



Small-scale aquaponic food production

Integrated fish and plant farming



Cover photographs:

Top: Illustration of a media bed aquaponic system, clearly showing the connection of the fish tank and plant growing area. Bottom left to right: a mixed culture of tilapia (*Oreochromis niloticus*) and catfish (*Clarias fuscus*) in a aquaponic system (courtesy Irene Nurzia Humburg); farmer lifting the polystyrene raft to show the roots of curly kale (*Brassica oleracea*) growing within a deep water culture aquaponic system (courtesy Hilla Noam); and a farmer harvesting tomatoes (*Solanum lycopersicum*) from an aquaponic system on a rooftop (courtesy Christopher Somerville).

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Christopher Somerville

FAO Consultant

Ireland

Moti Cohen

FAO Consultant

Israel

Edoardo Pantanella

FAO Consultant

Italy

Austin Stankus

FAO Consultant

Italy

and

Alessandro Lovatelli

FAO Aquaculture Branch

Italy

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Preparation of this document

This technical paper showcases current wisdom in aquaponics, focusing on small-scale production. The publication is divided into nine chapters and nine appendixes, with each chapter dedicated to a specific facet of an aquaponic system. The target audience is agriculture extension agents, aquaculture officers, non-governmental organizations, community organizers, companies and individuals – worldwide. The intention is to bring a general understanding of aquaponics to people who previously may have only known about one aspect, i.e. aquaculture agents without experience in hydroponics, and vice versa.

This publication 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. A broad range of parties may find interest in aquaponics, especially those whose programmatic focus incorporates at least one of the following topics: sustainable agriculture, resilient methods of domestic food production, or urban and peri-urban food security. Although not strictly necessary, some experience with vegetable and/or fish production would be advantageous for the reader. This publication is written in a style designed to be digestible by a non-technical reader. This technical paper includes diverse subjects from aquaculture to hydroponics, water chemistry to ecosystem balance and technical aspects of plumbing and construction; the challenge has been to provide a bridge towards common understanding of the broad field of aquaponics, using adequate technical details in substantial depth without allowing the publication to become unwieldy and unusable.

This publication is the product of practical experience with small-scale and commercial aquaponic systems, and was developed to share the lessons and current knowledge learned so that fledgling farmers can benefit from these experiences.

This publication was prepared in recognition of multiple FAO strategic objectives, major areas of work and regional initiatives; small-scale aquaponic systems reinforce interventions of the regional water scarcity initiative, and support the major area of work regarding sustainable intensification of agriculture through the efficient use of resources.

Abstract

This technical paper begins by introducing the concept of aquaponics, including a brief history of its development and its place within the larger category of soil-less culture and modern agriculture. It discusses the main theoretical concepts of aquaponics, including the nitrogen cycle and the nitrification process, the role of bacteria, and the concept of balancing an aquaponic unit. It then moves on to cover important considerations of water quality parameters, water testing, and water sourcing for aquaponics, as well as methods and theories of unit design, including the three main methods of aquaponic systems: media beds, nutrient film technique, and deep water culture.

The publication discusses in detail the three groups of living organisms (bacteria, plants and fish) that make up the aquaponic ecosystem. It also presents management strategies and troubleshooting practices, as well as related topics, specifically highlighting local and sustainable sources of aquaponic inputs.

The publication also includes nine appendixes that present other key topics: ideal conditions for common plants grown in aquaponics; chemical and biological controls of common pests and diseases including a compatible planting guide; common fish diseases and related symptoms, causes and remedies; tools to calculate the ammonia produced and biofiltration media required for a certain fish stocking density and amount of fish feed added; production of homemade fish feed; guidelines and considerations for establishing aquaponic units; a cost–benefit analysis of a small-scale, media bed aquaponic unit; a comprehensive guide to building small-scale versions of each of the three aquaponic methods; and a brief summary of this publication designed as a supplemental handout for outreach, extension and education.

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Authors

Chris Somerville

Urban Agriculture Consultant
Dublin, Ireland

Has worked with international and non-governmental organizations implementing sustainable urban agriculture projects in Ethiopia, Jordan and Palestine focusing on small-scale aquaponics and hydroponics. His current projects focus on developing innovative and integrated food production systems in conjunction with FAO in The West Bank and Gaza Strip.

Moti Cohen

Aquaponics Specialist
Hofit, Israel

Owner/director of a private company that provides sustainable agriculture technologies and water treatment solutions at the household level, especially focusing on aquaponics. He has designed and installed numerous commercial aquaponic units, has taught and led workshops on aquaponic food production, and has provided technical support to international projects.

