mg/L
- Nitrate (NO3): 5–150 mg/litre

(ppm or parts per million, which can be used interchangeably with milligrams per liter [mg/L])

Water Temperature

Water temperature in aquaponics systems will influence not only what type of fish can be reared but also plant growth and the performance of the biofilter. Tilapia prefer temperatures of (27–29°C) for maximum growth. When water temperature drops below 21°C, growth slows dramatically, reproduction stops, and the incidence of disease increases.

Vegetables grow best at temperatures ranging from 21-26 °C, and biofilters (nitrifying bacteria) perform optimally at temperatures ranging from 25 to 30°C. As with other water quality parameters, the key is to find a temperature that falls within the acceptable range for all three components of the aquaponics system.

Dissolved Oxygen

Dissolved oxygen (DO) is one of the most important parameters for growing fish and is also critical to the beneficial nitrifying bacteria that convert fish waste into nutrients plants can use.

Dissolved oxygen levels should be maintained at 5 ppm of DO or higher in most aquaponics systems. In a new system, dissolved oxygen should be measured frequently, but once the system is established, you can measure it less regularly.

Low levels of dissolved oxygen arise more in commercial aquaponics with high stocking rates of fish than in small systems with low fish stocking rates. If the dissolved oxygen is too low, you can increase it by using air stones or a larger pump to increase aeration. Dissolved oxygen levels relate to your water temperature: the warmer the water, the less oxygen it can hold.

There is no risk of adding too much oxygen; when the water becomes saturated, the extra oxygen will simply disperse into the atmosphere. Dissolved oxygen levels are strongly related to temperature: the warmer the water, the less oxygen it can hold.

Carbon Dioxide

Almost all living organisms continuously add CO2 to the water through respiration. CO2 forms an acid when it is added to water, resulting in a pH decline. Conversely, pH increases when CO2 is removed.

Carbon dioxide can be a problem when associated with oxygen depletion, but usually is not a problem by itself unless it is present at extremely high concentrations (> 20 mg/L). When dissolved oxygen is limited, elevated CO2 levels may interfere with the ability of fish to take up the remaining oxygen.

pH

One of the most important water quality variables in aquaponics systems is pH. pH levels can range from 0 to 14, with 7 being neutral. The values between 0 and 7 are acidic, while the values between 7 and 14 are basic or alkaline.

pH means "the power of hydrogen," and it refers to the concentration of hydrogen ions in a solution.

1. Tilapia, for example, require pH to be in the range of 5.0 to 10.0.
2. Plants, on the other hand, grow best when pH levels are below 6.5.
3. Nitrifying bacteria perform optimally at pH levels greater than 7.5.
4. Nitrification is an acidifying process.
5. When pH levels fall below 6, nitrification will slow down or stop and ammonia will accumulate to levels that are toxic to the fish.

Adjusting pH

It is important to measure pH every day because it normally declines daily in response to nitrification processes.

When pH drops below 6, a base in the form of calcium hydroxide or potassium hydroxide should be added to the system to bring it back up to 7.0.

(calcium (Ca) and potassium (K) are essential nutrients that must be supplemented. Also the choice of the buffer can be chosen based on the plant type being cultivated, as leafy vegetables may need more calcium, and fruiting plants more potassium.)

In aquaponics, it is ideal to keep your pH levels between 6.8 and 7.4, which is the compromise range for the fish, the plants, and the nitrifying bacteria.

However, maintaining pH within such a narrow window can be difficult and may lead to unnecessary adjusting and tweaking. As long as the pH is maintained between 6 and 7.4 it will be tolerable to all three components of the system.

At pH 4.5, nitrification has stopped and TAN concentrations can climb to over 30 ppm. When this happens, it is crucial to add base very slowly over several days. Adding a large amount of base all at once will shift the majority of the TAN into the toxic un-ionized form (NH_3), and this could kill all the fish.

Rising or stable pH over time is a problem that can develop. Rising or stable pH can also be indicative of anaerobic (oxygen-free) zones in your aquaponics system where denitrification is occurring. High pH means more ammonia will be present in the toxic in-ionized (NH3) form. To remediate this situation, filter tanks should be cleaned once a week, and all deposits of organic matter accumulated in the hydroponic section should be removed.

Total Ammonia Nitrogen (TAN)

In water, ammonia occurs in two forms, which together are called the Total Ammonia Nitrogen, or TAN. Chemically, these two forms are represented as NH4+ and NH3. NH4+ is called Ionized Ammonia because it has a positive electrical charge, and NH3 is called Unionized Ammonia since it has no charge. This is important to know, since NH3, unionized ammonia (abbreviated as UIA), is the form which is toxic to fish. So, a positive TAN test needs to be followed by a test to find the actual concentration of Un-ionized ammonia (UIA). **(See Attachment 5)**

Water temperature and pH will effect which form of ammonia is predominant at any given time in an aquatic system. In the system TAN should be < 1 mg/L (1 ppm).

Ammonia

Ammonia comes from fish urine, breakdown of solid fish waste, and it is also excreted through the fish gills. In a fish tank, high ammonia levels are toxic to the fish, so it needs to be monitored closely.

Levels Too High: Higher than desired ammonia levels occur when more ammonia is being produced than can be handled by the biofilters. Possible causes for this include overfeeding of fish, fish densities that are too high for the volume of water or not enough aeration. Pumps and DO levels should be checked, and adjustments in feeding rates or fish density should be made.

Ammonia Levels Too Low: If plants are not growing, it could be because not enough ammonia is being produced in the system. Enough ammonia must be produced and converted to nitrate in order for the plants in your system to grow. Low ammonia occurs when there are not enough fish or there is too much water for the number of plants being grown. The solution is to add more fish to your system, feed them more, or use a smaller tank.

Nitrite

Nitrite (NO2) is the intermediate product of the oxidation of ammonia to nitrate and is performed by nitrosomonas bacteria. It is also toxic to fish at high levels Nitrite enters the blood of fish across gill membranes where it combines with the oxygen-carrying portion of red blood cells (hemoglobin) to form a compound called methemoglobin, which cannot carry oxygen.

Methemoglobin has a brown color that it imparts to the blood of fish suffering from nitrite poisoning. Nitrite poisoning thus has the name "brown blood disease."

Nitrate

Nitrate (NO3) is the final product of ammonia in the nitrification process. Processing of nitrite to nitrate is done by Nitrobacter. In fresh water. Nitrate is relatively non-toxic to fish. Weekly water exchanges are a standard practice in recirculating aquaculture to prevent the buildup of nitrate in the system. Because nitrate is the fully oxidized form of nitrogen, high oxygen levels must be maintained in all areas of the recirculating system to prevent reduction of nitrate back to nitrite or ammonia.

Levels Too High

While nitrate is the essential and desirable nutrient by-product of biofiltration, excessive levels (greater than 150 ppm) could be an indication that not enough plants are being grown in the grow beds to take up all the nitrates that are being produced by the nitrifying bacteria. To address overly high nitrate levels, more plants could be added to the existing grow beds, more fish could be harvested to reduce the amount of ammonia being produced, or another grow bed could be added to the existing aquaponics system.

Water Testing

Water testing is essential to maintaining good water quality in the system. In order to maintain good water quality in aquaponic units, it is recommended to perform water tests once per week to make sure all the parameters are within the optimum levels. However, mature and seasoned aquaponic units will have consistent water chemistry and do not need to be tested as often. Ammonia and nitrite tests should be used especially at system start-up and if abnormal fish mortality raises toxicity concerns.

Access to simple water tests are strongly recommended for every aquaponic unit. Colour-coded freshwater test kits are readily available and easy to use. Each test involves adding 5–10 drops of a reagent into 5 millilitres of aquaponic water; each test takes no more than five minutes to complete. Other methods include digital pH or nitrate meters (relatively expensive and very accurate) or water test strips (cheapest and moderately accurate)

It is worthwhile and recommended to test for nitrogen levels every week to make sure the system is properly balanced. Moreover, nitrate levels are an indicator of the level of other nutrients in the water.

Water testing kits

Simple water tests are a requirement for every aquaponic unit. Colour-coded freshwater test kits are readily available, fairly economical and easy to use, and thus these are recommended.

These can be purchased in aquarium stores or online. These kits include tests for pH, ammonia, nitrite, nitrate, GH (or General Hardness) and KH (or Carbonate Hardness)

. Be sure that the manufacturers are reliable and that the expiration date is still valid. Other methods include digital meters or test strips. If using digital meters for pH or nitrate, be sure to calibrate the units according to the manufacturer's directions.

GH (or General Hardness) *measures the amount of calcium and magnesium ions in the water – in other words, how hard or soft your water is.*

KH (or Carbonate Hardness) *measures the amount of carbonates and bicarbonates in water, which affects the buffering capacity of the water. This means that KH helps neutralize acids and prevents your pH from changing too rapidly,*

Key learning points

Water is the lifeblood of an aquaponic system. It is the medium through which plants receive their nutrients and the fish receive their oxygen.

Fish can tolerate elevated levels of nitrate

Water needs to be removed and exchanged when nitrate is greater than 150 mg/litre.

Water testing will provide information on the balance of the system.

High ammonia or nitrite (> 1 mg/litre) indicates insufficient biofiltration; low nitrate (<10mg/litre) indicates too many plants or not enough fish; increasing nitrate is desirable and indicates adequate nutrients for the plants,

NOTES:

LESSON 4

INTRODUCING THE COMPONENTS

Key Components Of Aquaponic Systems

Understanding each of the elements of aquaponics is key to running a thriving aquaponics system. From fish selection to grow bed selection, it is important to think about your objectives and constraints before building your system. Let us now introduce you to the Key Components of your aquaponics System.

The key Components in an Aquaponics system are the Lifeforms

- Our Fishes
- Our Plants
- Bacteria

These three living entities play critical role. They each rely on the other to live. This is discussed in more detail in Lesson 5

The other main physical parts (components) of an aquaponics system are:

- Rearing Tanks – where the fishes grow
- Grow Beds – where the plants are located
- Growing Media
- Aquaponics filters: mechanical and biological
- Pumps – air and water movement – Water Pump is located at the lowest point of the system and used to push water back to the upper level. Aeration system (air pump, air stone, filter, tubing) – to provide oxygen
- Sump tanks – lowest point in the system to catch water. The pump can be placed here.
- Water testing kits

LESSON 5

THE LIFEFORMS COMPONENTS IN AN AQUAPONICS SYSTEM AND UNDERSTANDING THE ROLES

Our Fish, Plants and Bacteria

In lesson 2 , we discussed Balancing The Aquaponic Ecosystem and all the measures you must take to ensure that the ecosystem of fish, plants and bacteria is at a dynamic equilibrium. It cannot be overstated that successful aquaponics is primarily about maintaining a balanced ecosystem. Achieving maximum production from aquaponics requires the maintaining of an appropriate balance between fish waste and vegetable nutrient demand, while ensuring adequate surface area to grow a bacterial colony in order to convert all the fish wastes. To achieve this there are roles that each of our key players must perform.

Our Fish

Fish plays a vital role in the aquaponics system as they will be the source of natural fertilizer for the plants, so proper selection of fish to raise in your aquaponics system is critical. To ensure the success of your aquaponics system it is important to know what the best fish for your system is.

Key things to consider when selecting the fish for your system:

1. Purpose: Aside from providing food for your plants, what is the goal of raising your fish? The easiest way to start your aquaponics system is to grow a few fish for recreation like koi or food like tilapia. You can expand to a larger scale in the future after you have gained experience and skills.

2. Temperature: Different fish have different water temperature requirements. It is important to choose a fish that is adaptable to our temperature and weather conditions. Some fish such as tilapia, prefer warm water.

3. What crops are to be grown? Fish should feed well at the same temperature at which the plants thrive. Make sure that both your fish and plants have the same temperature requirements.

4. Maintenance Difficulty: If you don't want to put much effort into maintaining your system, you can choose a sturdy fish that can live in dirty water and immune to parasites and disease. Some fish are hardy and don't require much care, while others are sensitive and costly. Koi and tilapia are easy to raise for a beginner.

Role of fish

Fish are the power house of an aquaponics system, they provide the nutrients for the plants and if your growing edible fish, then they also provide protein for yourself. Keeping fish may be a little daunting to some, especially those without any prior experience, however you shouldn't be discouraged. Keeping fish in an aquaponic system is more simple than keeping aquarium fish, so long as you follow simple guidelines then growing fish from fingerling size, to ready to eat fish can be extremely simple.

What fish should I grow?

Food for thought: In deciding what is the best species for you to grow, here are a few final things to consider:

Firstly and most importantly is '***To eat, or not to eat, that is the question***'. If you don't want to eat your fish then you probably won't want to grow edible fish, or you may want to grow an edible fish that is hardy.

The second most important factor is **'What's available?**' You need to be able to buy fish to stock your system, even with species such as Tilapia that breed readily, you need to get your broodstock in the first place.

Here are two useful aquaponic species I recommend with a few details about each

Koi

A species of carp, but better known as "Koi". Koi is a very common species sold by many breeders and aquarium shops in Trinidad and Tobago. For those who love Koi, an aquaponic system is a great proposition for stocking the fish.

Tilapia

The most cultured fish, and extremely popular in Aquaponics systems is the Tilapia. They are an ideal species for aquaponics for many reasons. They are easy to breed, fast growing, withstand very poor water conditions, and are good eating. Warm water fish; Tolerates pH shifts, temp changes, high ammonia, and low dissolved oxygen

Omnivorous – pellet fish food, duckweed, veggies from the system

Grows to plate size in about 6-9 months (ideal conditions)

Acclimatizing fish

The fish must be properly acclimatized to the new water. Acclimatizing fish into new tanks can be a highly stressful process for fish, particularly the actual transport from one location to another in bags or small tanks. The main factor that cause stress when acclimatizing fish is changes in temperature between the original water and new water**.** The best method to do address this is to slowly allow the temperature to equilibrate by floating the sealed transportation bags containing the fish in the culture water. This should be done for at least 15 minutes.

So how many fish can I have?

This can be quite a hot topic of debate amongst people who practice aquaponics. Stocking levels of fish within a system can be as high as many intensive recirculating aquaculture systems, however the higher the stocking density the higher the likelihood of things going wrong. In very heavy stocking densities, you need to keep a constant eye on all water parameters to be sure that conditions are kept at the optimum.

So let's do a little calculation on Fish Stocking Density

Ask Question

Question :

What is the number of fish that I can have in a tank of 300 gallon?

Tank size = 300 gallon

Assume

- 0.25lb fish per gallon (conservative) to 0.5lb per gallon (moderate)
- Important to know final grow out weight of fish to determine appropriate stocking density
- Assume we want Tilapia with average harvest size = 1.5lb

Answer

Tank size = 300 gallon

Total fish weight = 300 x 0.25lb = 75 lbs

Number of fish = 75lb/1.5lb = 50 fish

What do I need to know about feeding my fish?

