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MULTISTAKEHOLDER WORKSHOP ON ADVANCING AQUAPONICS

Bogor, Indonesia, 4 October 2016

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PREPARATION OF THIS DOCUMENT

This report describes the activities and outputs of the workshop entitled “Multistakeholder workshop on Advancing Aquaponics”, which was held in Bogor, Indonesia, on 4 October 2016, and technical appendixes of two aquaponic studies commissioned by FAO.

This report was prepared by Austin Stankus, FAO Consultant.

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ABSTRACT

A total of 12 participants participated in the Multistakeholder Workshop on Advancing Aquaponics on 4 October 2016. This 1-day multistakeholder workshop provided an appropriate forum for the identification, discussion and resolution of issues using input from multiple stakeholders towards supporting the wider adoption of the Yumina/Bumina technique of integrated agriculture and aquaculture. It served as a follow-up to the international training workshop in direct response to recommendations, and supported strengthened stakeholder networks including increased inter-ministerial communication and identified potential areas for collaboration.

CONTENTS

	Page
PREPARATION OF THIS DOCUMENT	iii
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
ABBREVIATIONS AND ACRONYMS	vi
BACKGROUND	1
WOKSHOP PROGRAMME	2
APPENDIXES	
1. WORKSHOP AGENDA	5
2. PARTICIPANT REPORTS	6
3. REPORT OF NUTRITIONAL COMPOSITION STUDY OF AN AQUAPONICALLY GROWN VEGETABLE IN INDONESIA	11
4. REPORT OF THE TECHNICAL AND SOCIO-ECONOMIC STUDY OF AQUAPONICS IN INDONESIA	23
5. LIST OF PARTICIPANTS	31
6. GROUP PHOTO	32

ABBREVIATIONS AND ACRONYMS

BIOTROP	Southeast Asian Regional Centre for Tropical Biology
EAFSAE	Executing Agency for Food Security and Agricultural Extension
FAO	Food and Agriculture Organization
FSA	Food Security Agency
IAARD	Indonesian Agency for Agricultural Research and Development
IFARD	Institute for Freshwater Aquaculture Research and Development
MMAF	Ministry of Marine Affairs and Fisheries
MOA	Ministry of Agriculture
NGO	Non-governmental organization
RAP	Asia and Pacific Region
RAS	Recirculating aquaculture system
SEAMEO	Southeast Asian Ministers of Education Organization
SFRG	Sustainable Food Reserve Gardens
SP2	Strategic Programme 2 of the FAO
WAIBI	Indonesia Initiative for Blue Economy

BACKGROUND

Aquaponics is a symbiotic integration of two mature food production disciplines: aquaculture, the practice of fish farming; and hydroponics, the cultivation of plants without soil. These are combined within a closed recirculating system. In a standard recirculating aquaculture system (RAS), the organic matter ("waste") that builds up in the water needs to be filtered and removed so that the water is clean for the fish. In an aquaponic system, the nutrient-rich effluent is filtered from the settleable part of its solids and then passes through an inert substrate containing plants. Here, bacteria metabolize the fish waste, and plants assimilate the resulting nutrients. The purified water is then returned to the fish tanks. The result is value-added products such as fish and vegetables, together with reductions in nutrient pollution into the watershed. Aquaponics was first introduced to Indonesia in 2005, and then in 2012 the name was changed to Yumina/Bumina during World Food Day to reflect the unique modifications that had been made by Indonesian experts. This specific version of aquaponics is well-adapted to local conditions and especially applicable to small-scale operations. The major benefits are lower initial investment, relatively simpler management techniques, and increased adaptability and resilience. A technical description of the Yumina/Bumina technique can be accessed on the FAO TECA platform here: http://teca.fao.org/read/8763

An international FAO technical training workshop on advancing aquaponics was held in Bogor, Indonesia, on 23–26 November 2015. Twelve participants were present from 11 countries and one regional scientific and technical organization. The 4-day workshop was convened by FAO and consisted of lectures, demonstrations and hands-on activities supported by aquaponics experts from the Indonesian Ministry of Marine Affairs and Fisheries and Ministry of Agriculture, FAO technical officers and aquaponics consultants. Recommendations were gathered based on participant feedback and included: (i) education, training and communication; (ii) research and development; (iii) socio-economic and feasibility studies; (iv) regional and international cooperation; and (v) capacity development of an enabling environment at the national level. Participants from Indonesia particularly highlighted the need to improve the extension services to build capacity in farmers and enable them to manage their aquaponics systems efficiently. Moreover, the investment in communities and research and development are seen as an asset to make systems more productive and economically more profitable.

The workshop report can be accessed here: *FAO. 2016. Report of the FAO technical workshop on advancing aquaponics: an efficient use of limited resources, Bogor, Indonesia, 23–26 November 2015. FAO Fisheries and Aquaculture Report No. 1133. Rome, Italy.* URL: www.fao.org/3/a-i5543e.pdf

In follow-up to this training workshop, and in response to the recommendations made by the participants, FAO convened a 1-day national workshop of experts, practitioners and other stakeholders to elaborate a comprehensive picture of the current state and future direction of aquaponics in Indonesia.

Purpose

This 1-day multistakeholder workshop provided an appropriate forum for the identification, discussion and resolution of issues using input from multiple stakeholders towards supporting the wider adoption of the Yumina/Bumina technique of integrated agriculture and aquaculture. It served as a follow-up to the international training workshop in direct response to recommendations, and supported strengthened stakeholder networks including increased inter-ministerial communication and identified potential areas for collaboration.

Objectives

A 1-day workshop served as a knowledge sharing event for participants from various stakeholder groups practicing Yumina/Bumina in Indonesia. The objectives were:

- Facilitating exchange of knowledge and experiences on Yumina/Bumina in Indonesia;
- Taking stock of Yumina/Bumina training materials and curricula currently available;
- Identifying opportunities for advancing Yumina/Bumina; and
- Understanding the status of upscaling and expansion.

Expected outputs

- Knowledge, experiences and good practices for Yumina/Bumina as applied in Indonesia were shared and documented;
- Inventories of Yumina/Bumina curricula were identified, and priority areas for strengthening were highlighted;
- Priorities and plans were drafted and discussed for continued Yumina/Bumina work in Indonesia; and
- International support opportunities were evaluated and discussed.

Organization

The workshop was jointly organized by FAO Headquarters, FAO Indonesia and the Government of Indonesia.

Participants

Twelve participants attended the workshop. Participation included representatives from the Ministry of Marine Affairs and Fisheries (MMAF), Ministry of Agriculture (MOA), the Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP), private sector aquaponic practitioners, extension agents and representatives of farmers groups. All participants had significant previous experience with aquaponics. A list of participants is included as Appendix 5, and a group photo is included as Appendix 6.

WOKSHOP PROGRAMME

The activity consisted of a 1-day workshop, the agenda of which is included as Appendix 1. The participant presentations included ongoing and planned activities in aquaponics, key results of research and/or commercial ventures, identified challenges and suggestions for further advancing Yumina/Bumina. Moderated discussion of key points further elucidated these considerations.

SESSION I: Sharing knowledge and experiences: ongoing and planned work of Yumina/Bumina including research, extension, results and challenges

Opening remarks were presented by Dr Estu Nugroho from MMAF and by Austin Stankus of FAO.
The first session saw presentations from the MMAF, MOA and SEAMEO BIOTROP. Summaries of each participant report are included in Appendix 2. The MMAF presentation included information on the extension network and training activities, number of farmers trained and ongoing research. The MOA presentation included an update on the Sustainable Food Reserve Gardens, production results of a FAO-style aquaponic system, the number of farmers trained and ongoing research. SEAMEO BIOTROP presented the results of nutrition and socio-economic studies (included in Appendixes 3 and 4), results of training Department of Corrections staff and some regional perspectives with SEAMEO partners.

SESSION II: Next steps and future prospects

The second session saw general discussion on future direction, work planning, opportunities and remaining challenges on identified priority areas. Some of the key priorities and identified recommendations are summarized as follows:

Interventions should be divided between business-oriented and other types. A related priority is addressing the targeting of beneficiaries, and it was suggested to divide interventions between hobby-oriented and business-oriented persons, and between rural and urban areas. There is an identified problem of supporting farmers to become more business minded. In this regard, interventions and training should not only be focused on technology transfer, but also include capacity strengthening for business development including financial and business planning activities, and possibly require business planning as a prerequisite to input provision. Non-business related interventions may emphasize the healing aspects of aquaponics for rehabilitation and stress relief (therapy healing horticulture), especially in prisons, hospitals and health facilities. Similarly, urban aquaponics should be attractive, and space saving, in order to be accepted and incorporated in family gardens.

Active leadership and champions are an essential entry point into communities. One of the most effective strategies is working with community women’s groups, often associated with schools and education, as these groups hold an important role in the village and neighbourhoods. Individual extension agents are required to service many people and thus are spread thin, so volunteer extension or village champions are useful to support and follow up with extension activities.

Communication materials should be strengthened, consolidated and shared. Currently there is no single repository of the communication materials such as technical manuals, training curricula, educational videos and others. It was specifically highlighted that the various stakeholders should take action to facilitate sharing of these materials. Publications and books are considered less important than demonstration sites and videos because few people are using printed materials. Only research institutions, and to a lesser extent extension agents, use texts. Instead, social media (e.g. Facebook), video sharing sites (e.g. YouTube) and social networking (e.g. Viber, WhatsApp) are more commonly used to access information, and extension agents have begun to take advantage. Relatedly, promotional and marketing materials targeted to consumers need to be strengthened because currently the market price of aquaponic vegetables is less than traditionally grown. World Food Day was hosted by IIARD in Boyolali, Indonesia from 28–30 October, 2016 and featured Sustainable Food Reserve Gardens (SFRG) in which aquaponics featured prominently among the innovative techniques. Field scale aquaponics (minapadi) was on display, though the smaller yard-scale aquaponics was not displayed. As World Food Day is an event attended by high-level decision-makers and politicians, it was a prime opportunity to showcase the work being done.

Technical improvements and continued research needed to address certain issues including: 1) improving water use efficiency; 2) the relationship between fish stocking density and vegetable planting density; 3) the organoleptic, quality and nutritional composition of fish and plants; 4) methods of solids filtration; 5) mosquito control; 6) branding and marketing; and 7) alternative power sources. Water use efficiency is a key opportunity provided by aquaponics and directly addresses the challenges of shifting rainfall patterns, and current research is documenting the water consumption and identifying techniques to increase the water savings. The relationship between the number of fish and number of plants is being optimized to provide the best production with the lowest cost. The quality of fish and plants is being tested through consumer taste-testing backed up with laboratory analysis. Additional methods of solids filtration are being investigated to improve root performance and reduce stress of the fish. Mosquito control is a serious issue in aquaponics, and currently aquaponics is being opposed by a community group fighting dengue fever. As such, research is documenting the amount of mosquito breeding occurring in aquaponics and identifying practices to reduce the numbers. Branding and marketing are not only about getting the target market to select aquaponic produce over the competition, but also about informing the consumers about the multiple benefits of aquaponics for society and the environment. Finally, alternative power sources are required, particularly photovoltaic, to address the unreliability and high cost of grid-based power especially in rural areas. Ongoing research is being carried out to address these issues by the three key organizations, and there was agreement to share the results.