Edoardo Pantanella

Agroecologist and Aquaponics Research Scientist
Rome, Italy

Research scientist focusing on integrated farming systems, especially aquaponics. His work is focused on aquaculture development, including freshwater and saline aquaponics for sustainable food systems and livelihoods in rural and urban sectors, especially in arid and saline environments. His interests include commercial development of aquaponics for fish nurseries, sea-agriculture, and wastewater farming.

Austin Stankus

FAO Consultant
Rome, Italy

His studies and work experience are in integrated aquaculture and agriculture systems, specifically aquaponics and organic farming, urban forestry mapping and spatial planning using GIS, biocomposting using black soldier flies to recycle food waste as alternative animal feed, and incorporating sustainable agriculture within the education sector as project-based learning for young farmers.

Alessandro Lovatelli

FAO Aquaculture Officer
Rome, Italy

A marine biologist and aquaculturist with extensive experience in global aquaculture development working with FAO and other international organizations. His area of work focuses mainly on marine aquaculture development, transfer of farming technologies and resource management. He has been active in promoting farming technologies applicable for food production in areas poor in freshwater resources.

Abbreviations and acronyms

AC/DC	alternating current / direct current
AOB	ammonia-oxidizing bacteria
C:N	carbon and nitrogen ratio
CaO	calcium oxide
Ca(OH) ₂	calcium hydroxide
CaCO ₃	calcium carbonate
CO ₂	carbon dioxide
CO ₃ ²⁻	carbonate
CHIFT-PIST	constant height in fish tank – pump in sump tank
CP	crude protein
DE	digestible energy
DIY	do it yourself
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DWC	deep water culture
EAA	essential amino acids
EC	electrical conductivity
EFA	essential fatty acids
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
GAP	good agricultural practice
GH	general hardness
H ⁺	hydrogen ion
H ₂ CO ₃	carbonic acid
H ₂ S	hydrogen sulphide
H ₂ SO ₄	sulphuric acid
H ₃ PO ₄	phosphoric acid
HCl	hydrochloric acid
HCO ₃ ⁻	bicarbonate
HNO ₃	nitric acid
IBC	intermediate bulk container
IPPM	integrated production and pest management
K ₂ CO ₃	potassium carbonate
KH	carbonate hardness
KHCO ₃	potassium bicarbonate
KOH	potassium hydroxide
LDPE	low-density polyethylene
LECA	light expanded clay aggregate
NaCl	sodium chloride
N	nitrogen
N ₂	molecular nitrogen
NFE	nitrogen-free extract
NFT	nutrient film technique
NH ₃	ammonia
NH ₄ ⁺	ammonium
NHO ₃	nitric acid
NO ₂ ⁻	nitrite

NO ₃ ⁻	nitrate
NOB	nitrite-oxidizing bacteria
μS/cm	microSiemens per centimetre
pH	power of hydrogen
ppm	parts per million
ppt	parts per thousand
PVC	polyvinyl chloride
RAS	recirculating aquaculture system
RCD	residual-current device
SSA	specific surface area
TAN	total ammonia nitrogen
TDS	total dissolved solids
USD	US dollar
UV	ultraviolet

Figure credits

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4.3 - 4.43 - 9.14	Austin Stankus
4.4 - 4.51 - 6.12	Mosh Kasirer
4.7	Yizhak Ben Israel
4.8	Yaniv Fieldust
4.11	Yehuda Feingold
4.12 - 4.75	Mendi Falck
4.14 - 4.70	Alon Zimerman
4.15 - 4.64 - 4.65 - 6.8(a) - 8.5 - 8.6 - 8.7(a) - 8.8 - 9.3 - 9.7	Idan Ben Yakov
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4.40	Guy Tabak
4.42	Paolo Usseglio
4.61	James Ebeling
6.5(a,b,c) - 9.4	Nitzan Solan
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7.7(b)	Ming Junchao
7.8	Koi on Demand Ltd.
7.9(b)	Victor Pouomogne
7.10(b)	Produttori Ittici Trevigiani
7.11(b)	Marc Towers
7.14	Pierpaolo Patarnello
9.9	Yaniv Cohen
9.10	Karen Tagury
9.12(b) - 9.13	Itai Levi
9.17 - 9.18 - 9.19 - 9.20	Edoardo Pantanella
9.21	Slamet Widayadi
A1.19	Nir Kroshaniwski

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