Fish Feeds

- Commercial fish feeds contain exact protein, carbohydrate and other vitamin requirements for specific fish
- Plant based proteins can include soy meal, corn meal, wheat meal etc…
- Most commercial feeds are between 10 to 35% protein
- Alternative feeds should be considered like duckweed, insects, or worms
- Avoid fish meal based feeds as this source is not sustainable.

You may wish to refer to **Attachment 3** for more information on how to properly feed, handle and harvest tilapia culture.

Alternative feed source

I will say a little about duckweed which MAY be the food of the future. There is no doubt about that. I do not profess to be an expert at growing farm-raised duckweed to feed our fish however grown under ideal conditions, duckweed ranges between 25% and 45% protein and doubles its growth every 36 hours, and OUR TILAPIA love to eat it. Farmers from pig farms, rid their waste through large duckweed lagoons." It helps manage their animal wastes through biological treatment and can even 'clean' pig-waste water and makes the water potable by running the water through enough duckweed. Interesting, eh?

Duckweed seems to overgrow in places that people do not want it to grow – like ponds, rivers and lakes, but it's been difficult for us to raise it in tubs for more than a few weeks before it dies. If duckweed covers the surface of a body of water, there is an oxygen depletion which kills fish in the ponds or rivers. (Feed tilapia only enough for them to eat. The remnants are picked off over time.)

How do I Keep my Fish Healthy?

Fish diseases

The three major groups of pathogens that cause fish disease are fungus, bacteria and parasites. All of these pathogens can easily enter an aquaculture system from the environment, when adding new fish or new water, or could have previously existed in the unit. Prevention is by far the best way to prevent disease in fish. Daily observation of fish and monitoring for disease allows the disease, if present, to be treated quickly to prevent more fish from being infected.

Keeping Fish Healthy

Keeping your fish healthy is critical to the success of your Aquaponics venture. Remember the fish is the engine for your system. To do this you need to

1. **Ensure the tank parameters are maintained**
2. **Manage your Fish Health**
3. **Maintain your Fish**

***Tank Parameters*:**

- pH – Most fish like pH between 6-8
- Ammonia and nitrites are very toxic to fish

- Nitrates are fairly safe for fish (and great for plants)
- Fish need oxygen (they can die in 30 min. without it) Battery based aerators are available for power outages
- Drastic temp changes can cause health issues and death
- Fish can not regulate their body temperature like humans do. They are dependent on the water temperature for their body temperature
- Sensitive to light (avoid direct light)

Fish Health Management

- Always exercise good hygiene and biosecurity— prevention, avoidance, selective access, and common sense.
- Quarantine fish from other facilities before stocking them in your system. Monitor their health for several days—treat if necessary.
- The best defense is your fish's own immune system. Provide a low-stress environment and your fish will maintain their health.

Fish Maintenance

- Feed fish 2 - 3 times a day, but don't overfeed
- Fish eat 1.5 – 2% their body weight per day
- Only feed fish what they can eat in 5-10 minutes
- Fish won't eat if they are too cold, too hot or stressed
- Check water quality, add water or do partial water changes if necessary
- Observe fish behavior and appearance Some fish become "social" and will "greet you"

Think like a fish, "What would make you happy?

Bacteria

An aquaponics system requires beneficial bacteria for the fish and plants to thrive. As we discussed before Bacteria plays an important part in the aquaponic cycle. Once converted into nitrates, they can be absorbed by the plants. These bacteria can be present in the grow bed, grow media, fish tank, and biofilter.

Role of Bacteria

The role of bacteria in an aquaponic system is to remove ammonia from the wastewater by converting it to nitrate, which is then used by the plants.

The ecosystem within the aquaponic unit is totally reliant on the bacteria. If the bacteria are not present or if they are not functioning properly, ammonia concentrations in the water will kill the fish. So it is vital to keep and manage a healthy bacterial colony in the system at all times in order to keep ammonia levels close to zero.

Recall from **Lesson 2**, 50% of fish waste is in the form of ammonia released through urine, fecal matter and gills. Bacteria consume fish waste, decaying plant matter and uneaten food. The bacteria transform waste into nutrients for the plants; this process is known as **nitrification**. Remember the Nitrogen Cycle?

Nitrification is a process in which organic compounds are converted into nitrites and then into nitrates.

Bacteria nitrosomonas converts ***Ammonia (NH3 or NH4+) to Nitrite (NO2-) –*** (Nitrite is toxic to fish.)

Bacteria nitrobacter converts **Nitrite (NO2-) to Nitrate (NO3-)** (Nitrate is primary source of plant nutrition.)

Nitrate is the good stuff – it is relatively safe for fish and great for growing plants

Maintaining A Healthy Bacterial Colony

The major parameters affecting bacteria growth that should be considered when maintaining a healthy biofilter are adequate surface area and appropriate water conditions.

Water quality tolerance ranges for nitrifying bacteria

	Temperature (°C)	pH	Ammonia (mg/litre)	Nitrite (mg/litre)	Nitrate (mg/litre)	DO (mg/litre)
Tolerance	17–34	6–8.5	< 3	< 3	< 400	4–8

Surface Area: Remember bacterial colonies will thrive on any material, such as plant roots, along fish tank walls and inside each grow pipe. The total available area available for these bacteria will determine how much ammonia they are able to metabolize and remove. Depending on the fish biomass and system design, the plant roots and tank walls can provide adequate area. Systems with high fish stocking density require a separate biofiltration component where a material with a high surface area is contained, such as inert grow media – bioballs / fish net in the filter or expanded clay / gravel in the media beds.

Water pH: The pH is how acidic or basic the water is. The pH level of the water has an impact on the biological activity of the nitrifying bacteria and their ability to convert ammonia and nitrite (Optimal pH 7-8). For our aquaponics system however, an appropriate pH range is 6–7 because this range is better for the plants and fish. While this will cause a loss of bacterial efficiency it can be offset by having more bacteria, thus biofilters should be sized accordingly.

Water temperature: Water temperature is an important parameter for bacteria, and for aquaponics in general. The ideal temperature range for bacteria growth and productivity is 17–34°C. In Trinidad and Tobago this does not impact our system greatly. Our hot climate however does causes evaporation so monitoring of water levels are important.

Dissolved oxygen: Nitrifying bacteria need an adequate level of dissolved oxygen (DO) in the water at all times in order to maintain high levels of productivity. Nitrification is an oxidative reaction, where oxygen is used as a reagent; without oxygen, the reaction stops. Optimum levels of DO are 4–8 mg/litre. Nitrification will decrease if DO concentrations drop below 2.0 mg/ litre. Moreover, without sufficient DO concentrations, another type of bacteria can grow, one that will convert the valuable nitrates back into unusable molecular nitrogen in an anaerobic process known as denitrification.

Ultraviolet light: Nitrifying bacteria are photosensitive organisms, meaning that ultraviolet (UV) light from the sun is a threat. This is particularly the case during the initial formation of the bacteria colonies when a new aquaponic system is set up. Once the bacteria have colonized a surface (3–5 days), UV light poses no major problem. A simple way to remove this threat is to cover the fish tank and filtration components with UV protective material while making sure no water in the hydroponic component is exposed to the sun, at least until the bacteria colonies are fully formed.

Bacteria Maintenance

- Proper pH 7 – 8
- Best temperature 22 ^{o}C – 27^{o}C (ideal 25 ^{o}C)
- No pesticides, algaecides, chlorine, chloramine, cleaning agents or chemicals
- Started with a fishless or fish cycling

Our Plants

There are many plants that you can grow in an aquaponics system, and picking plants to grow in your aquaponics system can be a fun part. However, different plants have different needs and thrive under different conditions. Making the right choice in aquaponics plants is essential to the success of the system and the success of your harvest. The most common plant types found in aquaponics systems are: lettuce, tomatoes, peppers, basil, cucumbers.

Why do Plants like Aquaponics?

- Nutrients constantly provided
- Warm water bathing the roots
- Don't have to search for water or food
- Less effort needed in putting out roots
- All the energy goes into growing UP not DOWN
- No weed competition

To choose the best plant for your aquaponics system, do some additional research or consult the Ministry of Agriculture Farms.

Don't limit your imagination to just these plant types. You can grow almost any plant variety in an aquaponics system.

Role of Plants

The main role of plants in an aquaponic system is in the conversion of wastewater to clean water. Remember the Bacteria remove ammonia from the wastewater by converting it to nitrate. Plants the use the nitrates in the water for growth, thereby removing the nitrates from the water and in so doing, clean up the water in which the fish live.

So how many plants can I have?

Many plants can be grown in aquaponic systems, and the choice of plants will depend on the stocking density of the fish being grown because this will influence the concentration of nutrients in the fish effluent. Plants that have low to medium nutrient requirements that are well adapted to aquaponic systems include lettuce, basil, spinach, chives, herbs, and watercress.

Other plants, such as tomatoes, cucumbers, and peppers, have higher nutrient requirements and will only do well in aquaponic systems that have high stocking densities of fish. Root crops require special attention, and they can only be grown successfully in deep media beds

It is important to consider the effect of harvesting the plants on the entire ecosystem.

If all of the plants were to be harvested at once, the result would be an unbalanced system without enough plants to clean the water, resulting in nutrient spikes. If this is done it must correspond with a large fish harvest or a reduction of the feed ration. Be aware that the presence of too many plants growing synchronously would result in the systems being deficient in some nutrients towards the harvest period when the uptake is at a maximum.

I recommend that you consider a staggered harvesting and replanting cycle. By having plants at different life stages, i.e. some seedlings and some mature, the overall nutrient demand is always the same. This ensures more stable water chemistry, and also provides a more regular production.

What influences the amount of available nutrients to plants?

- Density of fish population
- Size of fish
- Temperature of water
- Amount of uneaten fish feed in water
- Availability of beneficial bacteria
- Amount of plants in the system
- Media present in system
- Water flow rate

How do I Keep my Plants Healthy?

PLANT HEALTH, PEST AND DISEASE CONTROL

Plant health has a broad meaning that goes far beyond just the absence of illnesses; it is the overall status of well-being that allows a plant to achieve its full productive potential. Plant health, including disease prevention and pest deterrence and removal, is an extremely important aspect of aquaponic food production.

Successful plant production is the result of management strategies to avoid disease outbreaks that mainly focus on the environmental conditions, pest deterrence (pests such as whitefly may carry lethal viruses) on plant management as well as the use of organic remedies that help to prevent or to cure the plants. Integrated disease management relies on prevention, plant choice, and monitoring as a first line of defence against disease and uses targeted treatment only when necessary.

For pest management in aquaponics, prevention is fundamental. Regular and thorough monitoring for pests is vital, and, ideally, minor infestations can be identified and managed before the insects damage the entire crop. Attachment 4 provides natural measures for pest control.

Nutrition greatly affects a plant's susceptibility to disease. It also affects a plant's ability to respond against disease. A correct balance of nutrients not only provides optimal growth but also makes plants less susceptible to diseases.

NUTRIENT REQUIREMENTS

In addition to these basic requirements for photosynthesis, plants need a number of nutrients, also referred to as inorganic salts. These nutrients are required for the enzymes that facilitate photosynthesis, for growth and reproduction. In aquaponics, all of these essential nutrients come from the fish waste. Deficiencies in these nutrients are a result of the composition of the fish feed. Fish feed pellets are a complete food for the fish, meaning they provide everything that a fish needs to grow, but not necessarily everything needed for plant growth. Fish simply do not need the same amounts of iron, potassium and calcium that plants require. As such, deficiencies in these nutrients may occur. This can be problematic for plant production (**see Attachment 4).**

There are two major categories of nutrients: macronutrients and micronutrients. Both types of nutrients are essential for plants, but in differing amounts. Much larger quantities of the six macronutrients (nitrogen, phosphorous, potassium, calcium, magnesium and sulphur) are needed compared with the micronutrients (iron, zinc, boron, copper, manganese and molybdenum), which are only needed in trace amounts.

Nitrogen is supplied to aquaponic plants mainly in the form of nitrate, converted from the ammonia of fish waste through bacterial nitrification. Some of the other nutrients are dissolved in the water from the fish waste, but most remain in a solid state that is unavailable to plants. The solid fish waste is broken down by heterotrophic bacteria; this action releases the essential nutrients into the water.

The best way to ensure that plants will not suffer nutrient deficiencies in aquaponics is to maintain the 6-7 pH water level and feed the fish with a balanced and complete diet and use the feed rate ratio to balance the amount of fish feed to plants.. Another good way is to provide all the nutrients that plants require to grow by growing media beds. Grow media beds offer an excellent environment for nutrients to develop into your system, and you can also add worms in your grow media bed to help break the solids and provide more nutrients for your plants.

However, over time, even an aquaponic system that is perfectly balanced may become deficient in certain nutrients, most often iron, potassium or calcium. Calcium and potassium are added when buffering the water to the correct the pH, as nitrification is an acidifying process. The choice of the buffer can be chosen based on the plant type being cultivated, as leafy vegetables may need more calcium, and fruiting plants more potassium.

Iron Deficiency: Add chelated iron to reach concentrations of about 2mg/litre.

Calcium Deficiency: Add calcium hydroxide or potassium carbonate.

Potassium Deficiency: Add potassium hydroxide, or potassium carbonate.

Key learning points

Aquaponics is a system that needs to be balanced for the fish, plants, and bacteria to thrive.

Achieving maximum production from aquaponics requires the fish, plants, and bacteria to play their roles.

Fish are the powerhouse of an aquaponics system, they provide the nutrients for the plants and if your growing edible fish, then they also provide protein for yourself.

It is vital to always keep and manage a healthy bacterial colony in the system in order to keep ammonia levels close to zero so that your fish do not die, and your plants will have food.

Bacteria remove ammonia from the wastewater by converting it to nitrate.

Plants the use the nitrates in the water for growth, thereby removing the nitrates from the water and in so doing, clean up the water and allowing it to be recirculated in the system.

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.

The most important water quality parameter for plants is pH because it affects the availability of essential nutrients.

It is essential to always check the specific water quality parameters.

NOTES:

Activity Worksheet #2

KNOW BEFORE YOU BUILD: THE NUTRIENT CYCLE

How do different living things (organisms) in an aquaponics system depend on each other? Use the table below to help you organize your thoughts.

Organism	What's the role? (producer, consumer, or decompose	What do they need from other living things to survive?	How do they get it?	How do they help others?	Where do they get their energy?
Fish					
Plant					
Bacteria					bacteria obtain their energy from the ammonium oxidation process.

LESSON 6

THE BUILD OUT COMPONENTS IN AN AQUAPONICS SYSTEM

Essential components of your aquaponic unit.