APPENDIX 1

WORKSHOP AGENDA

Time	Activity	Remark
09:00 – 09:30	Welcome and Keynote • Government of Indonesia • FAO	
Session I: Sharing knowledge and experiences: ongoing and planned work of Yumina/Bumina including research, extension, results and challenges		
09:30 – 10:15	Ministry of Marine Affairs and Fisheries	Including: • extension network and training • number of farmers trained • ongoing research
10:15 – 11:00	Ministry of Agriculture	Including: • update of Sustainable Food Reserve Gardens • production results of FAO-style aquaponic system • number of farmers trained • ongoing research
11:00 – 11:45	SEAMEO BIOTROP	Including: • results of nutrition and socio-economic study • results of training Department of Corrections staff • regional perspective with SEAMEO partners
11:45 – 13:00	General discussion	
13:00 – 14:00	*lunch*	
Session II: Next steps and future prospects		
14:00 – 15:30	Moderated discussion	General discussion on future direction, work planning, opportunities and remaining challenges on identified priority areas
15:30 – 16:00	Communication product development	Identify key messages and target audiences

APPENDIX 2

PARTICIPANT REPORTS

Institute for Freshwater Aquaculture Research and Development – Ministry of Marine Affairs and Fisheries AND Executing Agency for Food Security and Agricultural Extension

The Institute for Freshwater Aquaculture Research and Development (IFARD) of the MMAF, located in Bogor, has been active in researching and extending aquaponic technology since around 2012. The Bogor research institute is primarily focused on the development of yumina/bumina in 12 locations with the involvement of local fisheries departement and its extension and providing technology transfer and equipment; IFARD does not take a direct role in extension work. Already, the technology of aquaponics has been extended to communities in the cities of Bogor, Boyolali, Jakarta, Pacitan, Pandeglang, Temanggung, and Sleman on Java Island, as well as Makassar on Sulawesi Island, Palangkaraya on Kalimantan Island, and Palembang on Sumatra Island. Separately, 165 households were provided local funding to build aquaponics throughout 33 sub-districts, with implementation targeted for farmer organizations. IFARD provides follow-up support to aquaponic interventions, developing capacity and infrastructure for hatcheries, fish disease management and better feeding practices.

Ongoing research is being conducted on the effects of implementing external mechanical and biofiltration units in the aquaponic system. Previously IFARD identified problems with fouling and sedimentation on the plant roots, as well as high ammonia and nitrite levels. Early results suggest that plant growth increases in systems with additional filtration. Other work is ongoing regarding the construction and testing of different system configurations, as well as the use of probiotic additions. The Yumina/Bumina systems in Indonesia and espoused by IFARD generally fit into four categories: 1) floating raft system, 2) surface flow system, 3) bottom flow system, and 4) ebb-flood system. Different systems are recommended based on the vegetable crop choice, the fish choice, the pre-existing infrastructure and desired pond construction.

Training courses have been held for many different groups, in collaboration with the Executing Agency for Food Security and Agricultural Extension (EAFSAE). A variety of beneficiary groups have been trained (Figure 1) including: academic institutions, both national and international; farmers organizations; business/entrepreneurial groups; and FAO. In the last year (2015), many participants have benefitted from a variety of workshops, many of which were held in Palasari Village, Cijeruk sub-district of Bogor city at the farming site of the Rahmatan 3 Farmers Group led by the champion farmer Sholeh Zakaria. A video interview with Mr Zakaria and the extension agent, Mr Mohamad Nurdin of the EAFSAE was commissioned by FAO in 2015 and can be found here: www.youtube.com/watch?v=558nSVsL5nI

These extension activities have been strengthened with a strong media presence, with YouTube videos, online newspapers and national radio all picking up the stories. Indeed, there is a network of extension workers that have online video conferences twice per week, which have included aquaponics in the past. It is estimated that approximately 300 people were trained in 2015 through IFARD workshops.

Figure 1: Selection of photographs showing training activities held in Palasari Village in Bogor city at the farming site of the Rahmatan 3 Farmers Group led by Sholeh Zakaria, with technical support of the Institute for Freshwater Aquaculture Research and Development. *Courtesy of:* IFARD-MMAF.

Indonesian Agency for Agricultural Research and Development – Ministry of Agriculture

The Indonesian Agency for Agricultural Research and Development (IAARD), under the auspices of the MOA, is supporting the implementation of Sustainable Food Reserve Gardens (SFRG). The purpose of SFRG is the empowerment of households in a village to produce food that is diverse, nutritious and safe independently and sustainably through the utilization of the yard, local resources and innovative technologies. Recommended technologies for SFRG include: plant nurseries and fish hatcheries; production of plant growing media and organic fertilizer; integrated pest management and biological pesticide production and use; container gardening, vertical farming, hydroponics and aquaponics; crop rotation and crop cultivation calendars; small livestock raising; and small scale food processing. In general, practices support the utilization of the small family land holdings that are environmentally friendly and designed for: durability and food self-sufficiency; diversification of food based on local resources; conservation of genetic resources of food; maintaining sustainability through the village nursery gardens; and increasing income and social welfare.

Of the 7 800 SFRG established to date throughout the country (Table 1), about 1 500 (20 percent) have installed aquaponic systems. There is a difference in the implementation of aquaponics in rural versus urban areas. For rural areas it is better to use standard Yumina/Bumina. For urban sites like the SFRGs, it is better to use vertical aquaponics, known as vertiminaponik and wolkaponik.

The Food Security Agency (FSA), a separate department of the MOA, entered into an agreement with IAARD to support SFRG. Essentially, the IAARD continues the research of SFRG appropriate technology and extension and the FSA handles administrative matters and budgeting. The number of SFRG has grown steadily since 2011 when the first 44 units were built, with a current total of about 7 800 units. Table 1 shows the proliferation of SFRGs per year, while Figure 2 shows the geographical coverage. The Government of Indonesia has a similar programme supporting organic villages, and though not directly related to SFRG, similar practices are used and there may be an opportunity for aquaponics.

IAARD maintains a research and demonstration centre in south Jakarta that also serves as an example of the SFRG. At this site, there are 10s of small-scale aquaponic and Yumina/Bumina systems. Some of the systems are of the "Western" style. IAARD constructed and experimented with a small-scale aquaponic system based on the FAO design. This design uses 1 cubic metre bulk liquid container as the fish and plant tanks, and careful water management and filtration, and is a similar model to that commonly used throughout the world. Full details and construction techniques are explained on page 209 of the FAO aquaponics manual, found here: www.fao.org/3/a-i4021e/index.html. Based on the experiments on the FAO models, IAARD recommends modifications. One of the problems is high evaporation which is wasteful of water and increases costs. The construction and operating costs are relatively high for the target community in medium/low income families, so alternative and locally available materials are being investigated. Also, the size is too large for the yard especially in urban areas, so additional modifications are necessary.

Year	# of SFRA
2011	44
2012	379
2013	1033
2014	1515
2015	2873
2016	2012
Total	**7856**

Table 1: Number of Sustainable Food Reserve Gardens implemented by year by the Indonesian Agency for Agricultural Research and Development and the Food Security Agency of the Ministry of Agriculture

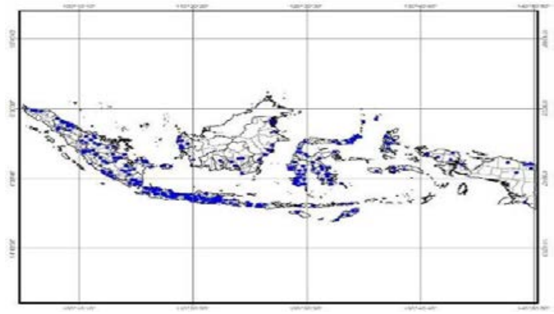

Figure 2: Location of Sustainable Food Reserve Gardens implemented by the Indonesian Agency for Agricultural Research and Development and the Food Security Agency of the Ministry of Agriculture

One of the activities (2016–2017) of IAARD in cooperation with the army headquarters is to support the development of aquaponics on all military district command posts (Komando Distrik Militer). IAARD has prepared a set of standard operating procedures for military installations, which was adapted from the resources of FAO, MMAF and MOA. The purpose is to use the military base demonstration units to sensitize and train military members and their families, and support the adoption of aquaponics at their own private houses.

Overall, aquaponics enjoys a positive prospective for development. Contributing factors include the increase in the number of affluent people, especially in big cities. In addition, widespread advocacy for healthy food and healthy living, especially for food free from pesticide and chemical residues, has encouraged the use of pesticide-free production systems such as aquaponics. Also, the global issue of climate change highlights the need to increase the efficiency of crop cultivation, livestock and fish.

Several blocking issues to the advancement of aquaponics have been identified. Perhaps most importantly is a problem with customer awareness and preference. Communities are generally not familiar with aquaponic products, and aquaponic produce has prices equal to conventional agriculture. On a more technical level, the power source for the aquaponic pump is rather expensive and yet the cost is not recuperated in the final sale price of the produce. This therefore suggests further development of an alternative power source, specifically photovoltaic. A complex problem is the issue of mosquitoes breeding in aquaponic systems and spreading disease. Though mosquitoes generally do not breed in the moving water of aquaponic systems, the perception that they do is a real concern. Jumantik is a community group organized to eliminate mosquitoes as part of the fight against Dengue fever and other mosquito-borne illnesses, and to date have had vocal opposition to aquaponic interventions. One suggested option was to scientifically document the breeding potential of mosquitos within aquaponic units *in situ*, and to introduce mosquito mitigation practices during aquaponic interventions, ideally with the participation of Jumantik. At a policy level, the Ministry of Agriculture has prioritized the production of staple commodities, namely rice, maize and soybean, outlined in the MOA's PAJALE (padi, jagung, kedelai) policy. As a result, the budget for aquaponic work at IAARD has diminished in this budget cycle. Finally, because aquaponics is not a well-known technique, there is low technical capacity of the general population.

Noting these constraints, there are several priority research areas that are being targeted by IAARD. First, design improvements of aquaponic systems safe against mosquitoes will be tested and evaluated. There are also plans to evaluate systems using photovoltaic panels to supply power which will be assessed based on running costs and the initial investment. Finally, considering that IAARD targets urban, small-scale users there is a desire to make "beautiful" aquaponic systems that households are happy to display in their yards and common spaces. There is an important difference between urban and rural aquaponic systems, with the former needing to be space efficient and attractive and the latter more focused on economically profitable crop production.

In combination with this research programme, IAARD is actively disseminating and sensitizing people to aquaponic technologies. There is some lobbying and advocacy work to support a better market price for aquaponic products. There is ongoing multichannel dissemination through the governmental institutions, provincial and district agriculture extension offices, non-governmental groups and producer organizations. Guidelines have been prepared for the military implemented systems, and an aquaponic book in the final editing process. This aquaponic book combines the experiences of IIARD, IFARD and references the FAO aquaponic manual. A continuing training and technical assistance programme is available consisting of on-farm training, reference materials, online videos and tutorials, and manuals. The number of people trained in 2014 was 465, in 2015 was 888 and in 2016 was 996. IAARD provides free 1-day training at their demonstration site to individuals and groups, though institutions are invited to pay a small fee.

Aquaponics was displayed at World Food Day celebrations in Padang-West Sumatera (2013), Makasar, South Sulawesi (2014), and Palembang, South Sumatera (2015). In November 2016, field scale aquaponics (minapadi) was displayed in Boyolali. Examples of vertical aquaponics are shown regularly at an IAARD exhibitions, and have been on display at about 60 events from 2014–2016. The communication and extension strategy also includes sensitization through magazine, television, books and brochures, and importantly the organization's website.

