

February, 2017

Fundamentals of Aquaponics

A Course Book into the
Fundamentals of Aquaponic Science
and Operations



Ahmed Aibak
URBANSPACE AQUAPONICS

PREFACE

The Fundamental of Aquaponics is a Course book with a lot of material designed for an audience that has no experience in aquaponics and is looking to learn more in details about the science, functionality, operations and design of aquaponics systems. At the end of this course book you will have a much greater understanding of all the different components of an operating aquaponics system, processes in the operations of an aquaponics farm, climate and pest control and the fundamentals of designing a small scale commercial aquaponics system.

The course book is divided into 6 chapters. We will be starting with a brief introduction to aquaponics in chapter 1, then discussing the science behind aquaponics in chapter 2, chapter 3 will be about the fish and the crucial role they have in aquaponics. Chapter 4 is all about water quality, chapter 5 will discuss plants, their nutrient requirements, pest and pest control moving into design concepts in chapter 6 which will include a Case Study demonstrating the process of going from concept to design of a small commercial aquaponics system.

Table of Contents

PREFACE	2
1 CHAPTER 1: INTRODUCTION TO AQUAPONICS	7
2 CHAPTER 2. SCIENCE OF AQUAPONICS	10
2.1 SYMBIOSIS.....	10
2.2 MICROFLORA.....	11
2.3 NITRIFICATION PROCESS	12
2.4 DENITRIFICATION.....	13
3 CHAPTER III: FISH	15
3.1 WHY FISH	15
3.2 TYPES OF FISH IN AQUAPONICS	16
3.3 TILAPIA	17
3.4 GROWTH RATE FUNCTION.....	18
3.5 DESIGN EXAMPLE	19
4 CHAPTER IV. WATER QUALITY	22
4.1 NITROGEN.....	22
4.1.1 <i>Measuring Nitrogen</i>	24
4.1.2 <i>Nitrogen issues</i>	24
4.2 PH	25
4.2.1 <i>pH Overview</i>	25
4.2.2 <i>pH and Ammonia</i>	26
4.2.3 <i>pH and Nutrient Availability</i>	26
4.2.4 <i>Optimal pH</i>	27
4.2.5 <i>Measuring pH</i>	28
4.2.6 <i>pH Adjustment</i>	29
4.2.7 <i>pH Snapshot</i>	30
4.3 DISSOLVED OXYGEN.....	30
4.3.1 <i>Optimal levels</i>	30
4.3.2 <i>Aeration methods</i>	31
4.4 TEMPERATURE	32
4.4.1 <i>Optimum Temperature for Fish and Plant</i>	32
4.4.2 <i>The Effect of Temperature on Ammonia And pH Levels</i>	33
4.5 SOLIDS AND SOLIDS REMOVAL.....	34
4.5.1 <i>Solids Overview</i>	34
4.5.2 <i>Gravity Separation</i>	35
4.5.3 <i>Filtration</i>	36
4.5.4 <i>Granular Media</i>	37
4.5.5 <i>Porous Media</i>	38
4.6 CHLORINE AND CHLORAMINE	39

5	CHAPTER V: PLANTS.....	41
5.1	WHAT CAN YOU GROW.....	41
5.2	NUTRIENT REQUIREMENT	43
5.2.1	<i>Macronutrient.....</i>	43
5.2.2	<i>Micronutrient.....</i>	45
5.2.3	<i>Nutrient deficiency.....</i>	46
5.2.4	<i>Nutrient Antagonism</i>	50
5.2.5	<i>Nutrient supplementation</i>	51
5.3	ENVIRONMENTAL FACTORS	54
5.3.1	<i>Temperature</i>	54
5.3.2	<i>Carbon-Di-Oxide.....</i>	55
5.3.3	<i>Humidity/VPD</i>	56
5.3.4	<i>Lighting</i>	60
5.3.5	<i>Heating.....</i>	62
5.4	PEST CONTROL.....	65
5.4.1	<i>Biological controls.....</i>	70
5.4.2	<i>Beneficial insects.....</i>	72
5.4.3	<i>Biological agents.....</i>	75
6	CHAPTER VI: SIZING/DESIGN	78
6.1	BACKYARD AQUAPONICS LAYOUTS	78
6.1.1	<i>Flood and drain.....</i>	78
6.1.2	<i>CHOP</i>	78
6.1.3	<i>CHOP2</i>	79
6.1.4	<i>Hybrid.....</i>	80
6.1.5	<i>Barrel Ponics and Nutrient Film Technique (NFT).....</i>	81
6.1.6	<i>Snapshot and Recommendations</i>	81
6.1.7	<i>Sizing Ratios.....</i>	82
6.2	DESIGN CASE STUDY	84

Table of Figures

Figure 1: Chinampa canals of the Aztec civilization.....	7
Figure 2: Polycultural farming as early aquaponics (Source: Indiaeng.com)	8
Figure 3: Modern aquaponics greenhouse (Source: milkwood.net).....	9
Figure 4: The symbiotic relationship in aquaponics	10
Figure 5: Basic nitrification	12
Figure 6: The nitrification cycle	13
Figure 7: Denitrification (Bottom Image Source: aem.asm.org)	14
Figure 8: Feed conversion ratios for cattle vs. fish (source: GAAalliance.org)	16
Figure 9: Common fish species used in aquaponics (Source: Cebu Aquaponics)	17
Figure 10: Source of nitrogen in aquaponics.....	22
Figure 11: Nitrogen startup curve (Source: Timmons and Ebeling, 2007)	23
Figure 11: The pH scale (Source: ugao.com)	25
Figure 13: Relation between pH and ammonia concentration (Source:cornell.edu)	26
Figure 14: pH and nutrient availability (Source:Pat-international.com)	26
Figure 15: Relationship between temperature, ammonia and pH (Source: Ecofilms Australia)	34
Figure 16: Porous media filtration systems	39
Figure 17: Plants grown in aquaponics.....	41
Figure 18: Plants most frequently grown in aquaponics (Source: Canadianaquaponics.com).....	42
Figure 19: Plant deficiency guide (Source: Twitter @JSKProperty).....	50
Figure 20: Mobility and immobility of nutrients (Source: OKState.edu).....	54
Figure 21: The effect of CO ₂ on photosynthesis (Source: Amazonaws.com)	55
Figure 22: CO ₂ generator and liquid CO ₂ tank (Source: omafra.gov.on.ca)	56
Figure 23: Vapour pressure vs. Temperature (Source: ohioline.osu.edu)	56
Figure 24: Relative Humidity (Source: cmfac.groups.et.byu.net)	57

Figure 25: Effect of VPD on plant transpiration (Source: ohioline.osu.edu)	58
Figure 26: Light spectrum of various sources (Source: housecraft.ca)	60
Figure 18: Light intensity under various conditions (Source: Chronopharmacognosy)	61
Figure 19: Light duration for different types of plants (Source: Colorado State University)	62
Figure 29: Electric immersion and inline heaters (Source: Pentaires.com)	64
Figure 21: Basic Flood and Drain (Source: Aquaponics Gardening, Sylvia Bernstein).....	78
Figure 31: Constant Height with One pump (CHOP) (Source: Aquaponics Gardening, Sylvia Bernstein) ..	79
Figure 23: Constant height with two pump (CHOP) (Source: Aquaponics Gardening, Sylvia Bernstein) ...	80
Figure 24: Hybrid system (Source: Just Aquaponics).....	80
Figure 34: Barrel ponics and NFT (Source: 1.thehomestead.guru 2.hg-hydroponics.co.ok)	81
Figure 35: 40 x 8 growbed layout	85