Aquaponic systems come in all shapes and sizes, from simple, low-tech backyard operations to large-scale, more sophisticated commercial operations. Regardless of the size, materials used, or level of complexity, all systems share the same basic design that consists of the same components:

Rearing tank: The tank or container where the fish/aquatic animals are raised and fed.
Mechanical Filter or Settling basin: Some sort of unit to capture all uneaten food and detached biofilm (the film or coating that nitrifying bacteria form on inert material or organic particles), and where fine particulates can settle out.
Biofilter: A place where the bacteria can grow and convert ammonia to nitrates and organic wastes to carbon dioxide, which are used as nutrients for plants.
Hydroponics portion of the system: This is where the plants are grown by taking up the excess nutrients from the effluent water.
Sump: This is the lowest point in the system and is where the water flows, after which it gets pumped back into the rearing tanks.

Rearing Fish Tanks

Fish tanks are a crucial component in every unit. The fish tank is where your fish live, so choose the right fish tank that will help your fish thrive and make your aquaponics system run smoothly. You can use recycled bathtubs, stock tanks, IBC tanks, and recycles barrels as a fish tank if you choose to do a do-it-yourself fish tank. **Proper selection of fish tanks is critical to system design. Some key considerations are:**

- ***Tank size & shape***: Tanks must be large enough for the species selected. Tank shape greatly affects water circulation. Rectangular and square IBC tanks with flat bottoms are primarily used because of cost and availability however you should note that they allow solid wastes to collect and rot in corners and will require more active solid-waste removal. So be careful. Round fish tanks are recommended. The round shape allows water to circulate uniformly and transports solid wastes towards the centre of the tank by centripetal force.
- ***Material:*** Either strong inert plastic or fibreglass is recommended because of their durability and long life span. Metal is not possible because of rust. Plastic and fibreglass are convenient to install (also for plumbing) and are fairly light and manoeuvrable.
- ***Colour:*** White or other light colours are strongly advised as they allow easier viewing of the fish in order to easily check behaviour and the amount of waste settled at the bottom of the tank. White tanks will also reflect sunlight and keep the water cool.
- ***Failsafe and redundancy:*** Do not let the fish tank lose its water; fish will die if the fish tank accidentally drains. Ensure that there is no way for the tank to drain without a deliberate choice. Tanks should ideally have a drain that allows solid waste to get out of the tank easily.
- Choose a fish tank that is sturdy, durable, waterproof, and heavy-duty to withstand water pressure.
- ***Prior use:*** ***F***ish tanks should be inert, non-toxic, and food safe.
- ***Covers and shading:*** All fish tanks should be covered. The shade covers prevent algal growth. In addition, the covers prevent fish from jumping out, prevent leaves and debris from entering, and prevent predators such as cats and birds from attacking the fish. Often, agricultural shading nets that block 80–90_percent of sunlight are used. The shade cloth can be attached to a simple wooden frame to provide weight and make the cover easy to remove.

Aquaponics filters: mechanical and biological

Let's talk a bit about aquaponics filtering systems. Some level of filtration is essential to all aquaponics, although fish stocking density and system design determine how much filtration is necessary.

Aquaponics filtering systems involve two types: mechanical and biological.

Mechanical filters

Before we get started, you need to know there are different kinds of solids. These are:

1. Settable solids
2. Suspended solids
3. Floating solids

Mechanical filtration is the separation and removal of solid and suspended fish waste essentially for the health of the system. For aquaponics, mechanical filtration is arguably the most important aspect of the design.

Getting rid of the settable solids is easy as over time they will settle to the bottom.

Suspended solids are harder to remove. They are light and therefore do not settle to the bottom. You have to capture them using another filtering method. Some people use a sock or fish netting on the outlet to catch these solids. Others use a screen.

If you are using Media-filled bed, you don't have to worry about these kinds of solids because it's not that much. If you are using Deep Water Culture (DWC)/ Raft Culture or Nutrient Film Technique (NFT) you need to catch these suspended solids. Don't get worried we will discuss these systems below.

What I need you to understand however are:

- Media-filled bed: too many solids will clog up the growbeds and create aerobic zones. You can monitor this by watching the pH of your water go up. If solids build-up, aerobic zones are created, and nitrifying bacteria will die, this will lead to an increase in pH. Most people who are running a Media-filled bed system with a ratio that is too high (higher than 1) clean out the growbeds once every planting cycle.
- Deep Water Culture (DWC) or Raft Culture: Solids removal in DWC systems is not needed if your density is below 0.3. Solid filtration is necessary if you have a higher density system. If you do not remove solids from a high-density system, it will create a sludge at the bottom of the troughs and create gasses and aerobic zones, which is bad for your nitrifying bacteria. Solids will attach themselves to the roots of the plants you are growing and block their nutrient uptake.
- Nutrient Film Technique (NFT): If you are using an NFT system, your water needs to be very clean. This is probably the hardest part of aquaponics if you are using NFT. If you do not remove all the solids (settable and suspending solids), you will run into problems soon. The solids will attach to the roots and prevent the plant from taking up nutrients. It can also block up the channels themselves.

Mechanical Filter or Settling basin

A clarifier is a dedicated vessel that uses the properties of water to separate particles. Generally, water that is moving slower is unable to carry as many

particles as water that is flowing faster. Therefore, the mechanical filter is constructed in such a way as to speed up and slow down the water so that the particles concentrate on the bottom and can be removed.

There are many types of mechanical filters, including sedimentation tanks, swirl filter, radial-flow separator, sand or bead filters and baffle filters. Each of them can be used according to the size of solid wastes that need to be removed. We will discuss two main types: swirl filter, radial-flow separator.

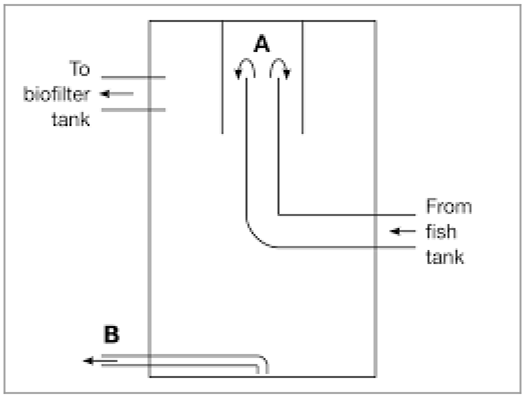
Swirl Filter

In a swirl clarifier, the water from the fish tank enters near the lower middle of the filter through a pipe. This pipe is positioned tangentially to the container thereby forcing the water to swirl in a circular motion inside the container.

The centripetal force created by the circular motion of the water forces the solid waste in the water to the centre and bottom of the container, because the water in the centre of the vortex is slower than that on the outside. Once this waste is collected on the bottom, a pipe attached to the bottom of the container can be periodically opened, allowing the solid waste to flush out of the container. The clarified water exits the clarifier at the top, through a large, slotted outlet pipe covered with a secondary mesh filter, and flows into the biofilter or into the media beds.

Radial flow separator

The radial flow separator, also called the radial flow filter or radial flow settler, is the most used filter in aquaponics. It’s more efficient than using a vortex or clarifier but is a little bit more complicated.



If you are using Media-filled bed, you don't have to worry about these kinds of solids because it's not that much.

If you are using Deep Water Culture (DWC)/ Raft Culture or Nutrient Film Technique (NFT) you need to catch these suspended solids

Adequate preliminary mechanical filtration is especially important for Deep Water Culture (DWC)/ Raft Culture or Nutrient Film Technique (NFT) units and are used to trap and remove solid waste. Without this preliminary process, solid and suspended waste will build up in the grow pipes and canals and will clog the root surfaces. Solid waste accumulation causes blockages in pumps and plumbing components. Finally, unfiltered wastes will also create hazardous anaerobic spots in the system. These anaerobic spots can harbour bacteria that produce hydrogen sulphide, a very toxic and lethal gas for fish, produced from fermentation of solid wastes, which can often be detected as a rotten egg smell.

Note:

***A general guideline is the mechanical filter container should be about 20% the volume of the fish tank*, but this depends on stocking density and the exact design.**

In a unit without the media beds, such as in NFT and DWC units, standalone filtration is necessary

Biofiltration

Biofiltration is the conversion of ammonia and nitrite into nitrate by living bacteria as we discussed earlier. Most fish waste is not filterable using a mechanical filter because the waste is dissolved directly in the water, and the size of these particles is too small to be mechanically removed.

In an aquaponic unit, the biofilter is a deliberately installed component to house a majority of the living bacteria. The biofilter is installed between the mechanical filter and the hydroponic containers.

Any biofilter should be designed to have

- a high ratio of surface area to volume,
- be inert and be easy to rinse.
- a large surface area supplied with oxygenated water.

Biofiltration is essential in aquaponics because ammonia and nitrite are toxic even at low concentrations, while plants need the nitrates to grow. Furthermore, the dynamic movement of water within a biofilter will break down very fine solids not captured by the clarifier, which further prevents waste build up on plant roots in Nutrient Film Technique (NFT) and Deep Water Culture (DWC).

One commonly used biofilter medium is Bioballs available from fish and aquaculture supply stores but can be costly. These are designed to be an ideal biofilter material, because they are small, specially shaped plastic items that have a very large surface area for their volume (500–700m^2/m^3). Other cheaper media can be used, including plastic bottle caps, discarded netting, and nylon scrub pads.

Biofilters occasionally need stirring or agitating to prevent clogging, and occasionally need rinsed if the solid waste has clogged them, creating anoxic zones. Anoxic conditions will occur if the rate of oxidation of organic matter by bacteria is greater than the supply of dissolved oxygen.

So another required component for the biofilter is aeration. Remember Nitrifying bacteria need adequate access to oxygen in order to oxidize the ammonia.

One easy solution is to use an air pump, placing the air stones at the bottom of the container. This ensures that the bacteria have constantly high and stable DO concentrations. Air pumps also help break down any solid or suspended waste not captured by the mechanical separator by agitating and constantly moving the floating Bioballs or other media material.

In Media Bed Systems the media beds themselves act as both mechanical filters and biofilters when using this technique, but additional mechanical filtration is sometimes necessary for higher fish densities (15 kg per m^3).

In a unit without the media beds, such as in NFT and DWC units, standalone filtration is necessary

The minimum volume of this biofilter container should be 25% that of the fish tank.

Sump Tank

The sump tank is a water collection tank at the lowest point in the system; water always runs downhill to the sump. This is often the location of the submersible pump. Sump tanks should be smaller than the fish tanks and should be able to hold one-third of the volume of the fish tank.

If your system has media filled beds, then there is an almost total drain down when the system flushes so the sump will need to be large enough to hold at least the entire volume of water in the media filled grow beds. A common method of aquaponics, and the one recommended here, is to have the pump located in the sump tank.

Having a sump tank in your system means that any water losses, including both evaporation and leaking components, are only manifested within the sump tank and do not affect the volume of the fish tank. It is then straight-forward to measure the normal evaporative losses and to calculate how often water needs replenishing, and it can be determined immediately if there is a leak.

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Hydroponics portion of the system

Grow Beds

In aquaponics, your grow bed is another critical component of your system. This is where your plants grow, so choosing the right grow bed is crucial to how your whole aquaponics system works. For the success of your aquaponics system, it must be balanced. It means there must be a perfect balance between the amount of fish waste produced by your fish to your biofilter's performance and the plants that absorb the nutrients from the water.

The rule of thumb is, start with the grow bed and the fish tank ratio of 1:1. The total volume of your grow bed should be equal to the total volume of your fish tank to ensure balance and sufficient filtration. You can expand once you're ready for a larger system.

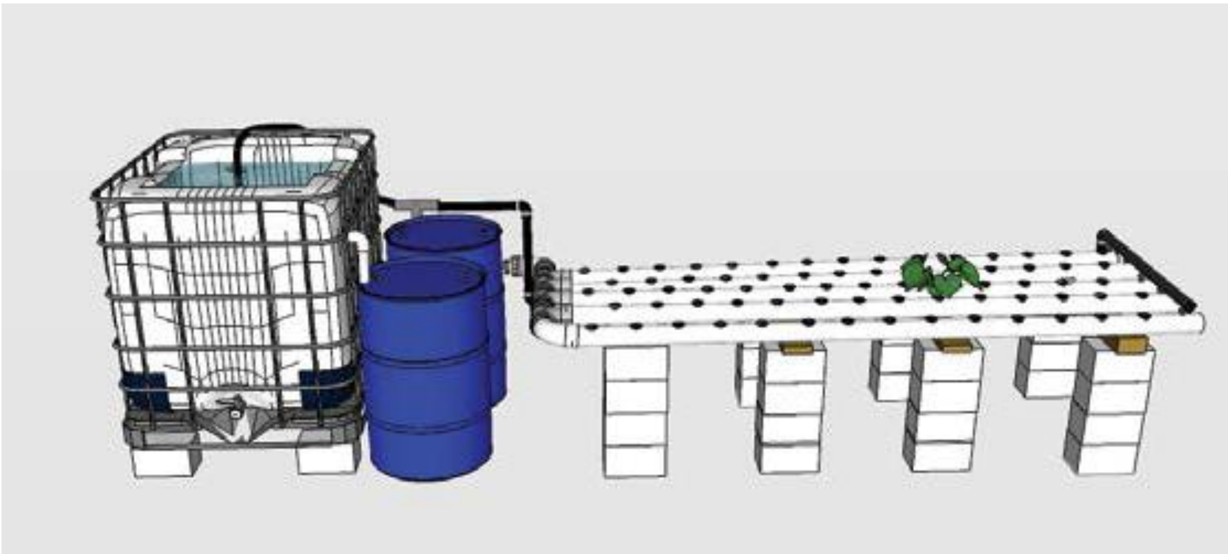
Things to consider in choosing grow bed:

- The grow bed must be strong and thick enough to hold the weight of the grow media, plants and the force of constant draining and filling of water
- Choose a food-safe non-toxic material for your grow bed.
- Avoid using metals because metals can corrode quickly and can cause an imbalance to your system and lower your pH.
- Choose a grow that is suitable for a variety of plants that you choose to grow.
- Use a waterproof, grow bed.

Let us now discuss the hydroponic techniques, these include:

1. Nutrient Film Technique (NFT)
2. Deep Water Culture (DWC) or Raft Culture
3. Media-filled bed

Nutrient Film Technique (NFT)



Source: Food and Agriculture Organization of the United Nations (FAO)

In the NFT method, the plants are grown in long narrow channels. A thin film of water continuously flows down, providing the plant roots with water, nutrients and oxygen. Water flows continuously from the fish tank, through filtration components, through the NFT channels where the plants are grown and then back to the fish tank

In NFT, a separate bio filter is required, because the volume of water is not large enough for the beneficial bacteria to live. The plumbing system in a hydroponics NFT system is not large enough for aquaponics because the organic matters in the system will cause clogging of small pipes and tubes. NFT aquaponics is used less than media-filled bed and raft culture.