Southeast Asian Regional Centre for Tropical Biology

The Southeast Asian Regional Centre for Tropical Biology (BIOTROP), one of the 20 regional centres of the Southeast Asian Ministers of Education Organization (SEAMEO) has an active programme of research and extension in aquaponics that includes research activities, capacity development and knowledge management. Through integration and syntheses of these programmes and activities, BIOTROP expects results in policy, curriculum and community development with an overall target to support the intensification of aquaponic systems to support food self-sufficiency and poverty alleviation in Southeast Asia.

During 2015–2016, BIOTROP carried out several activities in aquaponics. Two research projects, supported through FAO funding included a technical and social economic assessment of current aquaponics farming in Indonesia, as well as an analysis of the nutrient composition of a crop grown in aquaponics as compared to the same grown in soil. The two reports are included in this workshop report as technical Appendixes 3 and 4.

In collaboration with Indonesia Initiative for Blue Economy (WAIBI) and the Department of Law and Human Rights, BIOTROP conducted training from 10–11 August 2015 for prison corrections officers, and 15 officers were trained. Several aquaponic systems have been built inside prisons as a therapeutic activity for incarcerated persons as well as job skills training. The trained officers were expected to apply and transfer the knowledge to the inmates. This approach has also been integrated with mushroom culture because it can be used in urban context and also as a good business opportunity for former inmates. BIOTROP has ongoing training and extension support for the staff, including a training monitoring and evaluation program (Napi Berkebun) and a gardening programme for inmates at seven prisons. A recent festival was held for gardening with prisoners, during which healing horticulture including aquaponics was presented as a therapy and the belief was espoused that horticulture exposure can lead to lower rates of recidivism in inmates.

In addition, BIOTROP has ongoing research regarding the efficiency of aquaponic systems by adjusting the stocking density of fish and integrating biofloc technology, and monitoring the changes in yield and organoleptic qualities of the fish and plants. The biofloc, a common technology to increase pond productivity and improve water quality, is created within fish rearing tanks by using molasses and lactobacillus inoculations. Biofloc has been hypothesized to address problems of unbalanced nutrient composition in the fish waste water as well as lower pH.

As BIOTROP is part of the larger SEAMEO network, which is an intergovernmental organisation promoting regional cooperation through education, science and culture. As such there is a clear regional perspective to BIOTROP’s work. Within BIOTROP, programmes are prioritized that address current important needs in line with the global development agenda and country priorities while helping to achieve the vision, mission and goals of the organization. At the same time, programmes need to generate outputs in the form of knowledge, publications and technologies while informing policy and decision makers. There is a strong incentive to establish and strengthen collaboration within SEAMEO centres as well as engaging with partners including schools and universities. Innovation is important, but the achievability and applicability of results in the given time of implementation is paramount. Nationally, BIOTROP is governed under the Ministry of Higher Education.

A 5-year roadmap of activities has been developed including potential collaborators and users. This workplan is reproduced below in Table 2. Overall, it includes continued research on prototypes and priority research questions followed by dissemination, communication and technology transfer. Starting in 2020, there is a plan to scale up the aquaponic systems regionally based on the lessons learned in Indonesia. In collaboration with the SEAMEO partners, BIOTROP will create an aquaponic “Technopark” that will serve as a centre of excellence in aquaponic technology and support regional training activities with SEAMEO member states. BIOTROP will develop and support communications documents and policy briefs based on data from the project results targeting policy makers and relevant ministries, and conduct a performance and impact assessment of aquaponic interventions. In addition, BIOTROP is producing a book on aquaponics this year.

Table 2: Five-year work plan of SEAMEO Centre of Tropical Biology for aquaponic research, training and advocacy

Project title: Intensification of aquaponics system to support food self-sufficiency and poverty alleviation in Southeast Asia						
Project goal: To enable communities to become food self-sufficient and improve their standard of living						
	Activity	**2017**	**2018**	**2019**	**2020**	**2021**
Research	Develop prototype of intensive aquaponic systems	x				
	Apply prototype of intensive aquaponic systems in multi-location areas		x			
Training	Develop training module and curriculum	x				
	Develop revised training module and curriculum		x	x		
	Develop international module and curriculum				x	
	Conduct training on improvement of aquaponics production systems efficiency by biofloc technology application	x	x			
	Promote and implement prototype of intensive of aquaponic system to the community (nationally)			x		
Scale up	Build an aquaponic technopark on BIOTROP campus				x	
Communicate	Produce policy briefs from project results targeting policy makers in the relevant Ministries					x
Evaluation	Assess performance and impact					x

APPENDIX 3

REPORT OF NUTRITIONAL COMPOSITION STUDY OF AN AQUAPONICALLY GROWN VEGETABLE IN INDONESIA

Nutritional composition of water spinach (Ipomea aquatica) grown in Indonesian aquaponic systems

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Key words: aquaponics, nutrient composition, kangkong, water spinach, *Ipomea aquatica*

Abstract

The nutritional value of a particular food is determined primarily by its nutrient composition. This study was designed to evaluate the nutrient composition of a crop grown in aquaponics as compared to the same grown in soil (non-aquaponics culture). Kangkong (*Ipomea aquatica*) was chosen because it is regionally important and commonly grown in aquaponics. Fresh leaves of kangkong were planted, grown, harvested, stored and shipped at the same time on three separate farms according to the protocol of the nutrient analysis laboratory. Each sample was divided into three replicates, and analyses were conducted to determine the proximate chemical content, water soluble vitamins, fat soluble vitamins, carotenoids and xanthophylls, cholines and betaines, sterols, oligosaccharides, polyphenols, antioxidant activity, minerals, organic acids, bioactive substances as well as the amino acid and fatty acid profiles. All experiments were repeated three times except for electrophoretic analyses, which were duplicated. The significance of differences between means was determined by comparing confidence intervals for each treatment at an alpha of 0.05. The results of analyses revealed significant differences between the aquaponic and non-aquaponic samples for several of the minerals, namely: calcium, magnesium, sodium, potassium, iron, manganese, chromium and phosphorous. The results of all analyses were compared with literature reference values.

Introduction

Aquaponics is a symbiotic integration of two mature food production disciplines; aquaculture, the science of fish farming and hydroponics, and the science of growing plants without soil, are combined within a closed recirculating system. In a standard recirculating aquaculture system (RAS), the organic matter ("waste") that builds up in the water needs to be filtered and removed so that the water is clean for the fish. In an aquaponic system, the nutrient-rich effluent is filtered through an inert substrate containing plants. Here, bacteria metabolize the fish waste, and plants assimilate the resulting nutrients. The clean water is then returned to the fish tanks. The technology and techniques are relatively simple and easy to adopt once demonstrated to the farmers. Aquaponics builds upon several decades of work, and systems have been built successfully throughout the world. Currently, aquaponics serves many worldwide communities with limited freshwater resources, limited land and high sale prices of fresh vegetables and fish. The state of the art is advancing rapidly, and new techniques and technologies, are supporting commercial aquaponic development.

Food safety is an important issue in Indonesia, and at the production level, food safety issues have emerged in regards to pesticide residues and their improper use. Food production practices such as organic agriculture can provide considerable opportunity to produce safe food, however there are limitations such as high consumer cost and limited potential to produce sufficient food to feed the nation. Aquaponics is one of many methods that provides small-scale family farmers with an opportunity to grow organic vegetables, greens, herbs, and fruits, while providing the added benefits of fresh fish as a safe, healthy source of protein.

One of the identified benefits of aquaponics is the opportunity for small-scale farmers to diversify their diets through the cultivation of nutritious vegetable crops. However, few studies have quantitatively proven that aquaponic vegetables have equivalent nutrient composition to soil-grown or hydroponically-grown crops. Pantanella showed that the mineral composition of leaves was different between aquaponic and hydroponic crops (2012), which suggests that the differences in fertilizer regimes will affect the final nutrient composition of the crop.

Kangkong, also known as water spinach or water convolvulus, *Ipomoea aquatica*, is a vegetable used widely in Indonesian cuisine. This preliminary study reported here was designed to evaluate the nutrient composition of a crop grown in aquaponics as compared to the same grown in soil (non-aquaponics culture) while identifying methodology and experimental design for further work.

Materials and methods

Selection and recruitment of an adequate party to conduct the nutritional analysis

The study used field-based crop production with three (3) farmers growing the plants in both aquaponics and soil media (non-aquaponic culture), and each farm only grew one (1) replicate of both treatments (aquaponic vs non-aquaponic) for a total of six (6) samples. All farmers were located in West Java, Indonesia in the sub districts of Bogor and South Jakarta. The locations are provided in Table A.

Table A. Sample locations of plants in West Java and Jakarta, Indonesia

Locations	Latitude	Longitude
Pasar Minggu, Jakarta	6°17'8.3508”	106°50'4.8408”
South Bogor, Bogor	6°38'6.3576”	106°49'31.548”
West Bogor, Bogor	6°36'10.5732”	106°47'13.9128”

Experimental System and Data Collection

Kangkong (*Ipomea aquatica*) was chosen owing to the regional importance and diffuse use in aquaponics. Clarias catfish (*Clarias* sp.) was chosen as the fish for the same reasons. A single batch of seedlings were germinated by the Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP), to ensure that individual plants came from the same genetic stock (same seeds). Seedlings were germinated under standard conditions, grown until approximately 5 cm, and then randomly distributed to the three farmers. After 21 days, the kangkong was harvested with a sharp knife, all of the leaves were stripped, chilled and transported to the nutrient analysis laboratory (PT Saraswanti Indo Genetech [JL. Rasamala No. 20, Taman Yasmin, Curugmekar, Bogor Bar., Kota Bogor, Jawa Barat 16113, Indonesia]). All farmers harvested on the same day and followed the same protocol.

Analysis of the samples

Upon arrival at the nutrient analysis laboratory, the leaves were thoroughly washed with distilled water, and ground to reduce particle size and increase surface area. Each sample was divided into triplicate and laboratory analyses were conducted to determine proximate chemical content, water soluble vitamins, fat soluble vitamins, carotenoids and xanthophylls, cholines and betaines, sterols, oligosaccharides, polyphenols, antioxidant activity, minerals, organic acids, bioactive substances, amino acid profile, and fatty acid profile.

The method of Pearson (1976) was employed for proximate analysis. The soxhlet method was also employed in the determination of the crude fat/oil in the sample using petroleum ether (40–60 °C). The Kjedhal method was used for protein estimation while the crude fiber and ash contents were also determined (AOAC, 1980). A list of the laboratory methods for each parameter is presented in Table B.

Table B. List of tests and laboratory methods used to determine the nutrient composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameters	Methods
Carbohydrates: Available carbohydrates, free sugars and starches	Titration and gravimetric methods
Water soluble vitamins: Thiamine, Riboflavin, Niacin, Pantothenic acid, Pyridoxal, Pyridoxamine and Pyridoxine, Biotin and Folates	HPLC, LCMS-MS, GC
Fat soluble vitamins: Vitamin A, D, E, K,	HPLC
Carotenoids and Xanthophylls	Spectrophotometric
Cholines and betaines	*Cholinesterase test; Betaine HCL Test*
Sterols: Stigmasterol, Campesterol, β-Sitosterol and cholesterol	GC
Oligosaccharides: Raffinose, Stachyose, Verbascose and Ajucose	Chromatograhic methods
Polyphenols	Spectrophotometric
Water soluble and fat soluble antioxidant activity	DPPH methods
Minerals: Ca, Mg, Na, K, Fe, Mn, Zn, Cu, Al, As, Hg, Se, Sb, Pb, Cd, Ni, Li, Mo, Co, Cr and P	ICP, AOAC
Organic acids: Oxalic, Malic, Citric, Fumaric, Succinic, Ascorbic, Cis-Aconitic and Tartaric	HPLC
Bioactive substances: Trypsin inhibitor, Phytate, total saponin, total and soluble oxalates, non-protein nitrogen	Test kit
Complete amino acid profile	HPLC
Complete fatty acid profile	GC-FID

Data analysis

All nutrient analyses were repeated three times except for elecrophoretic analysis, which were duplicated. Microsoft Excel was used to calculate the descriptive statistics. Considering the low sample size (3 per each treatment), statistical differences were not expected to be apparent, and for this reason the raw data is provided in Annex 1. Means and confidence intervals were calculated for three samples from aquaponics (AP) and the three samples from the non-aquaponic treatment (non-AP). The results are presented in tabular form, noting the difference between not-tested and not-detected (-nd-). Confidence intervals were calculated with an alpha of 0.05, and samples were *not considered significantly different* if the confidence intervals overlapped. Only *interfarm* differences were calculated because no replication was done on individual farms with the same treatment.

