Food and Agriculture Organization of the United Nations

FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER

589

ISSN 2070-7010

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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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2014

ISBN 978-92-5-108532-5 (print)
E-ISBN 978-92-5-108533-2 (PDF)

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.

Somerville, C., Cohen, M., Pantanella, E., Stankus, A. & Lovatelli, A. 2014.
Small-scale aquaponic food production. Integrated fish and plant farming.
FAO Fisheries and Aquaculture Technical Paper No. 589. Rome, FAO. 262 pp.

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Acknowledgements

The authors gratefully acknowledge the vital contributions of the individuals who provided support during the preparation process of this paper.

In particular, the authors wish to thank the following individuals who provided photographs, preliminary editing and other technical support: Abu Ahmed, Iyad Al Attar, Yosi Bronfman, Rotem Bruner, Barak Cohen, Baruch Dach, Tim Evans, Mendy Falk, Eitan Hasman, Amit Hasman, Adar Marmur, Ayelet Ben Natan, Yoav Nevo, Irene Nurzia Humburg, Noga Perri, Nadav Reich, Valerie Rousselin, Tomr Sagee, Muhammad Shattali, Keren Taguri, Paolo Usseglio, Idan Ben Yaakov, Erez Yeruham and Efrat Zemer-Bronfman.

The authors wish to further acknowledge the contributions of Yogev Azulai, Akwak Geremew, Tal Pereg and Guy Rubinstein on aquaculture-related topics (including the small-scale production of fish feed); and of Philip Jones, Michael Raviv, Nitzan Solan and Lorena Viladomat for their inputs related to hydroponic and aquaponic food production.

The authors would also like to thank the following experts for reviewing the initial drafts of the document and providing their inputs during the review process. From the Food and Agriculture Organization of the United Nations (FAO), Wilfried Baudoin and Allison Hodder from the Plant Production and Protection Division, Tony Jarrett from the Fisheries and Aquaculture Department, and James Ebeling from the United States of America.

The development of this publication has benefited from many farmers, scientists, industry professionals, business owners, and technicians who have kindly shared their skills and experience.

This publication has been realized with the initial financial support from the European Union through the Indian Ocean Commission SmartFish Programme, and regular programme funds of FAO.

Special thanks go to Hilla Noam for her efforts on the technical drawings included in this publication. Page layout was prepared by José Luis Castilla Civit.

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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_2CO_3	carbonic acid
H_2S	hydrogen sulphide
H_2SO_4	sulphuric acid
H_3PO_4	phosphoric acid
HCl	hydrochloric acid
HCO_3^-	bicarbonate
HNO_3	nitric acid
IBC	intermediate bulk container
IPPM	integrated production and pest management
K_2CO_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

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