Media-filled bed

Source: Food and Agriculture Organization of the United Nations (FAO)

Media-filled bed units are the most popular design for small-scale aquaponics. These designs are efficient with space, have a relatively low initial cost and are suitable for beginners because of their simplicity.

A media-filled bed system uses a tank or container that is filled with gravel, riverstone, Expanded Clay (Hydroton) or other media for the plant bed.

In media bed units, the medium is used to support the roots of the plants and also the same medium functions as a filter, both mechanical and biological. This double function is the main reason why media bed units are the simplest; The bed is periodically flooded with water from the fish tank then the water drains back to the fish tank. All waste is broken down within the plant bed. The system uses very few components and no additional filtration is needed, making it simple to operate. However, production is much lower than the other two methods described.

However, the media bed technique can become unwieldy and relatively expensive at a larger-scale. Media can become clogged if fish stocking densities exceed the beds' carrying capacity, and this can require separate filtration. Water evaporation is higher in media beds with more surface area exposed to the sun. Some media are very heavy. The media-filled bed is good for applications where maximizing production is not a goal.

Irrigating media beds

There are different techniques to deliver water to media beds, each can be relevant depending on the local availability of materials, the degree of technology desired or your experience and comfort level. During this training we will briefly discusses two popular methods for irrigating our media beds: constant flow and flooding and draining.

Constant Flow Designs

The simplest system is the **constant flow designs**, where the water level within the grow bed is always the same, support the same growth rates of plants as more complicated methods. These water distribution systems can become clogged with solid fish waste and should be periodically cleared.

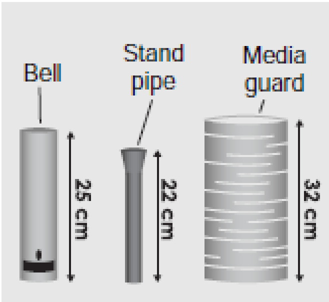
Flood-And-Drain Design

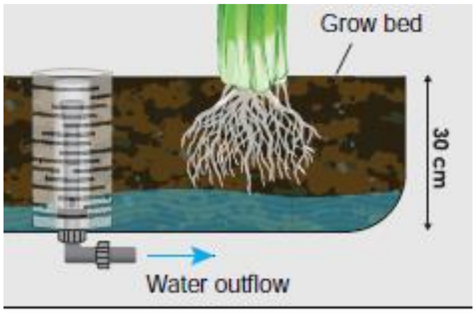
The **flood-and-drain design**, also known as ebb-and-flow, can be used where the system of plumbing causes the media beds to flood with water from the fish tank and then drain back in the sump tank. This is accomplished through timed pumping or autosiphons. This alternation between flooding and draining ensures that the plants have both fresh nutrients and adequate air flow in the root zone. This thereby replenishes the oxygen levels for plants and bacteria. It also ensures that enough moisture is always in the bed so the bacteria can thrive in their optimum conditions.

Usually, these systems go through the complete cycle 1–2 times every hour. I have found that managing the water flow cycle may be frustrating and time-consuming for novice operators.

Autosiphons: ***Bell siphon***

The bell siphon is a type of autosiphon that exploits a few physical laws of hydrodynamics and allows the media bed to flood and drain automatically, periodically, without a timer.



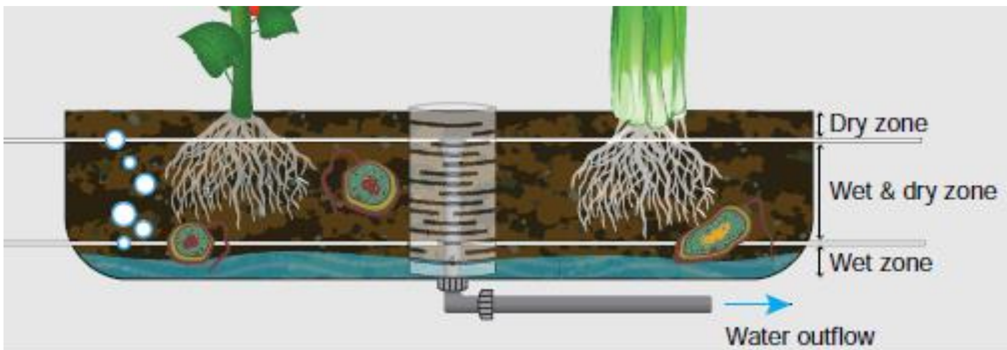


The action, timing and ultimate success of the siphon are dependent on the water's flow rate into the bed, which is constant. Bell siphons can nevertheless be finicky and require attention. The making of the Bell siphons is discussed in the practicum.

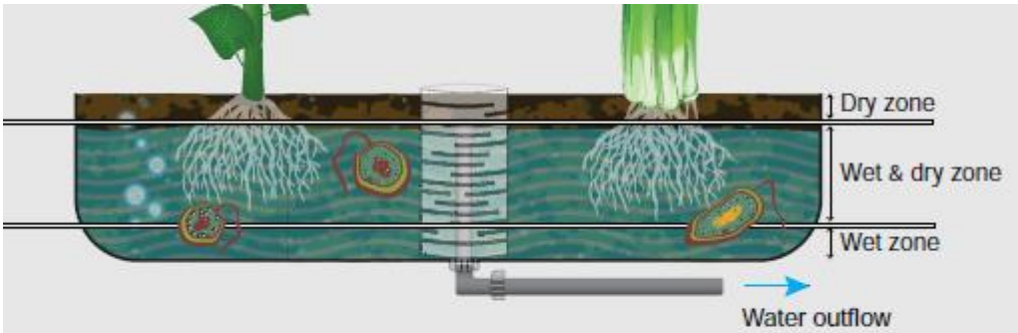
The Three Zones Of Media Beds-Characteristics And Processes

The nature of a flood-and-drain media bed creates three separate zones that can be considered microecosystems, which are differentiated by their water and oxygen content.

The three zones of a media bed during the drain cycle



The three zones of a media bed during the flood cycle



Source: Food and Agriculture Organization of the United Nations (FAO)

Dry zone:

The top 2–5 cm of the bed is the dry zone. This zone functions as a light barrier, preventing the light from hitting the water directly which can lead to evaporation and algal growth. It also prevents the growth of fungus and harmful bacteria at the base of the plant stem, which can cause collar rot and other plant diseases. Moreover, beneficial bacteria are sensitive to direct sunlight.

Dry/wet zone: This is the zone that has both moisture and high gas exchange. This is the space where the media bed intermittingly floods and drains. Most of the biological activity will occur in this zone. The root development, the beneficial bacteria colonies and beneficial micro-organisms are active in this zone. The plants and the animals receive their water, nutrients and oxygen because of the interface between air and water. One common technique is adding earthworms to the media bed which will live in this dry/wet zone. The earthworms will contribute to the breakdown of solid fish waste and they will also consume any dead leaves or roots. This activity will prevent wastes from clogging the system.

Wet zone*:* This zone, the bottom 3–5cm of the bed, remains permanently wet. In this zone, the small particulate solid wastes accumulate, and, therefore the organisms that are most active in mineralization are located here. These organisms are responsible for breaking down the waste into smaller fractions and molecules that can be absorbed by the plants through the process of mineralization.

Growing Media

Growing media is simply the material you use to grow your plants in. With Aquaponics you don't use soil, so you need something to support the plant and roots to grow sturdy and healthy.

In addition to a support mechanism for the plants, the media is used as a filter as well as a great breeding ground for bacteria. Remember in Aquaponics, bacteria is essential for growing your plants. Once you get started with Aquaponics you will see how much faster a well cycled system will make your plants grow compared to a typical soil-based grow bed. It's truly amazing…

Regardless of what type of media you choose to buy, though there are a few things to watch out for. Try and stick to the points below and you should be safe. OK so what are the properties that your grow media must have in order to maintain an effectively run aquaponics system.

Firstly, it Must Not Decompose - Your grow media must never decompose otherwise the levels of the pH and nutrient will fluctuate out of control.

Size matters – There's the rock or particle size, we prefer to use a media that is between 8mm and 16mm, there are some disadvantages if you go very far out of this range.

If your grow media is too small, then there's not a much air space between the media when it's in your bed. The system can get clogged up with solid waste and will prevent a good circulation of air and water for your plant's root zones.

Grow media that's too big a solid foundation for the roots is minimized and this won't allow plant roots to properly establish themselves due to the large air pockets created from big media. Also your surface area for bacteria is markedly reduced, plus planting becomes harder.

Your choices are to go for a hydroponic expanded clay or alternatively you can use a local crushed rock media.

It Must Not Change pH Water Levels – pH neutrality is important. The grow media must not produce anything that will alter the pH water levels both in the short-term and long-term. The majority of river stones and gravel are pH neutral but be careful of limestone as they have a tendency to produce high pH environments which can lead to nutrient lock out.

We have found that High pH can be a bit of a problem in an aquaponic system so if you are unsure, a quick way to check any rock you are thinking of using is to do the vinegar test.

Get a handful of the media you want to use, drop it into a jug of normal household vinegar, if the rocks appear to be visibly bubbling, releasing bubbles from the rock, then chances are it has a high pH and best if you can look at an alternative.

Expanded clay are pH neutral, hence why they are so popular. While most stones are pH neutral, not all are, so be conscious while buying.

Weight of media needs to be taken into consideration as well. Rock media or gravel is very heavy so you need to plan to have enough support for it when building your growbeds and their stands and supports otherwise you will regret it once your system has crashed to the ground… Clay pebbles are light weight but a bit more expensive than gravel.

Grow media with good porosity. This holds air and water better and weighs less. It will allow for more surface area for the bacteria to establish itself which will result in a better producing system.

There are many different types of growing media you can use in your aquaponic system, however here are some of the most popular forms of grow media.

Expanded Clay (Hydroton) – This is usually imported from Germany or China, expanded clay is pH neutral and is easy to handle, but quite expensive.

River Stone – Mined near local rivers, the river stone is heavy but easy to handle. It's relatively cheap but may contain limestone which will gradually increase pH levels over time.

Gravel – This consists of washed gravel stone so it's also quite heavy and will have the same pH issue. Though washed stone is very cheap, it usually is of different sizes which will affect plant differently.

Expanded clay is extremely light, pH neutral, comes in handy bags, it's easy to plant in, easy to clean and sterile. However, it's downside, usually very expensive. The advantages of rock media are that it's readily available and usually very cheap.

You will need to weigh up the pros and cons yourself. If you want efficiency and money is not the most limiting factor, then expanded clay is the way to go, if you are more concerned about cost and you're willing to spend a lot more time on constructing stronger supports and moving and cleaning your media, then go for the rock.

Maybe you may like to take the middle road, you can fill the bottom of your bed with gravel/rock then fill the top half with expanded clay, this reduces cost a bit, but still keeps the weight at a reasonable level, and makes sure that you have a nice media for planting and harvesting in.

Media bed construction

Materials

The most popular media beds are made from plastic containers, modified IBCs or even old bathtubs but they must meet the following requirements:

- strong enough to hold water and growing media without breaking;
- able to withstand difficult weather conditions;
- made of food grade material that is safe for the fish, plants and bacteria;
- can be easily connected to other unit components through simple plumbing parts and
- can be placed in close proximity to the other unit components.

Shape: The standard shape for media beds is a square or rectangle, with a width of about 1m and a length of 1-3m. Larger beds can be used / manufactured, but they require additional support (i.e. concrete blocks) in order to hold their weight. The beds should not be so wide that you are unable to reach across, at least half-way.

Depth: Media bed depth is important because it controls the amount of root space volume which determines the types of vegetables that can be grown. If growing large fruiting vegetables such as tomatoes, okra or cabbage, the media bed should have a depth of 12″, without which the larger vegetables would not have sufficient root space, would experience root matting and nutrient deficiencies, and would probably topple over. Small leafy green vegetables only require 6″–8″ of media depth.

Choice of medium: All applicable growing media will have several common and essential criteria. Remember it is important to wash the medium thoroughly before placing it into the beds, particularly volcanic gravel which contains dust and tiny particles. These particles can clog the system and potentially harm the fishes' gills. Finally, it is important to work with material that is comfortable for you.

Displacement of water by media

Depending on the medium, it will occupy roughly 30–60% of the total media bed volume. This percentage will help decide on the sump tank size for each unit, because the sump tank, at the very least, will need to hold the total water volume contained in all the media beds. Sump tanks should be slightly oversized to ensure that there is always adequate water for the pump to run without ever running dry.

For example, for a media bed of 1000 litres (dimensions 2m long × 2m wide × 0.25m medium depth), the growing medium will displace 300–600 litres of this space, and therefore the water volume of the media bed would be 400–700 litres. It is recommended that the sump volume be at least 70% of the total media bed volume. For this example, the sump tank should be approximately 700 litres.

Filtration

The media beds serve as very efficient filters, both mechanical and biological. Unlike the NFT and DWC systems, the media bed technique utilizes a combination filter and plant growing area.

Mechanical filtration: The medium-filled bed functions as a large physical filter, capturing and containing the solid and suspended fish waste and other floating organic debris. The effectiveness of this filter will depend on the particle size of the medium because smaller particles are more densely packed and capture more solids. Moreover, a high water flow rate can force particles through the media bed and escape the filter. Over time, the captured solid wastes will break down and be mineralized. A properly balanced system will process all of the incoming solid wastes.

When media beds are improperly sized for the stocking density, the media bed can become clogged with solids. This indicates a mistake in the original design when the feed rate ratio was used to balance the system. This situation leads to beds clogged with solid waste, poor water circulation, anoxic areas and dangerous conditions. When this occurs, the medium needs to be washed, which is labour-intensive, disrupts the plant growing cycle and can briefly disturb the nitrifying bacteria.

To avoid this situation be sure that the original design considered the stocking density, feeding regime, and used the feed rate ratio to calculate the required area of the media bed. This is also recommended where the stocking density exceeds $15 kg/m^3$ and/or if the feeding rate is above 50g/day for each square metre of grow bed.

Alternatively, another solids capture device can be integrated into the system design or a cheap technique is to place an old sock to the pipe where water from the fish tank enters the media bed.

Biological filtration: The growing media used will have a large surface area where nitrifying bacteria can colonize. Of all of the aquaponic designs, media beds have the most biological filtration because of the huge area of media on which the bacteria can grow. So generally media beds have more than adequate biological filtration.

Brainstorm with the Group

Media system calculations

Ideal Grow bed volume to fish tank volume ratio typically 2:1

Can go up to 3:1 or as low as 1:1

Ideal grow bed depth is 12”

ACTIVITY

You have a 50 Gallon fish tank.