Results

Proximate analysis

The results of the proximate analysis are presented in Table C. There were no significant differences between the two treatments. Moisture content, total carbohydrate, total fat, protein, ash, total energy and energy from fat were analysed.

Table C. Proximate chemical composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameter	Unit	X̄ ± CI AP	X̄ ± CI non-AP	Difference @ α 0.05
Proximate Analysis				
Water	% of sample	92.95 ± 1.41	92.75 ± 1.92	-
Carbohydrate	% of sample	3.48 ± 0.91	4.51 ± 1.96	-
Total fat	% of sample	0.34 ± 0.36	0.31 ± 0.41	-
Protein	% of sample	1.81 ± 0.43	1.16 ± 0.88	-
Ash	% of sample	1.43 ± 0.50	1.26 ± 0.16	-
Total energy	kcal/100 g	24.1 ± 7.91	25.5 ± 9.37	-
Energy from fat	kcal/100 g	3.59 ± 2.32	2.79 ± 3.62	-

Water soluble vitamins

The results of the water soluble vitamin analysis are presented in Table D. There was a significant difference in riboflavin (B2), but the overall amount was quite low in both samples. There were no significant difference in niacin (B3) nor biotin. Pantothenic acid (B5), pyridoxal (B6) and folate were not detected. Vitamin-B12 was not tested.

Table D. Water soluble vitamins composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameter	Unit	X̄ ± CI AP	X̄ ± CI non-AP	Difference @ α 0.05
Water soluble vitamins				
Thiamine (B1)	mcg/dL	-nd-	-nd-	
Riboflavin (B2)	mg/100 g	0.12 ± 0.02	0.07 ± 0.02	*
Niacin (B3)	ppm	0.37 ± 0.11	0.28 ± 0.10	-
Pantothenic acid (B5)	ppm	-nd-	-nd-	
Pyridoxal (B6)	mg/100 g	-nd-	-nd-	
Biotin	ppm	0.62 ± 0.20	0.5 ± 0.23	-
Folates	mcg/100 g	-nd-	-nd-	

Fat soluble vitamins

The results of the fat soluble analysis are presented in Table E. There were no significant differences detected between treatments for vitamin E or vitamin K. Vitamins A and D were not detected.

Table E. Fat soluble vitamins composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameter	Unit	X̄ ± CI AP	X̄ ± CI non-AP	Difference @ α 0.05
Fat soluble vitamins				
Vitamin A	mcg/100 g	-nd-	-nd-	
Vitamin D	ppm	-nd-	-nd-	
Vitamin E	mg/100 g	1.39 ± 0.19	1.49 ± 0.19	-
Vitamin K	mcg/100 g	48.66 ± 11.34	43.77 ± 7.25	-

Carotenoids and Xanthophyll

The results of the carotenoid and xanthophyll analyses are presented in Table F. There was no difference detected between the treatments for carotenoids, though there was high variance among samples. Xanthophyll was not detected.

Table F. Carotenoids and Xanthophyll composition

Parameter	Unit	$\bar{X}$ ± CI AP	$\bar{X}$ ± CI non-AP	Difference @ α 0.05
Carotenoids and Xanthophyll				
Carotenoids	ppm	234.78 ± 172.03	197.51 ± 197.24	-
Xanthophyll	ppm	-nd-	-nd-	

Minerals

There were significant differences between the treatments for several of the minerals as presented in Table G. Calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), aluminium (Al), chromium (Cr) and phosphorous (P) were all significantly higher in the aquaponic samples than in the non-aquaponic samples. Sodium (Na) was higher in the non-aquaponic samples. There was no difference in molybdenum concentrations.

Zinc (Zn), copper (Cu), mercury (Hg), arsenic (As), selenium (Se), tin (Sn), lead (Pb), cadmium (Cd), nickel (Ni) and cobalt (Co) were not detected.

Table G. Mineral composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameter	Unit	$\bar{X}$ ± CI AP	$\bar{X}$ ± CI non-AP	Difference @ α 0.05
Minerals				
Ca	mg/100 g	73.38 ± 1.19	67.74 ± 2.24	*
Mg	mg/100 g	18.21 ± 0.65	15.28 ± 0.43	*
Na	mg/100 g	30.05 ± 1.58	39.55 ± 1.90	*
K	mg/100 g	327.02 ± 22.98	382.13 ± 8.00	*
Fe	ppm	18.75 ± 1.17	5.51 ± 1.02	*
Mn	ppm	7.83 ± 0.78	3.82 ± 0.94	*
Zn	ppm	-nd-	-nd-	
Cu	ppm	-nd-	-nd-	
Al	ppm	10655.9 ± 665.02	5969.41 ± 60.19	*
Hg	ppm	-nd-	-nd-	
As	ppm	-nd-	-nd-	
Se	ppm	-nd-	-nd-	
Sb	ppm	-nd-	-nd-	
Pb	ppm	-nd-	-nd-	
Cd	ppm	-nd-	-nd-	
Ni	ppm	-nd-	-nd-	
Mo	ppm	0.88 ± 0.08	0.9 ± 0.05	-
Co	ppm	-nd-	-nd-	
Cr	ppm	69.04 ± 2.33	0.05 ± 0.01	*
P	ppm	525.6 ± 8.44	382.54 ± 14.85	*

Chromium was detected at a concentration approximately 1 000 times higher in the aquaponic samples. Table H shows the full results from each farm of the chromium analysis.

Table H. Concentration in parts per million of chromium in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Farm	Parameter	Unit	AP	non-AP
Farm 1	Cr	ppm	66.76	0.06
Farm 2			69.62	0.05
Farm 3			70.75	0.04

Organic acids

The results of the organic acid analyses are presented in Table I. There were no significant differences detected.

Table I. Organic acid composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameter	Unit	X̄ ± CI AP	X̄ ± CI non-AP	Difference @ α 0.05
Organic acids				
Oxalic acid	ppm	9.09 ± 4.37	8.62 ± 7.32	-
Malic acid	ppm	4.24 ± 3.19	5.92 ± 4.76	-
Citric acid	ppm	2.13 ± 1.94	2.35 ± 3.02	-
Fumaric acid	ppm	-nd-	-nd-	
Ascorbic acid (Vitamin-C)	mg/100 g	-nd-	-nd-	
Tartaric acid	ppm	-nd-	-nd-	

Amino acids

The results of the organic acid analyses are presented in Table J. There were no significant differences in any of the measured acids. Cysteine was not detected in any of the samples. Methionine was only detected in one sample of the non-aquaponic treatment and therefore is not reported with a confidence interval.

Table J. Amino acid composition in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods

Parameter	Unit	X̄ ± CI AP	X̄ ± CI non-AP	Difference @ α 0.05
Amino acid profile				
L-Histidine	ppm	337.14 ± 170.03	395.19 ± 62.21	-
L-Serine	ppm	780.97 ± 160.57	803.1 ± 189.00	-
L-Arginine	ppm	626.4 ± 549.14	868.75 ± 216.51	-
Glycine	ppm	792.23 ± 340.4	856.92 ± 295.14	-
L-Aspartic Acid	ppm	1717.08 ± 681.37	1293.31 ± 158.3	-
L-Glutamic Acid	ppm	1385.13 ± 572.54	1368.13 ± 553.37	-
L-Threonine	ppm	631.03 ± 348.43	649 ± 273.06	-
L-Alanine	ppm	749.42 ± 427.25	751.01 ± 318.43	-
L-Proline	ppm	565.11 ± 317.68	605.81 ± 265.59	-
L-Cysteine	ppm	-nd-	-nd-	
L-Lysine HCl	ppm	705.5 ± 570.17	739.9 ± 401.65	-
L-Tyrosine	ppm	559.62 ± 266.98	601.2 ± 237.53	-
L-Methionine	ppm	131.79 ± 108.2	15.47 ±	
L-Valine	ppm	687.67 ± 379.18	699.61 ± 340.40	-
L-Isoleucine	ppm	494.76 ± 385.08	513.34 ± 322.71	-
L-Leucine	ppm	946.89 ± 635.95	1008.11 ± 488.37	-
L-Phenylalanine	ppm	654.89 ± 546.79	942.45 ± 392.22	-
Tryptophan	ppm	143.19 ± 49.30	189.11 ± 80.06	-

Complete fatty acid profile

Fatty acids were detected in some, but not all of the samples, and generally around the limit of detection. The results are presented only in the Annex and are not discussed.

Other parameters

The analyses did not detect any cholines nor betaines. There was no evidence of any sterols, including stigmasterol, campesterol, β-Sitosterol nor cholesterol. There were no oligosaccharides, including raffinose, stachyose, verbascose or ajucose. There were no polyphenols. There were no antioxidants detected. The results revealed that kangkong did not contain trypsin inhibitor, phytate, total saponin, total oxalates, soluble oxalates, and non-protein nitrogen.

Discussion

This is one of the first published studies of nutrient composition of a crop grown in an aquaponic system. It was designed as a pilot study to establish the methodology and protocol. More importantly, it was designed to provide guidance on future studies as to what parameters may be more or less important to measure. The sample size was low, with only three samples per treatment and no replication within the farms. As a consequence, many of the differences were not statistically significant. Even so, the study illuminated several important results.

The high concentration of chromium in the aquaponic system deserves further investigation, specifically on the source and the chemical composition. The study did not determine what type of chromium was present; trivalent chromium (Cr(III)) is a naturally occurring trace mineral with limited human health risks, while hexavalent chromium (Cr(VI)) is a toxic and carcinogenic industrial waste product, sometimes found as an environmental pollutant from steel mills or chrome plating factories. It will be important to determine what type of chromium was present in the samples to determine if there are any health risks. It is assumed that the chromium is present in the water, and because the water in the aquaponic treatment was recirculated, the kangkong plant had higher concentrations. It is also postulated that the pH of the water, though it was not measured during this study, could have an effect on uptake of chromium and other metals as these are often chelated when in the soil. It is possible that the chromium is coming from the fish feed itself.

The statistical differences observed in the other minerals, including phosphorous, aluminium, iron, calcium, magnesium and potassium also merit further research. The source of these differences is unclear, though it is likely to be from the source water. This suggests that during extension of aquaponic technology to farmers, it would be worth testing the source water for heavy metals and other pollutants before beginning considering that the recirculating nature of the culture method could be concentrating them.

The sensitivity of this analysis does not permit a judgement of how nutritious aquaponically grown kangkong is compared to traditional methods. However, it is encouraging that there were few statistical differences in the key nutritional elements.

