Consumer Acceptance and Willingness to Pay Premium Price for Aquaponics Products in Debre Birhan and Shewa Robit Towns, Ethiopia

Almaz Akalewold; almazeyue@gmail.com

Received: June 20, 2021 Accepted: July 19, 2021 Published: July 30, 2021

DOI: https://doi.org/10.59411/nh3b8p83

ABSTRACT

A research project conducted between 2017 and 2018 delved into consumer perceptions and quality attributes of Aquaponics products in Shewa Robit and Debre Birhan towns, located in Ethiopia. In this context, Aquaponics, a novel approach to cultivating vegetables and fish, was explored. The primary objective of this investigation was to assess the extent of consumer acceptance towards Aquaponics technology and its resulting products. The findings of the study unveiled a notable level of consumer acceptance towards Aquaponics products, with a remarkable inclination among consumers to pay a premium of 5-10% above the prevailing rates for conventional products. Moreover, the study disclosed a strong consumer desire to foster greater trust in producers and enhance their confidence in the health benefits associated with consuming Aquaponics products. Interestingly, the outcomes did not exhibit significant variations based on the study site or the social structure within the study area.

Key words: Aquaponics products; consumers' acceptance; willingness to pay; consumers' preferences; Quality attribute; organoleptic; Debre Brehan; Shewa Robit

1. Introduction

1.1 Background of the study

Aquaponics is a method of combined fish and vegetables production without soil use (Rakocy *et al.*, 2006). The farmer cultivates freshwater fish (aquaculture) and plants (hydroponics) in a recirculating water system that exchanges nutrients between the two. Aquaponics merits expressed on its water use efficiency which is 90% water conserving than the conventional fish production systems (Rakocy, 2012). The system can be run without pesticides and herbicides due to the presence of all probiotic organisms in nature in the system (Amadori and Daley, 2012). Aquaponics can also be considered as a sustainable agricultural production system that does not deplete any non-renewable resources that are essential to agriculture in order to sustain the agricultural practices (Tyson *et al.*, 2011). Moreover sustainable agricultural production can be achieved by resembling natural ecosystems and "designing systems that close nutrient cycles," which is one of the main characteristics of aquaponics(Francis *et al.*, 2003).

Aquaponics role for food security would be particularly relevant because the global population now exceeds 7.2 billion and is growing rapidly. It is expected to reach 9.6 billion around 2050 with more than 75% living in urban areas. Urban population growth will require an increasing demand for animal protein. However, the challenge of conventional farming, including intensive animal protein production, in meeting this demand is rising but fluctuating energy and oil costs, climate change, and pollution exacerbate the problem. Resource limitations including the decrease of arable surfaces, constrained freshwater supplies, soil degradation, and soil nutrient depletion also add to these challenges (Klinger and Naylor, 2012). This alerts researchers to look for alternatives to compensate existing and future deficits in agricultural food systems.Aquaponics technology is one alternative for future sustainable protein and vitamin production despite its lack of production optimization.

Aquaponics can be run anywhere with limited resources. Aquaponics is most appropriate where land is expensive, water is scarce, and soil is poor. Deserts and arid areas, sandy islands and urban gardens are the locations most appropriate for aquaponic because it uses an absolute minimum of water. There is no need for soil, and aquaponics avoids the issues associated with soil compaction, salinization, pollution, disease, and tiredness. Similarly, aquaponics can be used in urban and peri-urban environments where no or very little land is available, providing a means to grow dense crops on small balconies, patios, indoors or on rooftops (Somerville *et al.*, 2014).

Green product is one of the products, which have placed either in local or in international market. The product is defines as green when the product has significantly improves rather than conventional product in terms of the production process, consumption and disposal by concerning towards the environment. Nowadays, aquaculture industries have stepped forward to enhance the productivity by justifying efficiency in aquaculture management. Efficient management in aquaculture leads to manage the waste and to restore the ecological relationship between humans, animal, and plants (Rakocy *et al.*, 2006). Thus, using the approach of combination between hydroponic and aquaculture in one recirculation system, aquaponic aims for better waste management where it can use to plants and improve the water quality for aquatic animals. Leafy green herbs and vegetables do extremely well in aquaponics; especially lettuce and basil. Large fruiting vegetables are also applicable, including tomatoes, peppers, eggplant, and cucumbers, peasand beans. Root crops and tubers are less commonly grown and require special attention (Somerville *et al.*, 2014).Plants yielding fruit (tomatoes, bell peppers, and cucumbers) have a higher nutritional demand and perform better in a heavily stocked, well established aquaponic system. Despite its potential on production and resource use efficiency, aquaponics product quality attributes and Consumer's acceptance are not yet documented. Therefore, the purpose of this research is to analyze the quality attributes of aquaponically produced lettuce as compared to hydroponically and conventionally produced ones and to analyze the consumer's acceptance of aquaponics products.