How do you determine the size of your grow beds using the 2:1 ratio and a grow bed depth of 1 ft?

What is the grow bed area if depth is 6”?

FYI

Participant’s Notes

How do you calculate the volume?

Determine cubic feet of the grow beds and fish tank (Length x width x height)

Convert to Gallons by multiplying cubic feet x 7.48

1 cubic foot = 7.48 Gallons

Answer

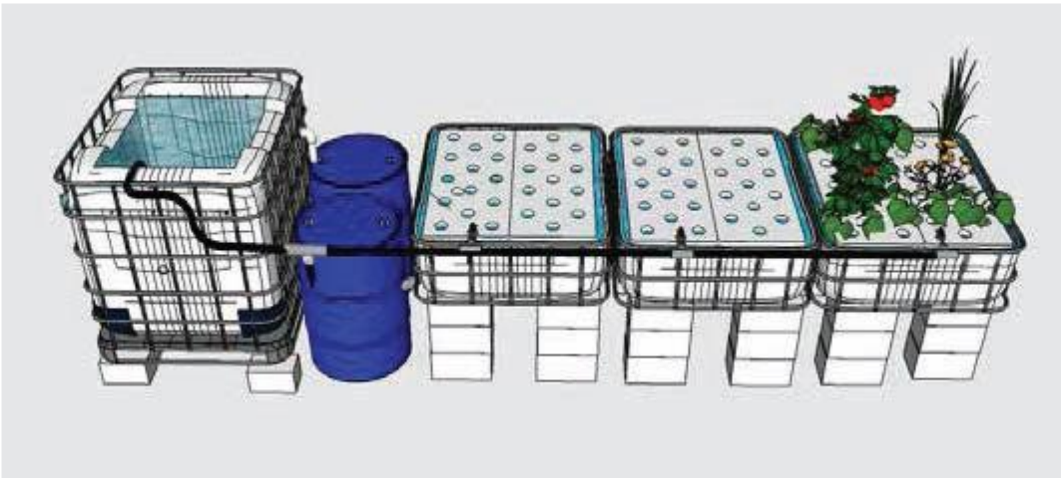
Following the 2:1 grow bed to fish tank ratio you will need approximately 100 gallons of grow bed volume

Divide 100 gallons by 7.48 (see **Participant’s**  **Note)** to determine cubic feet: Cubic ft = 14’ (rounded up)

Assuming ideal grow bed depth of 1 ft you can conclude that a single 2’ x 7’ grow bed would work Or two 2’ x 3.5’ grow beds

If depth is 6” you can double the grow bed area to 28 s.f.

Deep Water Culture (DWC) or Raft Culture



Deepwater Culture (DWC) with and without a mechanical solid separator or biofilter.

Source: Food and Agriculture Organization of the United Nations (FAO)

One of the simplest and most economical hydroponics systems in the world today is the floating raft culture or deep water culture (DWC). It requires lower start-up capital than the other systems on the market. Young seedlings are transplanted into a polystyrene board, which floats on top of a flood table or pond filled with nutrient water with their roots dangling down into the water

The tank can be 1ft – 3ft deep. It uses filtration that allow higher stocking densities of fish and, therefore, a higher production of plants. Even when power is lost, floating raft culture plants can survive for days.

The water is continually recirculated from the fish tanks through filters and large tanks. The solid waste from the fish tanks is removed using a clarifier or other forms of solids removal device. The beneficial bacteria live in the raft tank and throughout the system

In a commercial system, the raft tanks cover large areas, best utilizing the floor space. Plant seedlings are transplanted on one end of the raft tank. Rafts are pushed forward on the surface of the water over time and mature plants are harvested at the other end of the raft. Once a raft is harvested, it can be replanted with seedlings and set into place on the opposite end. This optimizes floor space, which is especially important in a commercial setting. The raft system is a well-developed method with very high production per area.

One of the unique advantages of the raft system is the high volume of water in the system. This acts as a buffer for the fish, reducing stress and potential water quality problems. This is one of the greatest benefits of the raft system. In raft aquaponics, the water is recirculating all of the time. A raft system needs large volume of water to fill but, it is an efficient system of water usage for food production. Since the water surface area (the tanks) is covered by the rafts, evaporation is minimal. No water lost to weeds because there are no weeds.

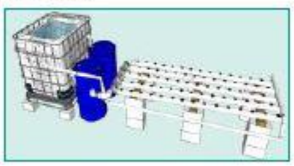
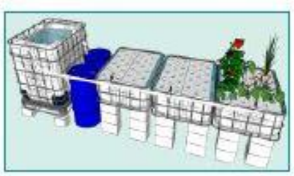
The aquaponics raft system is good for growing leafy crops like lettuce, herbs, chives, spinach, etc. because of the high nitrogen content in the water. It is ideal for small plants that do not need a great deal of physical support. These leafy crops also do well with the lower phosphorous and potassium found in aquaponics system.

For hydroponic lettuces production, harvesting starts from 40-50 days after planting. Plant every week to stagger harvests.

Lettuce, chives and other leafy crops were tested for aquaponics with successful results. We also have great success with tomatoes, peppers, flowers and other crops.

Strengths and Weaknesses of the Aquaponic Technique

Strengths and weaknesses of main aquaponic techniques

System type	Strengths	Weaknesses
Media bed units 	Simple and forgiving design Ideal for beginners Alternative/recycled parts can be used Tall fruiting vegetables are supported All types of plants can be grown Multiple irrigation techniques Many types of media can be used High aeration when using bell siphons Relatively low electrical energy Medium captures and mineralizes solids	Very heavy, depending on choice of media Media can be expensive Media can be unavailable Unwieldy at large scale Higher evaporation than NFT and DWC Labour-intensive to construct Flood-and-drain cycles require careful calculation of water volume Media can clog at high stocking density Plant transplanting is more labour-intensive as the media needs to be moved If water delivery is not uniform, plant performance may differ from bed to bed
NFT units 	More cost-effective than media beds on large scale Ideal for herbs and leafy green vegetables Minimal water loss by evaporation Light weight system Best method for rooftops Very simple harvesting methods Pipes spacing can be adjusted to suit different plants Well researched by commercial hydroponic ventures Smallest water volume required Minimal labour to plant and harvest	More complex filtration method Water pump and air pump are mandatory Cannot directly seed Low water volume magnifies water quality issues Increases variability in water temperature with stress on fish Water inlet pipes can easily clog Vulnerable to power outages
DWC units 	More cost-effective method than media beds on large scale Large water volume dampens changes in water quality Can withstand short interruptions in electricity Minimal water loss by evaporation Well researched by commercial hydroponic ventures Polystyrene rafts insulate water from heat losses/gains keeping constant temperatures Shifting rafts can facilitate planting and harvest Rafts provide biofilter surface area DWC canals can be fixed with plastic liners using almost any kind of wall (wood, steel frames, metal profiles) Can be used at multiple stocking densities	More complex filtration method Very heavy unit High dissolved oxygen required in the canal, and a more sophisticated air pump is required Plastic liners must be food-grade Polystyrene sheets are easily broken Tall plants are more difficult to support Large water volume increases humidity and the risk of fungal disease

Source: FAO 2015

Key learning points

The Key Components of your aquaponics System include: • Aquaponics filters: mechanical and biological; Rearing Tanks; Grow Beds and Sump tanks

Nutrient Film Technique (NFT)

- The NFT is a hydroponic method using horizontal pipes each with a shallow stream of nutrient-rich water flowing through it.
- Plants are placed within holes in the top of the pipes and are able to use this thin film of nutrient-rich water.
- For NFT units, the flow rate for each grow pipe should be 1–2 litres/minute to ensure good plant growth.
- It is most useful in applications, especially when vertical space or weight-limitations are considerations.
- This technique requires separate mechanical and biofiltration components, in order to respectively remove the suspended solids and oxidize the dissolved wastes (ammonia to nitrate).

Media-filled bed

- The media beds must have a depth of about 30cm;
- provide separate zones for different organisms to grow; and
- These designs are efficient with space, have a relatively low initial cost and are suitable for beginners because of their simplicity.
- In media bed units, the medium is used to support the roots of the plants and also the same medium functions as a filter, both mechanical and biological.

Deep Water Culture (DWC) or Raft Culture

- The DWC method involves suspending plants in polystyrene sheets, with their roots hanging down into the water.
- This method is the most common for large commercial aquaponics, growing one specific crop (typically lettuce, salad leaves or basil), and is more suitable for mechanization.
- As in the NFT, separate mechanical and biological filters are needed.
- For DWC units each canal should have a retention time of 2–4 hours.

NOTES:

Ask Question

Question :

Why You Need Aquaponics Filtering Systems?

Answer

Recall that excess waste such as solid waste can become quite a challenge in your aquaponics when they are produced in the fish tank. These solids are pushed and get into the pumps and into your grow beds causing build-up. It can become an issue getting rid of these particles from the water as they can cause your water quality to depreciate. The Mechanical filter helps filter excess waste, especially solid waste out of your aquaponics system. The system will ensure a clean and healthy environment for both fish and plants.

Also recall that your fishes produce ammonia waste but the ammonia is needed in the form of nitrates by the plants. Therefore, it's the availability of bacteria occurring naturally in your aquaponics system that will convert ammonia into nitrates needed by plants. The biofilter forms an essential part of your system; ensuring the plants have access to the nitrates they need while the fish have the clean water they need as it provides the home for the bacteria and the place for them to work.

LESSON 7

LET'S BUILD IT OUT

Balanced vs. decoupled systems

There are two large divisions within aquaponics, balanced systems and decoupled systems.

A **decoupled system** is also called a "dual-loop" system. It is a standard Recirculating aquaculture (RAS) system (fish tank to filter back to fish tank). The solid waste is diverted into a mineralization tank. Each day some of the fish tank water, 5 percent, is also given to the mineralization tank, and the fish tank is resupplied with fresh, clean water. From the mineralization tank, the nutrient rich water goes through a one-way valve to the hydroponics portion. This is a standard recirculating hydroponics system (reservoir to plants to reservoir). At no point does water from the plants go back to the fish. The benefits of a decoupled system are that you can add aquaponics to an existing RAS with minimal changes. Both systems can be run independently. If disease or pests occur, the systems can be separated and treated without hurting the other system. The negatives are increased water management, more complicated plumbing, more tanks, and more control valves.

A **balanced system** is the "normal" system, based on the design by James Rakocy at the University of the Virgin Islands. The water is recirculated between the fish to the plants and back to the fish. This is the system that we are focused on in this training.

As we discussed all aquaponic systems share several common and essential components. These include: a fish tank, a mechanical filter, a biofilter, and hydroponic containers. All systems use energy to circulate water through pipes and plumbing while aerating the water.

We will now discuss the factors to consider when selecting a site for an aquaponic unit, including access to sunlight, wind and rain exposure, average temperature and others.

We will remind ourselves on the importance of Water quality in aquaponics.

The movement of Air and water is critical to ensuring the efficiency of our system's operation and we will look at how pumps help us achieve this.

For ease of reference in setting Key figures and ratios for designing an aquaponic unit are provided. Remember this is not hard and fast you will need to tweak your system.

In the next session we will be Putting together the Essential components of an aquaponic unit. (Practical). A separate step by step guide will be provided for this part of the training.

Designing our Aquaponic System

Consideration while designing an aquaponic unit

- Site selection.
- Water quality in aquaponics.
- Pumps: Air and water movement
- Key figures and ratios for designing an aquaponic unit.
- Plumbing materials
- Putting together the Essential components of an aquaponic unit. (Practical)

Where Do I Place My Aquaponic System?

Site selection is an important aspect that must be considered before installing an aquaponic unit. For some of you this may not be an issue, you might only have one place it can go. But, if you have some choices as to location, there are a few things you may want to keep in mind when it comes to locating your system.

So at a minimal selected sites should be on a surface that is stable and level, in an area that is protected from severe weather but exposed to substantial sunlight.

Stability: Be sure to choose a site that is stable and level. Some of the major components of an aquaponic system are heavy, leading to the potential risk of the legs of the system sinking into the ground. This can lead to disrupted water flow, flooding or catastrophic collapse. Find the most level and solid ground available.

Utilities In site selection, it is important to consider the availability of utilities. Electric outlets are needed for water and air pumps. These outlets should be shielded from water. Moreover, the water source should be easily accessible, whether it is municipal water or rain collection units. Similarly, consider where any effluent from the system would go. Although extremely water efficient, aquaponic systems occasionally require water changes, and filters and clarifiers need to be rinsed.

Security and ease of access the system should be located where it is easy for daily access because frequent monitoring and daily feeding are required. Finally, consider if it is necessary to fence the entire section. Fences are sometimes required to prevent theft and vandalism, animal pests.

Severe weather: Extreme environmental conditions can stress plants and destroy structures It is recommended that the system be located in an area that is protected from severe weather.

Exposure to sunlight and shade: one of the first things to consider is sunlight. You need at least 4-6 hours of good sunlight a day for your plants to grow well, however, your fish do not need sunlight, and in fact you're better off not having any sun on your fish tank at all if possible. Sun on your fish tank leads to algae growing. If you can't help but have your fish tank in the direct sun, you might like to think about having some floating plants on the surface of your fish tank. Floating plants in your fish tank offer shelter and hiding places for your fish and fish are far happier when they feel protected.

The water's surface can be a food production area as well as a good place to grow invasive plants like duckweed, mint and water cress which will take over your media filled growbeds if you plant them in there.

Let's discuss greenhouses in Trinidad and Tobago!

All my research has led me to believe that it is beneficial in the temperate countries where it is cold, and a greenhouse is used to trap heat and moisture. In Trinidad and Tobago, we have a tropical climate. The only benefit is to keep out the rain, keep out weeds and grass if your floor is not covered. and you can mesh the sides to keep out insects.

If temperature is your concern i use a misting system to cool the air and create a differential in the temperature profile that causes the air to circulate.

Some credit can be taken for the fact that if you are doing hydroponics, NFT, you will have a lot more control of the dilution of the circulating nutrients.

I have seen many successful farmers cultivate their produce in open atmosphere without any issues. This cost is not necessary.

Let's hear your thoughts!

Water quality in aquaponics

Remember Water is the life-blood of an aquaponic system. It is the medium through which plants receive their nutrients and fish receive their oxygen.

In designing your aquaponic system it is important to identify the source as this will determine the quality. The water source can be: rainwater, aquifer water, tap water.

It is very important to understand water quality and basic water chemistry in order to properly manage aquaponics.

there are five key water quality parameters for aquaponics: dissolved oxygen (DO), pH, water temperature, total nitrogen concentrations and hardness (KH). Refer to **Lesson 3** for details.

Each organism in an aquaponic unit has a specific tolerance range for each parameter of water quality. The tolerance ranges are relatively similar for all three organisms, but there is a need for compromise and therefore some organisms will not be functioning at their optimum level.