Data from a food composition table SMILING D3.5-a (Sustainable Micronutrient Interventions to Control Deficiencies and Improve Nutritional Status and General Health in Asia) were compared to the experimental results. Substantial differences were noted in several of the nutrients. Table K summarizes the nutrient composition of the samples as well as the literature reference.

Table K. Composition of key nutrients important for human health in samples of kangkong from three farms using aquaponic and non-aquaponic culture methods and compared to a literature reference

Parameter	Unit	$\bar{X} \pm$ CI AP	$\bar{X} \pm$ CI non-AP	Literature reference
Proximate Analysis				
Water	% of sample	92.95 ± 1.41	92.75 ± 1.92	89.2
Carbohydrate	% of sample	3.48 ± 0.91	4.51 ± 1.96	3.82
Total fat	% of sample	0.34 ± 0.36	0.31 ± 0.41	0.70
Protein	% of sample	1.81 ± 0.43	1.16 ± 0.88	3.33
Ash	% of sample	1.43 ± 0.50	1.26 ± 0.16	1.0
Total energy	kcal/100 g	24.1 ± 7.91	25.5 ± 9.37	40
Ca	mg/100 g	73.38 ± 1.19	67.74 ± 2.24	67
Fe	ppm	18.75 ± 1.17	5.51 ± 1.02	2.3
Zn	ppm	-nd-	-nd-	0.5

Parameter	Unit	X̄ ± CI AP	X̄ ± CI non-AP	Literature reference
Retinol	mcg	not tested	not tested	0.0
Beta-carotene	mcg	not tested	not tested	2 741
Total Vitamin A	mcg	not tested	not tested	345
Carotenoids (all)	ppm	234.78 ± 172.03	197.51 ± 197.24	-
Thiamine (B1)	mcg/dL	-nd-	-nd-	0.07
Riboflavin (B2)	mg/100 g	0.12 ± 0.02	0.07 ± 0.02	0.36
Niacin (B3)	ppm	0.37 ± 0.11	0.28 ± 0.10	2.00
Pyridoxal (B6)	ppm	-nd-	-nd-	0.10
Folate	mg/100 g	-nd-	-nd-	57
Vitamin B12		not tested	not tested	0
Vitamin C	mg/100 g	-nd-	-nd-	17
Vitamin D		-nd-	-nd-	-nd-
Vitamin E	mg/100 g	1.39 ± 0.19	1.49 ± 0.19	not tested
Vitamin K	mcg/100 g	48.66 ± 11.34	43.77 ± 7.25	not tested

Several important nutrients were expected to be found in the samples based on previous literature research, and were notably missing. These nutrients include zinc, thiamine, pyridoxal, folate, vitamin-B12 and vitamin-C. Other nutrients were found, but at lower concentrations, which include protein, total energy, riboflavin and niacin. The lower measurements were found in both the aquaponic and non-aquaponic treatments.

Several important tests were not conducted. Most importantly, the vitamin A test was inconclusive and should have included tests for retinol, b-carotene and other vitamin A precursors rather than just vitamin A. Also, vitamin B12 should have been tested.

For future studies, it is recommended to only test the key nutrients, as outlined in Table K, and the minerals. This will provide a more rapid and relatively cheaper assessment, and would have yielded more data, as well as replication, with the same funding.

Aquaponics is increasingly important as a food production practice around the world, and especially in Indonesia. If aquaponics is to be suggested as a valid method, it will be important to understand the nutritional composition of crops growing in aquaponic systems as compared to traditional methods. It is possible that there are both positive and negative impacts of the production method. Positive impacts could be realized because crops are grown with lower stress as a result of adequate water and fertilizer. However, the concentrated and recirculating water could concentrate pollutants. Overall this study provides a first look at the nutrient composition, though more research on this topic to support the advancement of this efficient technology is needed.

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ANNEX 1

Complete results of nutrient composition of an aquaponically grown vegetable in Indonesia

Nutrient	Unit of Measure	Limit of Detection	Sample number					
			Farm 1		Farm 2		Farm 3	
			AP	Non-AP	AP	Non-AP	AP	Non-AP
			10411	10412	12733	12734	12735	12736
Proximate Analysis								
Water	% of sample	-	92.06	91.82	94.38	91.72	92.42	94.71
Carbohydrate	% of sample	-	4.04	5.83	2.56	5.15	3.83	2.56
Total fat	% of sample	-	0.65	0.72	0.02	0.13	0.34	0.08
Protein	% of sample	-	2.23	0.34	1.68	1.89	1.51	1.26
Ash	% of sample	-	1.02	1.29	1.38	1.11	1.9	1.39
Total energy	kkal/100 g	-	30.93	31.16	16.96	29.33	24.42	16
Energy from fat	kkal/100 g	-	5.85	6.48	1.85	1.17	3.06	0.72
Water soluble vitamins								
Thiamine (B1)	mcg/dL	-	nd	nd	nd	nd	nd	nd
Riboflavin (B2)	mg/100 g	-	0.10	0.05	0.13	0.07	0.12	0.08
Niacin (B3)	ppm	0.03	0.41	0.34	0.45	0.32	0.26	0.18
Pantothenic acid (B5)	ppm	0.7	nd	nd	nd	nd	nd	nd
Pyridoxal (B6)	mg/100 g	0.61	nd	nd	nd	nd	nd	nd
Biotin	ppm	0.36	0.79	0.73	0.64	0.38	0.43	0.39
Folates	mcg/100 g	27	nd	nd	nd	nd	nd	nd
Fat soluble vitamins								
Vitamin A	mcg/100 g	30.77	nd	nd	nd	nd	nd	nd
Vitamin D	ppm	0.0067	nd	nd	nd	nd	nd	nd
Vitamin E	mg/100 g	-	1.31	1.30	1.58	1.63	1.28	1.54
Vitamin K	mcg/100 g	-	42.82	50.05	60.23	37.24	42.92	44.03
Carotenoids and Xanthophylls								
Carotenoids	ppm	-	402.67	398.77	195.24	97.94	106.42	95.82
Xanthophylls	ppm	-	nd	nd	nd	nd	nd	nd
Cholines and betaines								
Cholines	ppm	-	nd	nd	nd	nd	nd	nd
Betaines	ppm	-	nd	nd	nd	nd	nd	nd
Sterols								
Stigmasterol	ppm	-	nd	nd	nd	nd	nd	nd
Campesterol	ppm	-	nd	nd	nd	nd	nd	nd
β-Sitosterol	ppm	-	nd	nd	nd	nd	nd	nd
Cholesterol	ppm	1	nd	nd	nd	nd	nd	nd
Oligosaccharides								
Raffinose	mg/g		nd	nd	nd	nd	nd	nd
Stachyose	mg/g		nd	nd	nd	nd	nd	nd
Verbascose	mg/g		nd	nd	nd	nd	nd	nd
Ajucose	mg/g		nd	nd	nd	nd	nd	nd
Polyphenols								
Polyphenols	ppm	-	nd	nd	nd	nd	nd	nd
Antioxidant activity								
Water soluble antioxidant activity	mg/mL	-	nd	nd	nd	nd	nd	nd
Fat soluble antioxidant activity	mg/mL	-	nd	nd	nd	nd	nd	nd
Minerals								
Ca	mg/100 g	-	72.21	68.59	74.25	69.15	73.68	65.47
Mg	mg/100 g	-	17.60	15.25	18.72	14.92	18.32	15.68
Na	mg/100 g	-	29.60	41.49	28.92	38.52	31.62	38.65
K	mg/100 g	-	312.59	383.49	350.25	388.42	318.22	374.47
Fe	ppm	-	19.81	5.03	18.69	6.54	17.75	4.95
Mn	ppm	-	7.03	3.14	8.25	3.58	8.21	4.75
Zn	ppm	0.19	nd	nd	nd	nd	nd	nd
Cu	ppm	0.12	nd	nd	nd	nd	nd	nd
Al	ppm	-	10416.8	6030.72	11325.45	5941.82	10225.43	5935.68
Hg	ppm	0.004	nd	nd	nd	nd	nd	nd
As	ppm	0.008	nd	nd	nd	nd	nd	nd
Se	ppm	0.3	nd	nd	nd	nd	nd	nd

Nutrient	Unit of Measure	Limit of Detection	Sample number					
			Farm 1		Farm 2		Farm 3	
			AP	Non-AP	AP	Non-AP	AP	Non-AP
			10411	10412	12733	12734	12735	12736
Sb	ppm	0.55	nd	nd	nd	nd	nd	nd
Pb	ppm	0.24	nd	nd	nd	nd	nd	nd
Cd	ppm	0.00011	nd	nd	nd	nd	nd	nd
Ni	ppm	0.0008	nd	nd	nd	nd	nd	nd
Mo	ppm	-	0.82	0.94	0.95	0.87	0.88	0.9
Co	ppm	0.0008	nd	nd	nd	nd	nd	nd
Cr	ppm	-	66.76	0.06	69.62	0.05	70.75	0.04
P	ppm	-	518.32	396.47	525.27	380.72	533.22	370.42
Organic acids								
Asam oksalat	ppm	-	12.91	15.23	5.2	2.31	9.17	8.31
Asam malat	ppm	-	7.45	10.71	3.07	2.82	2.19	4.23
Asam sitrat	ppm	-	3.93	5.42	1.95	1	0.52	0.62
Suksinat	ppm	48.11	nd	nd	nd	nd	nd	nd
Askorbat	mg/100 g	0.16	nd	nd	nd	nd	nd	nd
Asam tartrat	ppm	5.45	nd	nd	nd	nd	nd	nd
Bioactive substances								
Trypsin inhibitor	TUI/mg	-	nd	nd	nd	nd	nd	nd
Phytate	U/g	-	nd	nd	nd	nd	nd	nd
Total saponin	ppm	-	nd	nd	nd	nd	nd	nd
Total oxalates	mg/100 g	-	nd	nd	nd	nd	nd	nd
Soluble oxalates	mg/100 g	-	nd	nd	nd	nd	nd	nd
Non-protein nitrogen	%	-	nd	nd	nd	nd	nd	nd
Amino acid profile								
L-Histidine	ppm	-	453.24	451.51	390.76	392.42	167.43	341.65
L-Serine	ppm	-	936.17	907.08	748.88	891.77	657.86	610.44
L-Arginine	ppm	-	1183.61	1050.8	399.11	886.13	296.49	669.32
Glycine	ppm	-	1139.2	1013.88	604.62	1001.03	632.86	555.84
L-Aspartic Acid	ppm	-	2312.68	1404.63	1729.96	1339.01	1108.61	1136.2 8
L-Glutamic Acid	ppm	-	1960.05	1648.61	1187.66	1652.32	1007.68	803.47
L-Threonine	ppm	-	982.78	852.36	500.07	712.3	410.25	382.35
L-Alanine	ppm	-	1185.31	1013.06	539.08	786.37	523.86	453.61
L-Proline	ppm	-	888.82	807.6	418.1	661.6	388.4	348.24
L-Cystine	ppm	48.42	nd	nd	nd	nd	nd	nd
L-Lysin HCl	ppm	-	1284.13	1043.52	468.85	826.51	363.52	349.68
L-Tyrosine	ppm	-	830.91	750.23	445.56	692.24	402.4	361.14
L-Metheonine	ppm	-	199.4	nd	nd	15.47	64.17	nd
L-Valine	ppm	-	1073.28	997.99	522.45	704.45	467.28	396.4
L-Isoleucine	ppm	-	887.69	813.33	300.14	480.96	296.44	245.73
L-Leucine	ppm	-	1595.66	1386.89	635.09	1099.18	609.91	538.27
L-Phenylalanine	ppm	-	1141.14	1280.53	174.78	958.93	648.75	587.89
Tryptophan	ppm	-	164.16	253.76	93.1	200.05	172.32	113.53
Fatty acid profile								
C 4:0 (*as.butirat*)	%	-	0.0038	nd	nd	nd	0.0018	nd
C 6:0 (*as.kaproat)*	%	0.0013	nd	nd	nd	nd	nd	nd
C 8:0 (*as.kaprilat)*	%	-	0.0309	nd	nd	0.0037	0.0262	0.0037
C 10:0 (*as.kaprat)*	%	-	0.0082	nd	nd	nd	0.0044	0.0037
C 11:0 (as.undekanoat)	%	0.0016	nd	nd	nd	nd	nd	nd
C 12:0 (*as.laurat)*	%	-	0.0150	nd	nd	nd	0.0075	nd
C 13:0 (as.tridekanoat)	%	-	0.0043	nd	nd	nd	0.0019	nd
C 14:0 (*as.miristat)*	%	-	0.0159	nd	nd	nd	0.0045	nd
C 14:1 (as.miristoleat)	%	0.0017	nd	nd	nd	nd	nd	nd
C 15:0 (as.pentadekanoat)	%	0.0016	nd	nd	nd	nd	nd	nd
C 15:1 (as.pentadekenoat)	%	0.0016	nd	nd	nd	nd	nd	nd
C 16:0 *(as.palmitat)*	%	-	0.1446	0.2233	nd	0.0359	0.1077	0.0264

Nutrient	Unit of Measure	Limit of Detection	Sample number					
			Farm 1		Farm 2		Farm 3	
			AP	Non-AP	AP	Non-AP	AP	Non-AP
			10411	10412	12733	12734	12735	12736
C 16:1 (as.palmitoleat)	%	0.0017	nd	nd	nd	nd	0.0028	nd
C 17:0 (as.heptadekanoat)	%	0.0015	nd	nd	nd	nd	0.0034	nd
C 17:1 (as.heptadekenoat)	%	0.0016	nd	nd	nd	nd	nd	nd
C 18:0 *(as.stearat)*	%	-	0.0339	0.0451	nd	0.0071	0.0224	0.0061
C 18:1 W9C *(as.oleat/ω9)*	%	-	0.0360	0.2007	nd	0.0139	0.0270	0.0052
C 18:1 W9T *(as.oleat/ω9)*	%	0.0015	nd	nd	nd	nd	nd	nd
C 18:2 W6C *(as.linoleat/ω6)*	%	-	0.0762	0.1092	nd	0.0176	0.0450	0.0114
C 18:2 W6T *(as.linoleat/ω6)*	%	0.0016	nd	nd	nd	nd	nd	nd
C 18:3 W3 *(as.linolenat/ω3)*	%	-	0.1882	0.1237	nd	0.0450	0.0710	0.0179
C 18:3 W6 *(as.linolenat/ω6)*	%	0.0016	nd	nd	nd	nd	nd	nd
C 20:0 (as.arachidat)	%	-	0.0058	nd	nd	nd	0.0070	0.0020
C 20:1 (as.eikosenoat)	%	0.0015	nd	nd	nd	nd	nd	nd
C 20:2 (as.eikosadienoat)	%	0.0015	nd	nd	nd	nd	nd	nd
C 20:3 W3 (as.eikosatrienoat)	%	0.0017	nd	nd	nd	nd	nd	nd
C 20:3 W6 (as.eikosatrienoat)	%	0.0016	nd	nd	nd	nd	nd	nd
C 20:4 W6 (AA) (arachidonat)	%	0.0017	nd	nd	nd	nd	nd	nd
C 20:5 w3 (eikosapentaenoat)	%	-	0.0460	nd	nd	nd	nd	nd
C 21:0 (heneikosanoat)	%	0.0014	nd	nd	nd	nd	nd	nd
C 22:0 (behenat)	%	-	0.0057	nd	nd	nd	0.0034	nd
C 22:1 (erukat)	%	0.0015	nd	nd	nd	nd	nd	nd
C 22:2 (dokosadienoat)	%	0.0016	nd	nd	nd	nd	nd	nd
C 22:6 w3 (dokosahexaenoat)	%	-	0.0311	0.0233	nd	nd	nd	nd
C 23:0 (trikosanoat)	%	0.0014	nd	nd	nd	nd	nd	nd
C 24:0 (lignokerat)	%	-	0.0047	nd	nd	nd	0.0032	nd
C 24:1 w9 (nervonat)	%	0.0016	nd	nd	nd	nd	nd	nd
Omega 3	%	-	0.2653	0.1469	nd	0.0450	0.0710	0.0179
Omega 3 total	%	-	0.2653	0.1469	nd	0.0450	0.0710	0.0179
Omega 6	%	-	0.0762	0.1092	nd	0.0176	0.0472	0.0114
Omega 6 total	%	-	0.0762	0.1092	nd	0.0176	0.0472	0.0114
Omega 9	%	-	0.0360	0.2007	nd	0.0139	0.0270	0.0052
Omega 9 total	%	-	0.0360	0.2007	nd	0.0139	0.0270	0.0052
Unsaturated fatty acid	%	-	0.3775	0.4567	nd	0.0764	0.1479	0.0353
Saturated fatty acid	%	-	0.2726	0.2683	nd	0.0536	0.1922	0.0448
MUFA	%	-	0.0360	0.2007	nd	0.0139	0.0298	0.0060
PUFA	%	-	0.3415	0.2560	nd	0.0625	0.1181	0.0293
AA	%	0.00128	nd	nd	nd	nd	nd	nd
DHA	%	-	0.0311	0.0233	nd	nd	nd	nd
EPA	%	-	0.0460	nd	nd	nd	nd	nd

1. Samples 10411 and 10412 come from the same farm (Pasar Minggu, Jakarta; S.), and sample 10411 was from Aquaponic and 10412 was Non-Aquaponic
2. Samples 12733 and 12734 come from the same farm (South Bogor), and sample 12733 was from Aquaponic and 12734 was Non-Aquaponic
3. Samples 12735 and 12736 come from the same farm West Bogor), and sample 12735 was from Aquaponic and 12736 was Non-Aquaponic

APPENDIX 4

REPORT OF THE TECHNICAL AND SOCIO-ECONOMIC STUDY OF AQUAPONICS IN INDONESIA

A technical and social-economic assessment of the current aquaponic farming in Indonesia

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Abstract

Aquaponics has expanded over the last five years in Indonesia, and production centres are located in nine key areas: Jakarta, West Java, Central Java, East Java, Jogjakarta, South Sumatra, South Sulawesi, and Central Kalimantan. Indonesia has many characteristics that make aquaponics an attractive option for food production, for example, the relatively stable temperatures and a large market for freshwater fish. The purpose of this study was to obtain a preliminary evaluation of the technical and social-economic aspects of aquaponic farming sector in Indonesia. Data were collected from surveys of aquaponics production centres in Indonesia, community leaders or leaders of farmer organizations. Data collected included demographics, technical designs and socio-economic information. The data were processed using descriptive methods. The average respondent uses floating rafts or drip irrigation designs, raises three species of fish i.e. catfish, gourami and tilapia, and raises more than two species of plants. The largest advantage recognized by the respondents was that aquaponic system resulted in improved community status, improved diet, increased income and reduced budget for food. On the other hand, the negative effects deriving from the aquaponic system included tension among household members over control/usage of aquaponic system, increased overall workload and potential loss of money. The biggest challenges with aquaponics in Indonesia were identified to be the high initial costs and required education/training, and that it was hard to commercialize the system and bring the fish and crops to market in a profitable way.

Introduction

Aquaponics is an emerging technology that supports integrated aquaculture and vegetable production. It combines the two most efficient methods in their respective fields: recirculating aquaculture systems (RAS) and hydroponics (FAO, 2014). As a combination of aquaculture and hydroponics, aquaponics is an efficient way to grow organic vegetables, greens, herbs, and fruits, while providing the added benefits of fresh fish as a safe, healthy source of protein. A handful of studies have documented the productivity of several aquaponics operations (FAO, 2016; Rakocy, 2012).

Currently, aquaponics serves many worldwide communities with limited freshwater resources, limited land and high sale prices of fresh vegetables and fish. The possibility to run an aquaponic system in a specific place requires an extensive cost-benefit analysis that should assess its success upon certain economic, environmental, logistical/managerial and social conditions. Many factors must be considered before embarking on an aquaponic project, whether it is for domestic production or more commercially focused. A decision to create a commercial enterprise requires significant research, a full business plan and complete risk analysis.

The aquaponic sector is rapidly expanding in Indonesia. In fact, it is estimated that 8 000–10 000 households have been exposed to aquaponics through extension activities which makes Indonesia as one of the countries with the most aquaponic activity, though only about $1/10^{th}$ of those households are actively practicing aquaponics. Examples of many styles of aquaponics can be found in Indonesia, where the cultivation and farming of fish in combination with rice fields is often considered as an example of early aquaponics system. A unique version of aquaponics, called Yumina/Bumina, was invented in Indonesia and, as of publication, has not been documented in the international literature or practiced outside of the country. Indonesia has many factors that support integrated aquaculture and agriculture including the relatively stable temperature typical of tropical areas which enables aquaculture and agriculture to be carried out throughout the year, and a large and consistent market for freshwater fish and residue-free vegetables. The technology and techniques of aquaponics are relatively simple and easy to adopt once demonstrated to the farmers, and aquaponics can be done not only in rural areas but also in urban centres. Together with an active government extension programme, these factors have stimulated interest and involvement of aquaponics industry.

The purpose of this study was to evaluate a technical and social-economic aquaponic farming sector in Indonesia. The aim of this preliminary study was to follow up with farmers to understand better how well previous aquaponic extension activities and interventions have worked, identify challenges and blocking issues, and to determine what, if any, changes the adoption of aquaponic technology has had on the household. Results of this preliminary study will guide further extension interventions.

Materials and methods

Survey method

The data collection method included collecting primary data from aquaponics farmers as well as secondary data from literature and consultations with various stakeholders. First, secondary data were collected through interviews with stakeholders from the Ministry of Marine Affairs and Fisheries and the Ministry of Agriculture, both of which have active aquaponic extension programmes. These interviews identified key aquaponic commodities, farming systems, geographical locations and communities for further investigation.

Primary data were collected in several provinces of Indonesia between December 2015 – February 2016. Building upon this selection, 33 respondents from five different areas were surveyed for primary data collection: Western Java, Central Java, Eastern Java, Banten, Jakarta, and Kalimantan. Formulation and implementation of the survey followed the work described by Love (2014).

The overall process was designed to provide an understanding of the performance of current aquaponic systems, key data for modelling, and a benchmark for identifying opportunities for improvement across key economic, social and environmental dimensions.

Data analysis method

Data in the survey were collected from aquaponics production centres in Indonesia, community leaders or leaders of farmer organizations. Data included demographics, technical assessment, and socio-economic information. Data from aquaponic production centres were processed using descriptive methods, while the other data from the survey were exported and analysed in XLSTAT.

Results

Aquaponics production centres in Indonesia

Indonesia has developed a particular type of aquaponics called Yumina/Bumina that has been adopted in many districts. Yumina/bumina uses simple and locally available materials and has proved to be an efficient and low-energy demanding system to build resilience and self-sufficiency in single households or communities and to provide effective diet diversification (FAO, 2016). Based on interviews with the Ministry of Agriculture officials and the Ministry of Marine Affairs and Fisheries officials, aquaponics has only truly blossomed over the last five years, starting around 2011, though until now data on the total number of aquaponic farms in Indonesia was not available. According to the results of the interviews, aquaponics production takes place in nine production centres located in Jakarta, West Java, Central Java, East Java, Jogjakarta, South Sumatera, South Sulawesi, and Central Kalimantan (Table a). That said, expert opinion suggests that the number of people exposed to aquaponic extension activities is around 8 000–10 000 households.