Remember water testing is essential for maintaining good water quality in the system.

Water testing kits

As introduced in Lesson 2 simple water tests are a requirement for every aquaponic unit. Colour-coded freshwater test kits are readily available, fairly economical and easy to use, and thus these are recommended. These can be purchased in aquarium stores or online.

These kits include tests for pH, ammonia, nitrite, nitrate and water hardness (GH and KH). Be sure that the manufacturers are reliable and that the expiration date is still valid.

Other methods include digital meters or test strips.

- If using digital meters for pH or nitrate, be sure to calibrate the units according to the manufacturer's directions.
- A thermometer is necessary to measure water temperature.
- In addition, if there is a risk of saltwater in the source water, a cheap hydrometer, or a more accurate but more expensive refractometer, is worthwhile.

The basic aquaponic system works in a wide range of conditions, and units can be designed and scaled to meet the skill and interest level of many farmers.

However, its success is derived from the appropriate selection of the locations while considering its limitations, the maintenance and management of the system on a daily basis by a motivated farmer or group of farmers.

Pumps: Air and water movement

Aeration

Another required component for aquaponics is aeration. Fish and plants need oxygen to breathe, and nitrifying bacteria need adequate access to oxygen in order to oxidize the ammonia. One easy solution is to use air pumps, placing the air stones at the bottom of the container.

Air pumps inject air into the water through air pipes and air stones that lie inside the water tanks. This ensures that all living organisms have constantly high and stable dissolved oxygen (DO) levels in the water. Additional DO is a vital component of Nutrient Film Technique (NFT) and Deep Water Culture (DWC) units.

Air stones are located at the end of the air line, and serve to diffuse the air into smaller bubbles. Small bubbles have more surface area, and therefore release oxygen into water better than large bubbles; this makes the aeration system more efficient and contributes to saving on costs.

Biofouling will occur and air stones should be cleaned regularly first with a chlorine solution to kill bacterial deposits and then, if necessary, with a very mild acid to remove mineralization, or replaced, when the flow of bubbles is inconsistent.

Siphons are another technique to increase the DO levels in aquaponics. Siphons use a hydrodynamic principle that pulls in air from the outside (aspiration) when pressurized water flows with a faster speed through a pipe section of a smaller diameter. As the water in the main pipe is forced through the narrower section, it creates a jet effect.

Water Movement

Water movement is fundamental for keeping all organisms alive in aquaponics. The flowing water moves from the fish tanks, through the mechanical separator and the biofilter and finally to the plants in their media beds, pipes or canals, removing the dissolved nutrients.

If water movement stops, the most immediate effect will be a reduction in DO and accumulation of wastes in the fish tank; without the mechanical filter and biofilter fish can suffer and die within a few hours. Without water flow, the water in media beds or DWC units will stagnate and become anoxic, and NFT systems will dry out.

A commonly cited guideline for densely stocked aquaponic systems is to cycle the water two times per hour. For example, if an aquaponic unit has a total water volume of 1000 litres, the water flow rate should be 2000 litres/h, so that every hour the water is cycled two times. However, at low stocking densities this turnover rate is unnecessary, and the water only needs to be cycled one time per hour. There are two commonly used methods of moving water through a system: submersible impeller pumps, and manpower. We recommend the use of submersible impeller pumps.

Submersible impeller water pump: Most commonly, an impeller-type submersible water pump is used as the heart of an aquaponics unit, and this type of pump is recommended

Regarding flow rate, the small-scale system need a flow rate of 2000 litres/h at a head height of 1.5 meters; a submersible pump of this capacity would consume 25–50 W/h.

A helpful approximation to calculate energy efficiency for submersible pumps is that a pump can move 40 litres of water per hour for every watt per hour consumed.

When designing the plumbing for the pump, it is important to note that pumping power is reduced at every pipe fitting; up to 5% of the total flow rate can be lost at each pipe connection when water is forced through. Thus, use the minimal number of connections between the pump and the fish tanks. It is also important to note that the smaller the diameter of the pipes, the larger the water flow loss. A ¾” pipe has twice the flow of a ½” pipe even if served from pumps with same capacity.

In addition, a larger pipe does not require any maintenance to remove the buildup of solids accumulating inside. In practical terms, this results in significant savings on electricity and operating costs. When installing an aquaponic unit, be sure to place the submersible pump in an accessible location because periodic cleaning is necessary.

Key figures and ratios

When designing your media bed, NFT and DWC units there are a number of parameters that should be calculated to ensure that your system is balanced. (Refer to Lesson 2). To design and set up a small-scale media bed, NFT and DWC units the Table below summarizes the key figures and ratios you need to be aware of. It is important to be aware that the figures are just guides

Fish tank volume (Litre)	***Max. fish biomass (kg)***	***Feed rate (g/day)***	***Pump flow rate (litre/h)***	***Filter volume (litre)***	***Min. volume of biofilter media (litre) Bioballs***	***Plant growing area (m2)***
200	***5***	***50***	***800***	***20***	***25***	***1***
500	***10***	***100***	***1200***	***20-50***	***50***	***2***
1000	***20***	***200***	***2000***	***100-200***	***100***	***4***
1500	***30***	***300***	***2500***	***200-300***	***150***	***6***
2000	***40***	***400***	***3200***	***300-400***	***200***	***8***
3000	***60***	***600***	***4500***	***400-500***	***300***	***12***

Source: FAO 2015

Plumbing materials

Every system requires a selection of PVC pipe, PVC connections and fittings, hoses and tubes. These provide the channels for water to flow into each component.

Bulkhead valves, uniseals, silicone sealant and Teflon tape are also needed.

In addition, some general tools are needed such as hammers, drills, hand saws, electric saws, measuring tapes, pliers, channel-locking pliers, screwdrivers, levels, etc.

One special tool is a hole-saw and/or spade bit, which is used in an electric drill to make holes up to 8 cm, necessary for inserting the pipes into the fish tanks and filters, as well as for making holes in the PVC or polystyrene grow beds in NFT and DWC systems.

Make sure that the pipes and plumbing used in the system have never previously been used to hold toxic substances.

It is also important that the plumbing used is of food-grade quality to prevent possible leaching of chemicals into the system water.

It is also important to use pipes that are black and/or non-transparent to light, which will stop algae from growing.

Aquaponic Routine management practices

Daily activities

1. Check that the water and air pumps are working well, and clean their inlets from obstructions.
2. Check that water is flowing.
3. Check the water level, and add additional water to compensate for evaporation, as necessary.
4. Check for leaks.
5. Check water temperature.
6. Feed the fish (two to three times a day if possible), remove uneaten feed and adjust feeding rates.

7. At each feeding, check the behaviour and appearance of the fish.
8. Check the plants for pests. Manage pests, as necessary.
9. Remove any dead fish. Remove any sick plants/branches.
10. Remove solids from the clarifier and rinse any filters.

Weekly activities

1. Perform water quality tests for pH, ammonia, nitrite and nitrate before feeding the fish.
2. Adjust the pH, as necessary
3. Check the plants looking for deficiencies. Add organic fertilizer, as necessary.
4. Clear fish waste from the bottom of fish tanks and in the biofilter.
5. Plant and harvest the vegetables, as required.
6. Harvest fish, if required.
7. Check that plant roots are not obstructing any pipes or water flow.

Monthly activities

1. Stock new fish in the tanks, if required.
2. Clean out the biofilter, clarifier and all the filters.
3. Clean the bottom of the fish tank using fish nets.
4. Weigh a sample of fish and check thoroughly for any disease.

Key learning points

The main factors when deciding where to place a unit are: stability of ground, access to sunlight and shading; exposure to wind and rain; availability of utilities; and availability of a shading structure.

Water movement is fundamental for keeping all organisms alive in aquaponics.

If water movement stops, the effect will be a reduction in DO, accumulation of wastes in the fish tank and fish can suffer and die within a few hours. Without water flow in media beds systems will dry out and plants will die.

High DO concentration is essential to secure good fish, plant and bacteria growth. In the fish tank DO is supplied by means of air stones. Media bed units have an interface between the wet zone and dry zone that provides a high availability of atmospheric oxygen. In NFT units, additional aeration is provided into the biofilter, while in DWC air stones are positioned in both biofilter and plant canals.

NOTES:

LESSON 8

WHAT CAN GO WRONG

Troubleshooting for common problems in aquaponic systems

The table below lists the most common problems when running an aquaponic unit. If anything appears out of the ordinary, immediately check that the water pump and air pumps are functioning. Low DO levels, including accidental leaks, are the number one killer in aquaponic units. As long as the water is flowing, the system is not in an emergency phase and the problem can be addressed systematically and calmly. The first step is always to conduct a full water quality analysis. Understanding the water quality provides feedback essential for determining how to solve any problem.

Situation	Reason	Problem	Solution
1) Electricity/pump and system problems			
Pump not working; electricity is off.	No electric power.	DO will decrease.	1) If electricity supply is unreliable, a DC backup power system should be installed. 2) Take water from the sump tank and pour into the fish tank, temporarily replenishing oxygen levels; repeat this process every 1–2 hours until power returns. 3) Install a 200 litre container above the fish tank that can release a slow stream of water into the fish tank, creating bubbles.
Pump not working; electricity is on.	Pump is either broken, faulty or clogged.	DO will decrease.	Check and clear any obstructions on pre-filter or in pipes. Replace pump immediately, if faulty.
Pool of water underneath system or water unusually low.	Leaks or cracks.	All water will drain out, stressing and eventually killing the fish and plants.	Fix any leaks or holes immediately. Use standpipe to prevent fish tank from losing water. Replenish water.
Water in system and sides of fish tank looks green.	Algal bloom.	DO will decrease.	Shade the system, and physically remove mature blooms of algae.

2) Water quality problems			
Ammonia or nitrite > 1 mg/litre.	1) The bacteria are not functioning. 2) Too many fish for the size of the biofilter. 3) Accumulated non-living biomass: uneaten food, dead fish, solid wastes.	Fish will be stressed and die.	1) Immediately change 1/3–1/2 of system water with new water. 2) Remove all uneaten food, dead fish or build-up of solid waste in the tank. 3) Stop feeding until levels decrease. 4) Make sure pH and temperature are optimum for bacteria. 5) If nitrite is high, add 1 g of salt for every litre to immediately neutralize the toxic water quality threat. Afterwards, change the entire water volume over a period of 2 weeks. 6) Recalculate component ratios, biofilter size and feeding regime.
Nitrate levels > 120 mg/litre for a number of weeks.	High feed rate ratio.	No immediate problems, but toxicities may occur if nitrate keeps increasing.	Exchange water and use dumped water to irrigate crops.
Carbonate hardness (KH) is 0 mg/litre.	All of the carbonate is used by the acid created in the aquaponic unit.	The pH of the water will change quickly, stressing the fish and plants.	Add calcium carbonate (limestone gravel or shells) to the unit.

3) Fish problems			
Fish are piping at water surface.	Oxygen levels are too low.	Fish will be highly stressed and die.	1) Make sure electricity is on and pump is fully working. 2) Make sure the bell siphon and air pumps are functional. 3) Make sure system tanks are fully covered to reduce temperature. 4) Add supplemental aeration.
Fish are not eating	1) DO is low. 2) Ammonia and/or nitrite are too high. 3) pH is too high or too low. 4) Fish have diseases.	Fish are stressed and will develop disease or die.	1) Perform water quality tests for ammonia, pH, nitrite and nitrate. 2) Identify why fish are stressed (pH increase, ammonia or nitrite increase, oxygen decrease, organic pollution, disease) and fix the problem.

Situation	Reason	Problem	Solution
Water temperature is too high (>33 °C) or too low (<15 °C).	Climate.	If temperature is too high: fish will stop eating and plants will begin to wilt and die. If temperature is too low: bacteria will stop working, some fish may not eat.	1) In summer, make sure system tanks are shaded so the water stays relatively cool. 2) In winter, first isolate and then insulate the fish tanks. Then, use solar or electric heaters, and reduce the amount of fish food and vegetables growing in the unit. 3) Change fish species with ones more appropriate for that climate.

4) Plant problems			
Plants are not growing and/or leaves are changing colour.	Plants are deficient in some essential nutrients (or temperature is too high for certain plants, plants are diseased).	Plants will not grow or produce fruit.	1) Make sure water quality is optimum for plants. 2) Check nitrate levels: if they are too low, slowly increase fish feed per day. 3) Check if there is any root/stem disease. 4) Add aquaponic-safe fertilizer to plants.
Nitrate levels are high yet plants leaves are yellowing	1) pH is not at optimal level (too high or low). 2) Plants are deficient in some essential nutrients.	Plants will not grow fully or produce fruit.	1) Check if the yellowing is on new or old leaves. If on new, add iron up to 3 mg/litre. 2) Check pH and adjust if it is not optimum. 3) Add aquaponic-safe fertilizer such as compost or seaweed tea to plants.
Vegetables surrounding the water entry pipe are thriving while other vegetables farther away are struggling.	Vegetables around the entry pipe are taking up all the nutrients.	Uneven growth of vegetables in media beds.	1) Spread the water all around the grow beds using irrigation pipe with small holes. 2) Remove the media bed standpipe every day to flush the water in the media bed out into the sump tank. 3) Check nitrate levels; if too low, slowly increase fish feed given per day.

Source: Food and Agriculture Organization of the United Nations (FAO)

Questions asked by farmers

What causes Root Rot?

Main cause of root rot is lack of oxygen however if your water temperature is too high you plant is not going to take up that oxygen. Dissolved oxygen diminishes drastically when temperatures are high.

Why does my lettuce have so much roots and the plant small?

The area in the pipe is wide and no restrictions, the roots spread out. The first couple weeks is about root development rather than lettuce size. If you have a lot of roots in the beginning, your lettuce will grow faster and bigger after 2-3 weeks.

LESSON 9

TO DO OR NOT TO DO THAT IS THE QUESTION

Key Economic Considerations

Key economic considerations for any type of business include:

1) the overall investment required to construct facilities and to purchase necessary equipment.

2) the annual costs to operate the system; and

3) realistic estimates of market prices, the degree of competition in the markets to be targeted, and realistic estimates of revenue to be received.

Estimating the amount of investment required is likely the easiest step when starting an aquaponics unit. Cost estimates for the various types of tanks, PVC, pumps, and filters are readily available. Careful thought must go into planning for all necessary components of the business.

Annual costs to operate the system become a bit more difficult to estimate, given that many of these systems are quite new with few comprehensive analyses of their costs and returns over time.

When estimating market prices very conservative estimates must be used, particularly for the pounds of fish that can be raised, the volume of vegetables that can be produced, and the risks involved.