The integrated nature of aquaponics implies that a successful intervention requires the support of both the Ministry of Fisheries and the Ministry of Agriculture or their equivalents, with further support possible from Ministries of Health and Education. The extension of aquaponic techniques to farmers in Indonesia in recent years carried out by Indonesian Agency for Agricultural Research and Development in the Ministry of Agriculture and by Institute for Freshwater Aquaculture Research and Development in the Ministry of Marine Affairs and Fisheries. Based on these interviews, there was consensus of a need to improve and harmonize the extension activities to build capacity in farmers and enable them to manage their aquaponics systems more efficiently and render them more economically profitable.

Table a. Aquaponic production centres and location of extension activities

No	Province	Location of Extension activities
1	West Java	Bandung, Parung, Bogor
2	Central Java	Temanggung
3	East Java	Pacitan
4	Jakarta	North Jakarta, South Jakarta
5	Banten	Pandeglang
6	Yogyakarta	Sleman
7	South Sumatera	Palembang
8	South Sulawesi	Makassar
9	Central Kalimantan	Palangkaraya

Community leaders or leaders of farmer organizations survey

Community leaders and leaders of farmer organizations are, in general, dependable sources of knowledge on the capabilities and attitudes of farmers in their villages and districts. The assessment focuses on the capabilities of the community, especially community leaders or leaders of farmer organizations. This targeting of beneficiaries and the scale of the intervention is important to understand in order to support entrepreneurial endeavours and start-up businesses. Several interview questions were designed to understand who was targeted, and how they were introduced.

In general, aquaponics was introduced equally to community leaders and farmer organizations through four modalities: government extension service (25 percent), other farmer cooperatives (25 percent), development projects (25 percent), and through internet and social media (25 percent).

The selection of recipients is quite important in aquaponics development activities. The appropriate criteria in the selection of recipients is important to be able to improve the chances of success. Farmer selection therefore should also be judged on the community leaders' intuition and available independent assessments. According to the community leaders, the recipients were chosen because they were land owners (43 percent), constituted a specific group (43 percent), and because of convenient geographical location (14 percent).

The size of most aquaponic systems was designed for farmers' cooperatives, with (43 percent) of respondents reporting this scale of aquaponic design. An equal number of respondents (43 percent) had chosen designs to service individual households. No respondents had planned to form private commercial enterprises.

Demographics

A series of questions was asked regarding the demographic makeup of aquaponic farmers, and also internal household dynamics of management and financing of aquaponic systems.

Of the 33 interviews with individual households, 25 of the respondents (75 percent) were male. However, it was often the wife who was first introduced to aquaponics, with 20 respondents (60 percent) indicating that the technology first started with the wife whereas only 12 respondents (36 percent) stated that the husband was the first sensitized. Despite this fact, it an overwhelming majority of cases (31 respondents), it was the husband who initially constructed and set up the system. After the initial set up, the daily management and operations of the system was more equally divided. The survey data were somewhat confounded with 27 respondents indicating it was the husband doing the most management, 17 indicating it was the wife, and 4 indicating it was both. The sum of these responses is 48, suggesting a misunderstanding of the question or options. Four respondents, or about 12 percent indicated that paid workers were used for the daily management.

Overall, the total amount of time spent on managing the system (including feeding the fish, harvesting and replanting vegetables, refilling the water, etc.) was 1–5 hours per day. Of the 33 respondents, 27 indicated that managing the system required 3–5 hours per day, while 16 indicated that management required 1–3 hours. It is suspected that the amount of labour is variable over the cropping cycle, and most days require 1–3 while some days (i.e. day of fish harvest) require substantially more time.

There were a variety of ways through which the household was first sensitized to aquaponics, ranging from an introduction as a student training (9 respondents) or on-farm training sessions (10 respondents) to social media (6), friends (1) and general interest (1).

Twenty six respondents (79 percent) had practiced aquaponics for 1–2 years, and no respondents had practiced aquaponics for more than four years.

Nineteen respondents (58 percent) had covered the initial capital costs of the aquaponic system with remittance, while nine (27 percent) had used credit. Other financing options included various forms of self-funding, including farm income (6 respondents), off-farm salary (5 respondents) or other private capital (7 respondents). Two respondents had a business in aquaponic installation.

Technical assessment

A series of survey questions were asked to assess the technical specifications of the most common aquaponic systems, including the types of fish and plants, the designs of the systems and other components of the respondents' aquaponics operation. Overall there was a large range of responses.

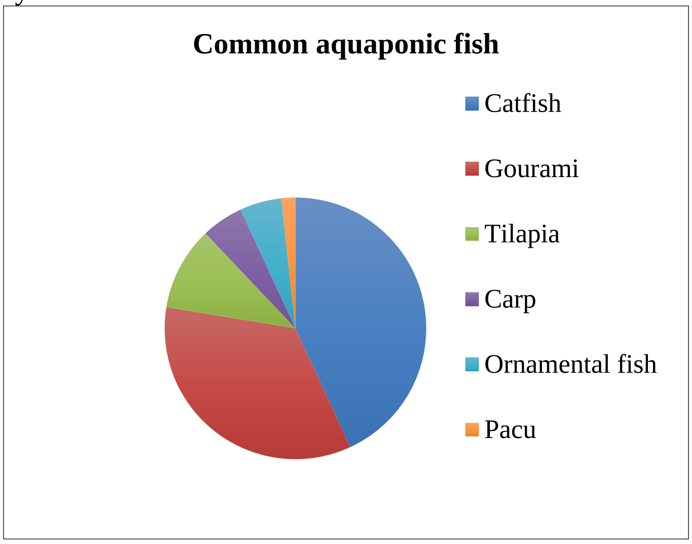
Aquaponics systems were primarily designed by the respondents themselves, and more than 50 percent of respondents (18/33) use a design of both floating rafts (deep water culture) and drip irrigation (using a media bed technique comprised of many small satellite pots). The next most common designs were the gutter system (similar to a modified media-filled nutrient film technique) and the tidal system (ebb and flow), with 6 respondents using each type. Other systems included the more vulgarized deep-water culture, nutrient-film technique, and a vertical nutrient film technique. Many respondents used multiple methods.

All of the respondents have reliable access to water sources, fish feed, water pump and plumbing materials. Based on the results of the survey, the majority of respondents still need more information about aquaponics, which they find through the community and neighbours (16 respondents), internet

(13), books (12) and government extension services (10). Most respondents indicated that more than one of these sources of information were available.

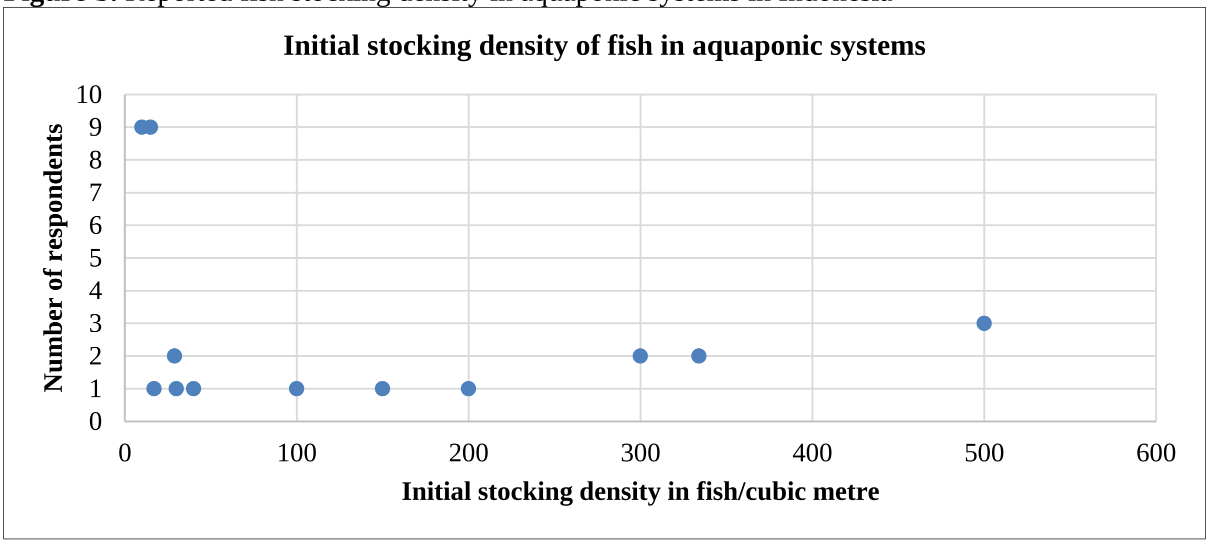
The average respondent raised more than one species of fish. The three most common groups of fish were catfish, gourami and tilapia. The most commonly raised by percent were catfish (76 percent of respondents), gourami (61 percent), tilapia (18 percent), ornamental fish (9 percent), carp (9 percent), pacu (3 percent), and other aquatic animals (27 percent), as presented in Figure a.

Figure a. Most commonly raised fish in aquaponic systems in Indonesia



The average initial stocking density of fish is 10–15 fish/m^3 of water, with an average fish size of about 50 g. However, there is a large range of initial stocking densities and fish sizes. Firstly, initial stocking can be calculated both by fish per square metre as well as fish per cubic metre, and both methods were reported. However, by making an assumption that most tanks were approximately 1 metre in depth, these stocking densities can be compared equally. The lowest stocking density was 10 fish/m^3, and the highest was 500 fish/m^3. Most respondents reported stocking between 0–50 fish/m^3 (23/33 respondents). This variable stocking density may be related to the different sizes of the fish at stocking, though these two data were not analysed together. While most respondents (21) reported initial stocking of 50 gram fingerlings, some fish were stocked both smaller and larger. In addition, respondents reported the size of fingerlings in both length and weight, making comparison challenging. Results are presented in Figure b.

Figure b. Reported fish stocking density in aquaponic systems in Indonesia



Not only is initial stocking density highly variable, yields were also different among the respondents. Overall, the average yield was about 1–3 kg/cubic metre after about 4–5 months. The range in yield was from 0.4–200 kg/cubic metre, though 17 of 21 respondents reporting yield less than 25 kg/cubic metre (Figure c), and several respondents had not yet harvested or not measured harvest yield. The range in time from initial stocking to harvest was from 6 weeks to 6 months (Figure d).

Figure c. Reported fish yields from aquaponic systems in Indonesia

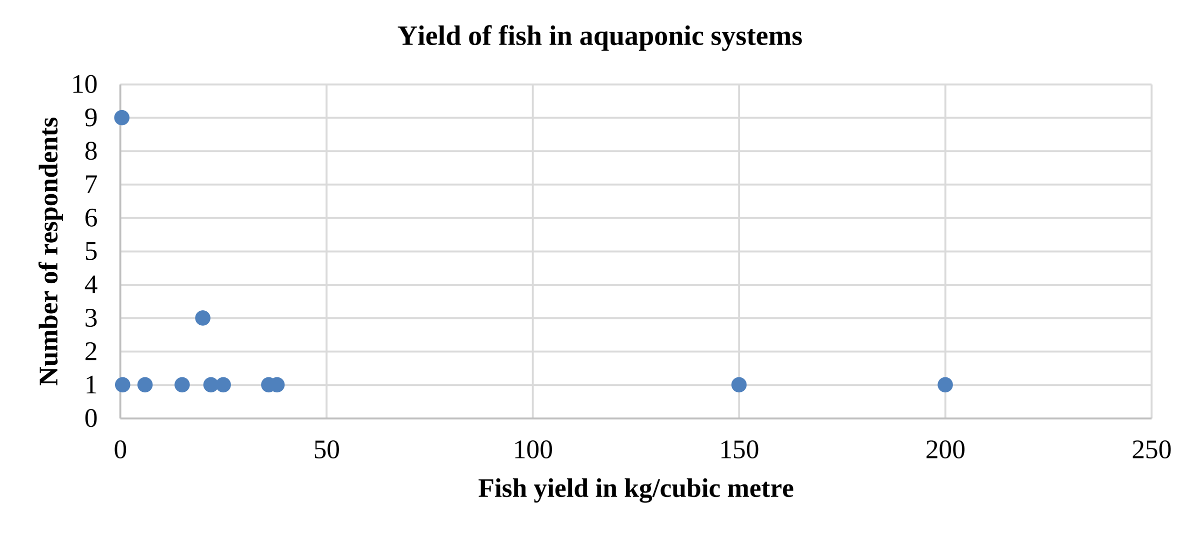
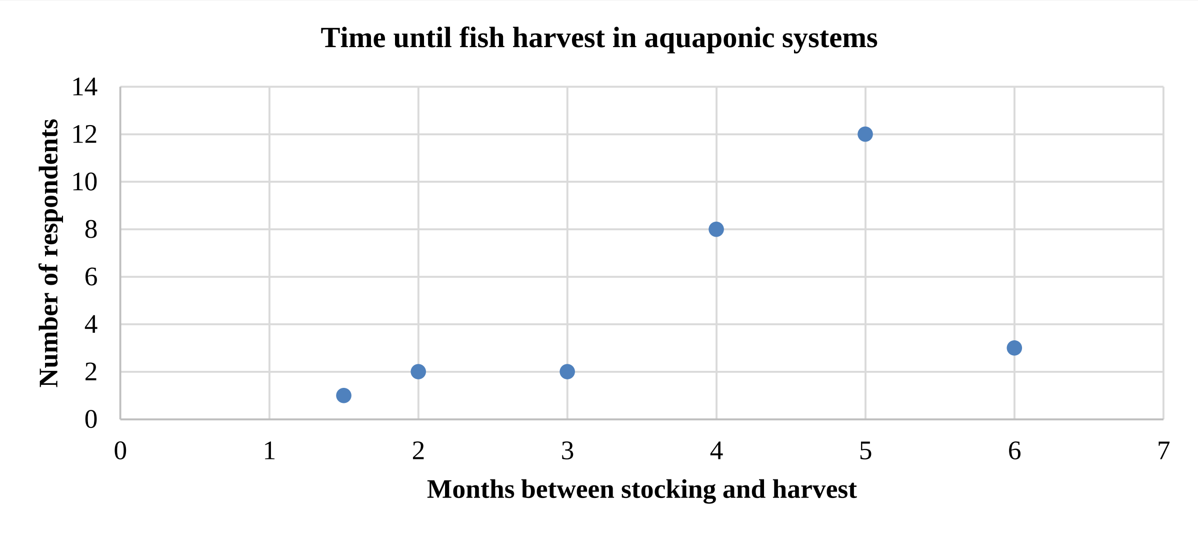
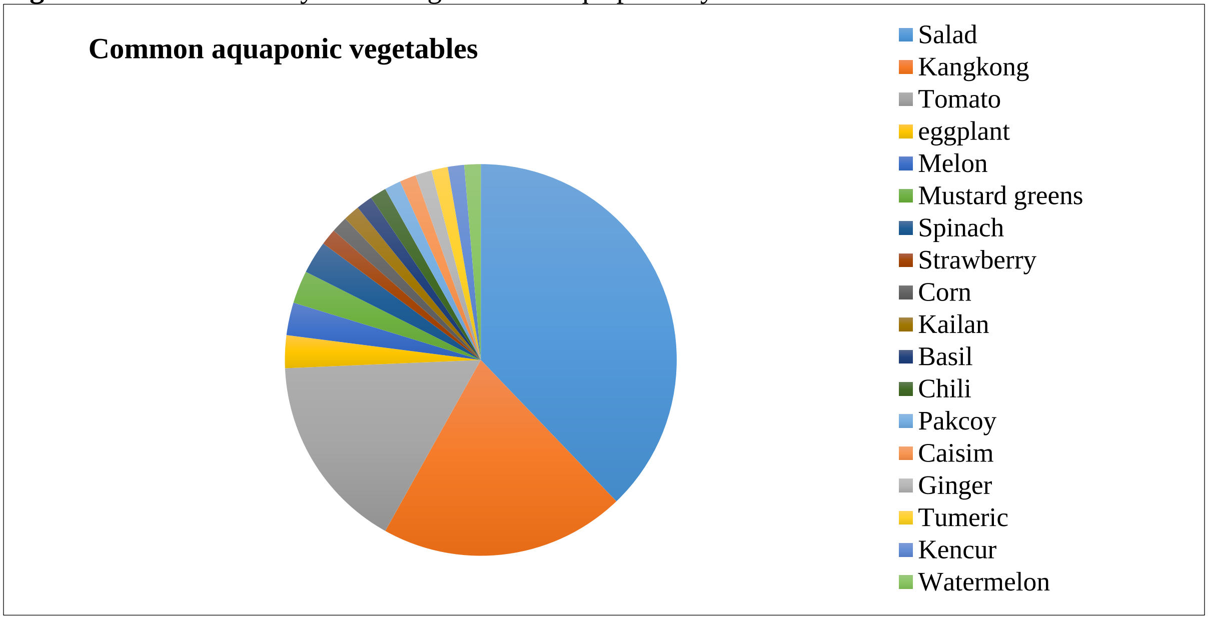


Figure d. Reported on-growing time for fish in aquaponic systems in Indonesia



The average respondent raised more than two species of plants. The most commonly raised plants were salad (85 percent of respondents), kangkong (45 percent), and tomato (27 percent). The time until harvest is generally quite short, with salad and kangkong harvested after about 30–40 days of culture, though tomatoes require about three months. A large variety of other vegetables were grown, including botanical fruits such as eggplant, chilies and melon, leafy greens such as mustard greens and spinach, herbs such as basil and even medicinal plants such as turmeric.

Figure e. Most commonly raised vegetables in aquaponic systems in Indonesia



Socio-economic assessment

Several questions regarding the social and economic impacts of aquaponics at the household level were asked. The respondents identified the greatest advantages of the aquaponic system to be improved community status, improved diet, improved education opportunities for youth, increased income and reduced budget for food. Generally, aquaponics affected/changed respondents family's diet through eating more fish and more diverse vegetables, with 29 of the 33 respondents (88 percent) recognizing this as a key result. In addition to affecting dietary consumption patterns, 21 of the 33 respondents reported that they sold the fish and 28 reported selling the vegetables.

However, negative effects were also recorded from the adoption of the aquaponic systems, which included tension among household members over control/usage of aquaponic system (52 percent), increased overall workload (33 percent) and loss of money (5 percent). The biggest opportunity with aquaponics was the opportunity to save water and create a cost-effective business, while the biggest challenges with aquaponics were the expensive initial costs, the need for further information and education and the difficulties to commercialize as a profitable business.

Discussion

Based on the survey results, there appears to be an active extension programme supporting the diffusion and adoption of aquaponic practices. These findings indicate that aquaponics is a growing field, yet there may be a collective lack of experience among producers. Aquaponics raises the community status of the farmers, while also improving diet and contributing to livelihood. Respondents also recognized the opportunities for education for youth, which could be a key entry point for further interventions and connection with education programmes or school curricula. Further, respondents reported that they needed more information and technical support, and that they all used the internet to look for this information. Noting that household tension was a result of the introduction of this new technology, extension agents should be aware of these interactions and identify ways to minimize the conflict.

The system designs used in Indonesia are quite diverse and are somewhat different than those used elsewhere in the world. Floating rafts and drip irrigation use simple and locally available materials and has proved to be an efficient and low-energy demanding system to build resilience and self-sufficiency in single households or communities. It is worth noting that the names of the systems are not exclusive, and a further technical elaboration of the different designs and their relative merits warrants further documentation. There is a clear demand to document and communicate the existing systems, to establish the good management practices and best designs for different local conditions. This research could also include investigation into how to reduce the overall workload.

All of the surveyed participants were practicing small-scale aquaponic systems. It appears that aquaponics operations employ few employees which could be due to the smaller average size of aquaponics operations compared to other agriculture and aquaculture operations. This is contrasted to the majority of respondents selling at least part of the harvest at market, which suggests a desire to move towards semi-commercial uses.

There was a huge variability in fish yield. It is likely that the survey methods were insufficient to capture the diversity of the fish culture techniques, especially considering the low amount of measurement and record keeping done by farmers. In addition, it was not determined the use of the harvested fish, and some uses (i.e. market) require fish at a larger size than other (selling to on-growing facilities). Therefore, it would have been important to identify the different intentions of the aquaponic system. It is suggested for future surveys to keep the data together, for example, each farmer's data should be analysed as a single package including the species, stocking size, density and harvest size and harvest time. Overall, the survey results indicate a wide range of expertise and experience in growing fish, which makes this an appealing aspect for further training interventions.

Many plants were grown, though most important by far are the salad lettuce, tomatoes and kangkong (water spinach). There are several follow up questions that should be addressed in further studies, including how the yield and production and the overall quantity and quality. In aquaponics, it is a common practice to balance the amount of fish with the amount of vegetables to ensure that the plants have adequate nutrients and the fish are having their water filtered enough. However, this balance was not investigated and requires a more thorough study, recommendations of which would support improvements in both fish and plant yield. In addition, most respondents did not use water testing kits or supplemental fertilizers, which would provide information and options to increase plant production.

Conclusion

Overall, this survey can serve to inform and guide further extension interventions and research projects. There were identified needs for research projects to document the various types of aquaponic systems and to investigate management practices to increase yield and decrease workload. Documentation and communication of these practices should be included in extension services and continuing education programmes, with a possibly synergy highlighted with school curricula. Finally, business planning and micro-scale financing support could address the reported desire to become more commercial-oriented.

APPENDIX 5

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APPENDIX 6

GROUP PHOTO

Group photo of the “Multistakeholder workshop on aquaponics”, which was held in Bogor, Indonesia, on 4 October 2016. (*Left to right*): Mochamad NURDIN, Umar HAMZAH, Soleh Eri SETIADI, Anang Hari KRISTANTO, Duma S. SIMBOLON, Agung PURNOMO, Austin STANKUS, Fauziyah ANNA, Nur Bambang Priyo UTOMO, Yudi SASTRO, Gleni Hasan HUWOYON, Fazri Khairiz ZAMAN. Photo courtesy Juniati/FAO.

A total of 12 participants participated in the Multistakeholder Workshop on Advancing Aquaponics on 4 October 2016. This 1-day multistakeholder workshop provided an appropriate forum for the identification, discussion and resolution of issues using input from multiple stakeholders towards supporting the wider adoption of the Yumina/Bumina technique of integrated agriculture and aquaculture. It served as a follow-up to the international training workshop in direct response to recommendations, and supported strengthened stakeholder networks including increased inter-ministerial communication and identified potential areas for collaboration.

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