LESSON 10

LETS RECAP

Aquaponic Rules Of Thumb

Whether you are starting your aquaponics unit at home, developing a large-scale aquaponics project, or championing small-scale aquaponic units in the classroom, here are some important rules to follow:

1. Choose the tank carefully. Fish tanks are a crucial component in every aquaponic unit. Any fish tank will work, but round tanks with flat or conical bottoms are recommended because they are easier to keep clean.

If you have flexibility here, 250 gallons (1000 liters) or larger seems to create the most stable aquaponics systems. Larger volumes are better for beginners because they allow more room for error' things happen more slowly at larger volumes.

Remember: Try using strong inert plastic or fibreglass tanks, because of their durability and long life span. Also they must be made of food safe materials and should not alter the pH of your system (again, beware of concrete).

2. Choose the hydroponic techniques that is right for you. (review Lesson 6)

Is it Nutrient Film Technique (NFT); Media-filled bed or Deep Water Culture (DWC)?

If you choose Media Beds

The industry standard is to be at least 12" (30cm) deep to allow for growing the widest variety of plants and to provide complete filtration.

Ensure that the material is inert – i.e., won't decompose or alter the PH of the system. Hydroton (lightweight Expanded Clay Aggregate) and Gravel are the most widely used media types. If you choose gravel, understand it's source and avoid limestone and marble as they could affect your pH.

3. Plan your System by following these steps.

1. Determine the total grow bed area in sq ft (or sq m)

2. From grow bed area, determine the fish weight required (pounds or kg) using the ration rule 1 lb. (.5kg) of fish for every 1 sq ft (.1 sq m) of grow bed surface area assuming the beds are at least 12” (30cm) deep.
3. Determine fish tank volume from the stocking density rule above (1 pound fish per 5 -7 gallons of fish tank volume or .5 kg per 20 -26 liters). When your fish are young and small, reduce the number of plants in proportion to the size of the fish and their corresponding feed rate /waste production.

For example, if you plan to have 2 2’x4’ grow beds, then you will have 16 sq ft of growing area. Plan to stock so you have a mature weight of 16 pounds of fish which require an 80 – 112-gallon fish tank.

4. Ensure adequate aeration

Be sure there is plenty of oxygen in your fish tank. This means you should use air pumps to make sure that the water has high levels of dissolved oxygen so that your fish, bacteria and plants are healthy.

You can do this through the use of a separate aeration device and by diverting part of the water from flooding and draining your grow beds directly into your aquaponics fish tank. The only way you can have too much oxygen in a fish tank is if you are literally blowing your fish out of the tank. If you don’t have enough oxygen being infused into your tank your fish will be gasping for air at the water surface, but if you reach this stage, you may have done permanent damage to your fish’s respiratory system.

5. Ensure adequate water circulation.

This means you should use water pumps to make sure that there is good water movement so that your animals, bacteria and plants are healthy.

Remember: Electricity costs are a significant portion of the system budget so choose the pumps and power source wisely.

Water Flow

You should flood, then drain your grow beds. The draining action pulls oxygen through the grow beds. You want to flow the entire volume of your fish tank through your aquaponics grow beds every hour if possible. Therefore, if you are running your pump for 15 minutes every hour, and you have a 100-gallon tank, you need at least a 400 gallon per hour (gph) pump. Now consider the “lift” or how far against gravity you need to move that water and use the sliding scale that is on the pump packaging to see how much more power you need beyond the 400 gph.

Starting your System or "Cycling" – Fishless Cycling is recommended because it will develop a robust bacteria base and allow you to fully stock your fish tank in a couple of weeks vs the traditional method of using fish which can be very stressful for the fish.

6. Know when to add plants

- Add plants as soon as you start cycling your system but accept that they may not grow well for the few weeks required for cycling to occur.
- If you add Maxicrop Liquid Seaweed to your tank when planting (Australians call this Seasol) at the rate of 1 quart bottle per 250 gallons (1000liters), your plants will establish themselves much more quickly.
- You can place your plants roughly twice as closely together as you would in soil.

7. Know when to add fish if you are using a Fishless Cycling technique

Add fish once nitrates are present and the ammonia and nitrite levels have peaked and declined below 1.0ppm.

8. Do not overcrowd the tanks.

Your aquaponic system will be easier to manage and will be insulated against shocks and collapse if the stocking density is kept low. The recommended stocking density is 1 pound of fish per 5-7 gallons of tank water (0.5kg per 20 -26 liters), which will still allow for substantial plant growing area. Remember: Higher stocking densities can produce more food in the same space, but will require much more active management.

9. Avoid overfeeding, and remove any uneaten food.

Wastes and uneaten food are very harmful for aquatic animals because they can rot inside the system. Rotting food can cause disease and can use up all of the dissolved oxygen.

Feeding Rate

Feed as much as your fish will eat in 5 minutes, 1-3 times per day. An adult fish will eat approximately 1% of its body weight per day. Fish fry (babies) will eat as much as 7%. Be careful not to over feed your fish.

If your fish aren't eating, they are probable stressed, outside of their optimal temperature range, or they don't have enough oxygen.

Remember: Feed the animals every day but remove any uneaten food after 30 minutes and adjust the next day's portion accordingly.

10. Choose and space the plants wisely.

Plant vegetables with short grow-out periods (salad greens) between plants with longer-term crops (eggplant). Continued replanting of tender vegetables such as lettuce in between large fruiting plants provides naturally shaded conditions.

Remember: In general, leafy green plants do extremely well in aquaponics along with some of the most popular fruiting vegetables, including tomatoes, cucumbers and peppers.

11. Maintain balance between plants and animals.

Using a batch cropping system can help keep a steady harvest of both aquatic animals and vegetables to keep a consistent production level and maintain a constant balance between fish and plants. Remember: A secure source of young plants and young fish is important, so make sure that the supply is considered during the planning phase.

12. Maintain good water quality.

Water is the life-blood of an aquaponic system. It is the medium through which all essential nutrients are transported to the plants, and it is where the fish live. Five key water quality parameters are important to monitor and control: dissolved oxygen (5 mg/litre), pH (6–7), temperature (18–30°C), total nitrogen, and water alkalinity. Remember: The water chemistry may seem complicated, but the actual management is relatively simple with the help of common test kits.

Remember: Perform water quality tests for pH, ammonia, nitrite and nitrate before feeding the fish. Adjust the pH, as necessary

The following are the Main Water Quality Parameters and the target ranges for each parameter:

- Dissolved oxygen (DO): 5 ppm or 5–8 mg/litre
- pH. 6–7
- Ammonia 0 mg/litre
- Total Ammonia Nitrogen (TAN): <1 ppm
- Nitrite (NO_2): 0 mg/litre
- Carbon Dioxide: < 15 mg/L
- Nitrate (NO_3): 5–150 mg/litre

- Water Temperature: 27–30°C

(ppm or parts per million, which can be used interchangeably with milligrams per liter [mg/L])

pH

- Target a pH neutral, or 7.0, in your aquaponic system. This is a compromise between the optimal ranges of the fish, the plants, and the bacteria. For fish, this is a pH of around 6.5 to 8.0. For plants, this is a pH of around 5.0 to 7.0 and for bacteria it is a pH of 6.0 to 8.0.
- Test pH at least weekly, and a frequently as 3-4 times per week.
- During cycling pH will tend to rise.
- During Cycling your aquaponics systems, pH will probably drop below 7.0 on a regular base and require being buffered up. If you need to lower pH it is generally because of the water source (such as hard ground water) or because you have a base buffer in your system (eggshells, oyster shell, shell grit, incorrect media).

Best method for raising (buffering) pH if it drops below 6.6

- Calcium hydroxide – "hydrated lime" or" builder's lime"
- Potassium carbonate (or bicarbonate) or potassium hydroxide ("pearlash) or "potash").
- If possible alternate between these two each time your system needs the pH raised. These also add calcium and potassium, which your plants will appreciate.
- While they work, be cautious about using natural Calcium Carbonate products (eggshells, snails shells, seashells). They don't do any harm, but they take a long time to dissolve and affect the pH. So, you add it, check pH two hours later and nothing has changed, so you add more. Then suddenly, the pH spikes because you have added so much.

Best methods for lowering pH in order of preference, if it goes above 7.6

- Acids like nitric or phosphoric as the plants can use the nitrate or phosphate produced.
- Other acids, such a vinegar (weak) hydrochloric (strong), and sulphuric (strong) -last resort as directly adding these acids to your system could be stressful for your fish.

Use caution when adding anything to your system containing sodium as it could build-up over time and cause harm to your plants.

Do not use citric acid as this is anti-bacterial and will kill the bacteria in your bio-filter.

Ammonia and Nitrite

- This levels should be less than 0.5ppm
- If you see Ammonia levels rise suddenly, you may have a dead fish in your tank.
- If you see Nitrite levels rise you may have damaged the bacterial environment in your system.
- If either of the above circumstances occur, stop feeding your fish until the levels stabilize and in extreme cases do a 1/3 water exchange to dilute the existing solution.
- Nitrates can rise as high as 150ppm without causing a problem, but much above that, you should consider adding another grow bed to your system.

Aquaponic Quiz!

Conduct Exercise

Answer the questions below. Do not discuss answers with your classmates. Do not consult worksheets or other materials. This quiz will not be graded, so just try your best and show us what you know!

1. What two types of farming are used together in aquaponics?

○ dry land farming plus wet land farming

○ fish farming plus growing plants in water instead of soil

○ raising water animals plus raising ponies

2. Is the aquaponics system a good example of sustainability?

Circle: True or False

Explain your answer:

____

____

3. Aquaponics is important to the future of food production because it allows a grower to produce a large quantity of food in a small space using minimal resources. Circle: True or False

4. Tick the best answers. What is the purpose of fish in an aquaponics system?

○ Make nitrate bioavailable to plants

○ Retain moisture in the soil

○ Add nutrients to the water in the form of waste

○ Provide food for sale at the market

5. What is excreted through a fish's urine and gills?

- ○ dissolved oxygen
- ○ nitrites
- ○ ammonia
- ○ nitrates

6. list two reason aquatic plants are good to add to an aquaponic system:

1. ____

2. ____

7. What is a growing medium?

____

8. What is the purpose of the bacteria in an aquaponics system?

- ○ Add nutrients to the water in the form of waste
- ○ Play an important role in converting ammonia into nitrates.
- ○ Retain moisture in the soil
- ○ Provide food for sale at the market

9. Where can bacteria be found in the aquaponics system?

____

____

10. List the three primary aquaponic system designs:

1. __________________________________

2. __________________________________

3. __________________________________

11. Media bed is recommended for new, hobby growers.

Tick the best answers.

- ○ Because the media bed also acts as the place for plant growth, it basically does everything all in one component -making it all simple.
- ○ Media also provides better plant support and is more closely related to traditional soil gardening because there is a media to plant into.
- ○ The cost of building the aquaponics system is lower because there are fewer components.
- ○ It is easier to understand and learn.

12. What filtering functions does a media bed perform?

- ○ Mechanical (solids removal)
- ○ Mineralization (solids breakdown and return to the water)
- ○ Bio filtration

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NOTES

Attachment 1

The Quiz: Do You Have What It Takes?

Aquaponics Farming like most things in life is fraught with uncertainty and risk.

The exercise is meant to be fun. The questions are not a judge of a person's actual ability to succeed in farming. However, the recommendations based on individual scores, are meant to be anecdotal, and to make participants think. Source: (www.beginningfarmers.org/)

Answer each question on a scale of 1-5 where:

1 = No, definitely not, this does not describe me at all

2 = This is not really, or at least not usually true about me

3 = I'm okay with this, but not totally, not all of the time, and/or not with everything.

4 = Yes, this is basically true of me in general

5 = Absolutely, this describes me perfectly

1) I prefer to work outside no matter what the weather is like.

Answer____

2) I'm not scared of bugs, fungus, slime, or other things that a lot of people think are gross.

Answer____

3) I am good at identifying what needs to be done and prioritizing tasks in order of importance.

Answer____

4) I like financial planning, and am good at taking notes, crunching numbers and evaluating expenditures.

Answer____

5) I am a good observer, and generally see details that a lot of other people miss.

Answer____

6) I like tinkering, building things, and am mechanically inclined.

Answer____

7) I am savvy, thrifty with money, and tend make do with what I have rather than buying new things.

Answer____

8) When I do buy things, I seldom regret the purchases I've made, and tend to use the things I buy.

Answer____

9) I'm not easily frustrated, and don't get too upset when stuff doesn't go my way.

Answer____

10) Making money is less important to me than accomplishment, and I don't mind not being 'rich' as long as I am happy with the work I do.

Answer____

11) I don't tend to wallow in failure. Instead, I simply consider it as a lesson and try to do it better the next time around.

Answer____

12) I like hard, physical work, and don't mind being tired at the end of the day.

Answer____

13) I am not easily bored, restless, or frustrated by mundane tasks.

Answer____

14) I am good at giving direction and explaining to others how I expect things to be done in a precise and tactful way.

Answer____

15) I'm better at doing a lot of different things pretty well than at doing only one or two things extremely well.

Answer____

16) I don't mind being alone and am happy working by myself for long periods of time.

Answer____

17) When something breaks, I usually try to fix it myself before getting help.

Answer____

18) I tend to ‘roll with the punches’ and can accept when things don’t go ‘according to plan’.

Answer____

19) I like to get up early, get going with my day, and don’t tend to stop until I feel like I’ve accomplished all the things I needed to get done.

Answer____

20) I’m comfortable taking risks, and accepting that not everything is within my control.

Answer____

21) I am constantly looking for new information and trying to understand how to do the things I do more effectively and efficiently.

Answer____

22) I don’t need people to tell me I’m doing a good job to be satisfied with the things I accomplish.

Answer____

23) I am a big picture person and can see how lots of different small things are related to one another.

Answer____

24) I’m a good long-term planner but am comfortable changing my vision when necessary.

Answer____

25) I love growing plants and/or taking care of fish and other animals and am generally good at keeping them alive and healthy.

Answer____

TOTAL SCORE ______

Attachment 2

Activity Worksheet

K-W-L Chart

K What I Know	W What I Want to Know	L What I Learned

Attachment 3

HOW TO PROPERLY FEED, HANDLE AND HARVEST TILAPIA CULTURE

It is generally accepted that feed costs account for the highest single production cost in aquaculture grow-out production systems. Typically, in intensive production systems, feed accounts for between 60% and 80% of operational costs. In contrast, in semi-intensive systems, feed and fertilizer use represents between 30% and 60% of the total cost of production (FAO 2010).

There are generally four physiological growth stages of the tilapia, fry fingerling, juvenile and adult. It is reported that the fish nutrient requirement for each of the physiological stages vary, specifically the protein requirement. Additionally, it is recommended that at each of the physiological stages, the animal be fed based on its body weight. (Please refer to the headlining "Calculation for average body mass of fish within rearing tank") Table below represents the recommended crude protein content and the amount of feed to be fed based percentage (1%) body weight.

Feeding table for tilpia using formulated feed

Life stage	Fish size (g)	General age (days)	Crude Protein Required (%)	Feed size (mm)	Feeding rate (% body weight)	Feeding frequency (no./day)
Early fry	0-2	0-7	70	0.2 - 1	20	4
Fry	3-5	8-30	70	1 - 1.5	15-20	2
Fingerling	5 - 20	31-90	50	1.5 - 2	10-15	2
Juvenile	20-100	91-150	30 - 50	2	5-10	1 - 2
Grower	> 100	>150	30	3 - 4	2-5	1 - 2
Broodstock	150 - 300		35	4	2-5	1 - 2

Feeding schedule

It is generally known that smaller fish consume more feed per unit body weight compared to larger fish. Recommended feeding schedules for different sized tilapia with expected growth rates is presented below.

Feed type	Fish size (g)	Feeding rate (% of biomass per day)	Growth rate (g/day)	Feeding duration (weeks)
Fry mash	0.01-2.0	15-20	0.02±0.01	1-3
Starter crumble	2-15	10-15	0.35±0.05	4-7
Starter pellet	16-37	5-10	0.47±0.07	8 - 9
Grower pellet	38-83	2-5	0.86±0.20	10 - 14
Finisher pellet	91-1,000	2-5	1.8±0.40	

Feed conversion ratios:

On average1.7lbs pounds of feed produces 1lb of product, Fish.

Fish Feeding

- On average, fish eat about 1.5% of their body weight daily.
- If you have 75 lbs of fish in system, multiply 75lbs x 1.5% = 1.125lbs of fish feed daily
- If needed, convert lbs to grams (1lb = 454 grams)
- 1.125 lbs = 510 grams
- Don't just rely on the math. Observe your fish eating to help determine the proper amount of feed. (Refer to Attachment 3).

Feed rate ratio: The feed rate ratio is a summation of the three most important variables, which are: the daily amount of fish feed in grams per day, the plant type (vegetative vs. Fruiting) and the plant growing space in square metres.

Recommended daily fish feed rates are:

- for leafy green vegetables: **40–50 grams of feed per square metre per day**
- for fruiting vegetables: **50–80 grams of feed per square metre per day**

There is a higher feed rate ratio for fruiting vegetables due to the greater amount of nutrients needed for these plants to produce flowers and fruits compared with leafy green vegetables.

Along with the feed rate ratio, there are two other simple and complementary methods to ensure a balanced system: health check, and nitrogen testing.

Harvesting and staggered stocking

A constant biomass of fish in the tanks ensures a constant supply of nutrients to the plants. To achieve a constant biomass in the fish tanks, a staggered stocking method should be adopted. This technique involves maintaining three age classes, or cohorts, within the same tank. Approximately every three months, the mature fish (500 g each) are harvested and immediately restocked with new fingerlings (50 g each). This method avoids harvesting all the fish at once, and instead retains a more consistent biomass.

Attachment 4

PEST AND DISEASE CONTROL

Pest Control

A common practice for dealing with problematic insect pests in soil vegetable production is to use chemical pesticides or insecticides, but this is impossible in aquaponics. Any strong chemical pesticide could be fatal for fish as well as the beneficial bacteria living in system. Therefore, commercial chemical pesticides must never be used

However, there are other effective physical, environmental and cultural controls to reduce the threat of pests from aquaponics. Nevertheless, successful management integrates crop and environmental management with the use of organic and biological pest deterrents.

For pest management in aquaponics, prevention is fundamental. Regular and thorough monitoring for pests is vital, and, ideally, minor infestations can be identified and managed before the insects damage the entire crop. Below is a list of simple inexpensive controls used in organic/conventional agriculture, which are also suitable for small-scale aquaponics, to avoid pest infestations.

Hand inspection and removal: The removal, either by hand or using a high-pressured stream of water, of heavily infested leaves or plants helps to avoid and/or to delay the spread of insects to surrounding plants.

If slugs are a problem, a small saucer filled with beer will attract them and they easily drown, making disposal simple and effective.

Plant choice: Some pests are more attracted to specific plant species than others. Similarly, different plant varieties from the same species have different resistance/tolerance to pests.

Fertilization: Excessive nitrogen makes plants more prone to pest attack because they have more succulent tissues. A correct balance of nutrients using the feed rate ratio helps plants to grow stronger to withstand pest attacks. Some water should be exchanged when nitrate levels are greater than 120mg/litre for this reason.

Sanitation: The removal of all plant debris, including all roots, at the end of each harvest helps to reduce the incidence of pests and diseases.

If pests remain a problem after using the above physical, mechanical, and cultural controls, it may be necessary to use chemical control using Natural Pesticides.

Natural Pesticides: (SOURCE: Fuglae, L.J. (1998) Producing Food Without Pesticides)

RED PEPPERS In powdered, liquid or with other ingredients, red peppers offer protection against many insects and bacterial, fungal and viral diseases. Red pepper powder at the base of the plant or sprinkled on dampened plants will deter many pests. Liquid sprays can be prepared by using 100 grams of crushed, chopped or dried peppers to 120 litres of water. Solutions can be prepared by boiling or allowing to stand overnight. Filtered and diluted to the required strength.

NEEM Neem sprays neem oil and neem cake, provide protection against a wide range of plant pests. Neem spray (mix 500 grams of crushed neem seed in 10 litres of water and let it sit for 12 to 24 overnight). Neem oil (use 1 kilogram of neem seed powder in water to make a paste. Alternatively knead and squeeze paste to extract about 100-150ml of neem oil. The remaining solid is neem cake). Neem leaf extracts are also effective when combined with other preparations.

WOOD ASH Wood ash, as a dry powder or in a solution, is effective against many soft bodied or sucking insects. Thick applications as mulch will deter nematodes, slugs, snails, etc. Can also be used as a dry dip for planting materials and cuttings to prevent bacterial, fungal and viral diseases. Spray mixtures of wood ash and soap solution will protect plants from flea beetles, mites and stink bugs, etc.

MILK Dilute solution sprays are effective against spider mites and some viral and fungal diseases. Use 1 liter of milk in 9 litres of water every 10 days for control of mosaic diseases in tomato. Use weaker solutions (1:12) for control of mites and viral and fungal diseases. All used in combination with wood ash.

MARIGOLDS Marigold sprays can deter a wide variety of insect pests and control certain plant diseases. Marigolds can also be planted among crops to act as a natural nematicide. Fill container with water to cover a mixture of stems, leaves and flowers and allow to decompose over 5-10 days. Filter and dilute with water in a 1:2 ratio. Add soap solution for effective spray applications. Sprays are also used in combination with onion, garlic and red peppers.

GARLIC Garlic is lethal to a wide range of insects and controls some fungal and bacterial diseases. Garlic spray solutions is prepared by using 1 crushed bulb in 1 litre of water. Add a little soap solution and use immediately. Do not use on legume crops since the strong taste will persist for some time. Garlic is also effective when used in combination with red peppers, onion and marigolds

POTASSIUM BICARBONATE: For moulds and fungus on plants you can use potassium bicarbonate sprayed onto the infected plants.

MISCELLANEOUS PLANTS/ PRODUCTS Many plants have been cited as having pesticides properties. Among them are: soursop, barbados nut (physic nut), basil, castor oil, crotalaria, eucalyptus, lantana, mahogany, mammy apple, beans, papaya, soybean, sweet potato, tamarind, tobacco, tomato, yam bean, etc. Other materials also cited as having pesticidal properties are: baking soda, dust and powders (clay, lime, laterite, etc), flour, manure, soap, sulphur, fermented urine, vegetable oil.

Plant Deficiency

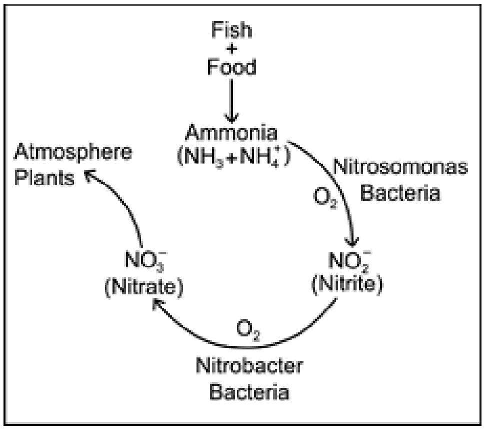
Nutrients		Plant Uses	Signs of Deficiency	Treatment
Nitrogen (N)		basis of all proteins and is essential for building structures, photosynthesis, cell growth, metabolic processes, and chlorophyll production. Usually, dissolved nitrogen is in the form of nitrate	Excessive nitrogen can cause excessive plant growth resulting in lush, soft plants susceptible to diseases and insect damage and difficulty in flowering, fruiting and include yellowing of older leaves, thin stems,	
Phosphorus (P)		essential for photosynthesis and the formation of oils and sugars and encourages germination and root development in seedlings.	Phosphorus deficiency can cause low root development. older leaves appear dull green or even purplish brown, and leaf tips appear burnt.	Add rock phosphate. directly to your grow beds
Potassium (K)		Regulates growth and metabolism	burned spots and wilting on older leaves visible as brown spots on the leaf margin	addition of potassium hydroxide, or potassium carbonate

Calcium (Ca)		essential for the plants' healthy growth and strengthening of stems and production of flowers, fruits, and vegetables. Tomatoes, and peppers are susceptible to calcium deficiency.	deficiency common. Tip burn of lettuces and blossom-end rot of tomatoes. Often, new leaves are distorted with hooked tips and irregular shapes. Plant growth stunted and can cause death.	addition of calcium hydroxide or calcium carbonate
Sulfur (S)		essential for the production of some proteins, chlorophyll, and other photosynthetic enzymes.	visible in the curled leaves and yellowing. Sulfur deficiencies are rare in aquaponics.	
Magnesium (Mg)		Magnesium helps in breaking down the chlorophyll.	**common deficiency** in aquaponics. yellowing of leaves between the veins sometimes with reddish brown tints and early leaf fall	
Iron (Fe)			**common deficiency** leaves turn yellow, but the veins remain green	Adding chelated iron will only be effective if your pH is 7.5 or lower. Your aim is 2 mg/liter of iron every 3-4 weeks.

Attachment 5

CALCULATING UN-IONIZED AMMONIA LEVELS (NH3) FROM TOTAL AMMONIA NITROGEN, (TAN)

Of all the water quality parameters which affect fish, ammonia is the most important after oxygen.



In water, ammonia occurs in two forms, which together are called the Total Ammonia Nitrogen, or TAN. Chemically, these two forms are represented as NH4+ and NH3. NH4+ is called Ionized Ammonia because it has a positive electrical charge, and NH3 is called Unionized Ammonia since it has no charge. **(Refer to your Nitrogen Cycle).**

This is important to know, since NH3, unionized ammonia (UIA), is the form which is toxic to fish. Water temperature and pH will effect which form of ammonia is predominant at any given time in an aquatic system.

Interpreting the Ammonia Test

In healthy ponds and tanks, ammonia levels should always be ZERO. Presence of ammonia is an indication that something in the system is out of balance. Therefore, ANY ammonia in a pond or tank should alert the producer to start corrective measures. However, it is only the unionized ammonia (UIA) which is toxic to fish. This toxicity to fish begins as low as 0.05 mg/l. At 2.0 mg/L, the fish will die.

So a positive TAN test needs to be followed by a test to find the actual concentration of Un-ionized ammonia (UIA). Again, any ammonia indicates a problem in your system. If you find it, take corrective measures immediately.

How to calculate your Un-ionized ammonia levels (NH3)

Once the pH and temperature are known, the fraction of UIA can be calculated using a multiplication factor found in Table 1.

To do this calculation,

Step 1. Use your water quality test kit to measure ammonia. The number from the kit is the **TAN (Total ammonia Nitrogen**).

Step 2: Measure the water temperature

Step 3: Measure the water pH.

Step 4: Using Table 1, find the temperature on the top row of the table, and the pH in the left column. The number at which the appropriate column and row intersect in the table is the **NH_3 Multiplication Factor Value.**

Step 5: Multiply the **TAN** and the **NH_3 Multiplication Factor Value**

The answer is the Un-ionized ammonia levels (UIA), **NH_3**, in mg/L (ppm).

Got It?

Let's do a calculation

Question 1: You measured the water in your system. Your TAN measured with the text kit is 1.0mg/L (or 1.001142303 ppm). Your water temperature is 75 F (24 C) and Your water pH is 8.0.

What is your reaction? What does the results tell you?

Follow the steps

Step 1. TAN (Total ammonia Nitrogen). 1.0mg/L (or 1.001142303 ppm).

Step 2: water temperature 75 F (24 C)

Step 3: pH. 8.0.

Step 4: Based on your water temperature and water pH the NH_3 Multiplication Factor Value factor from Table 1 is 0.0502. (This is where the pH in the left hand column intersects the temperature listed across the top of the table).

Step 5: Multiply the TAN and the NH_3 Multiplication Factor Value

= 1.0 X 0.0502 mg/L = 0.0502 mg/L UIA

INTERPRETATION: The un-ionized ammonia (UIA) **NH_3**, present is 0.050 mg/L. This level is high enough to cause some gill damage. If UIA is allowed to increase, the fish will be under considerable stress.

Question 2: You measured the water in your system. Your TAN measured with the text kit is 0.6mg/L. Your water temperature is 86 F (30 C) and Your water pH is 8.0.

Table 1: Fraction of un-ionized ammonia in aqueous solution at different pH values and temperatures. (Calculated from data in Emmerson et al. (1975)).

pH	Temperature													
	42.0 (°F)	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6
	6 (°C)	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617	.7929
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351	.8585
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892	.9058
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271	.9389

NOTES:

Aquaponics

Fresh, Healthy, Sustainable, Organic

This program seeks to improve conditions in rural communities through education. A critical part of the effort is to better equip community persons especially the young to create and benefit from livelihood opportunities in their communities rather than leaving to seek their fortunes elsewhere. Empowering community persons through education and livelihood opportunities in the entrepreneurship context benefits the communities as a whole.

This training seeks to build the skills necessary to assess opportunities in their wider context so that entrepreneurs specifically youth can make decisions to undertake activities that fit their abilities, interests and means as well as enable them to engage in productive livelihoods

. In Trinidad and Tobago where significant numbers of young people work in the informal economy, this resource material may be used to train those already in the workforce to systematize and improve the quality of their work, with the goal of eventually becoming contributors to the formal economy.

I view the ability to engage in a livelihood as a vital life skill. Therefore, this training package may be considered a contribution towards providing community young people and adults with access to quality life skills programmes.

Partners in Empowering Communities with Opportunities and Education Solutions