1.2 Statement of the problem

Today, consumer awareness of the health benefits of locally and organically produced products is on the rise and consumer's make more conscious decisions when buying food (Tokunaga *et al*, 2015) especially in urban areas. With respect to most green products Consumer's do not have sufficient knowledge about the product. Generally, consumer's lack knowledge about the process of the product where the product to be green and can be called as organic. Consumer preference for utilities (fish and vegetables) depends on the quality attributes of the utility. Most consumers' in developing countries lack sufficient knowledge about the quality attributes and process of production of the product in formal labeling; therefore, consumer's depend on their sense to choose products. Therefore, analyzing and stating aquaponics quality attributes will increase consumer acceptance for the product and limited aquaponics operation in business might be due to information gap consumer's' acceptance and also level of willingness to purchase aquaponics

products; therefore, this study will fill the information gap for private operators. The specific problems are there is limited information on consumer's preference and potential market for aquaponics products.

1.3.Objective of the study

The objective of this study is to map out consumer's acceptance and willingness to pay premium price for aquaponics products in ShewaRobit and DebreBirhan town.

3. Material and Methods

3.1. Study site description

Consumer's' acceptance and quality attributes of aquaponics lettuce experiment was conducted in Debre Birhan and Shewa Robit towns. Debre Birhan town is located 130km away from Addis Ababa on 9°41′N latitude and 39°32′E longitude coordinates and an elevation of 2,840 meters above sea level. Debre Birhan is the administrative town of North Shewa zone with a population size estimated to be 79,832. Rural dwellers are 13,261 and the remaining 66,571 live in the town. The population of the town becoming increasing from time to time in relation with the town development in investment, trade and other activities (Ermias, 2007).

Debre Birhan is 90km away from Shewa Robit town where some aquaponics activities have been started and are still ongoing. Shewa Robit is located at northeast of Addis Ababa, in the Amhara Region at 1,280 meters above sea level. The town has a longitude and latitude of 10°06′N 39°59′E respectively (Abate, 2013). In 2013, it reached a total population of 42,208 distributed over 10,048 households, with the average family size of 4.2. Religion is an important value and the population is divided in to Orthodox, Protestant and Muslim. The diverse religions also affect the pattern of food consumption, because several months a year "fasting" is present in the population, reducing the consumption of meat but increasing the consumption of fresh products (vegetables and fruits). This can be an opportunity to introduce an alternative food type from new technology such as aquaponics products which can be consumed by the population throughout the year without being affected by the religions requirements. Therefore, locally supported initiatives such as aquaponics under a business model profile, will enhance the supply of healthy products. It also promotes the empowerment of households which is necessary to create self-employment and therefore economic income to improve education and living status of present and future generations.

3.2. Data collection

Consumer's acceptance and willingness to pay for aquaponic products in Shewa Robit town and Debre Birhan town were analyzed by contingent valuation method. Data was collected from Shewa Robit town and Debre Birhan town using standard questionnaires and interview. Sampling sites were selected based on the existing aquaponics practices in Shewa Robit town and to take Debre Birhan town as a control for consumption. I was used Random sampling to save our efforts and also to keep our probability of sampling as fair as possible. From each town representative sample of 35 respondents (total 70 Respondents) was taken considering economic, social, and gender mutual representation. Each interview was done (filled) in Shewa Robit town and Debre Birhan town.

The first set of survey questionnaire was consisted of demographic information of the respondents. The demographic survey showed the social structure effect on consumer's acceptance for aquaponics products. The second sets of questions focused on respondents existing fish and vegetables access and consumption and preference level.

The third component was consisted of knowledge of consumer's on mode of fish and vegetables production and management. In addition, this section contained questions about respondent's knowledge about aquaponics. On this section by describing the merits and demerits of aquaponics for consumer's clearly; consumer's perception about the quality attributes of fish and vegetables produced by aquaponic and conventional system was asked. Semi structured qualitative yes/no questions were used to identify the consumer's stated preference for aquaponics products.

The fourth section of the survey consisted of questions about the perception of consumer's about aquaponics products, anticipated price by assuming all aquaponics products are available on the market. In this section, consumers were asked whether they ready to pay more for aquaponics products and their reason to pay more..

3.3. Data analysis

Collected data were organized and analyzed using appropriate statistical tools. Data was subjected to descriptive analysis and analysis of variance for numeric data. To analyze statistical difference chi-square and ANOVA were used for nominal and ordinal data sets and scale data sets respectively. Data that showed significance variation subjected to posthoc analysis by

Tukey test. Data will be considered significant at 95% confidence level. All data analysis will be performed using SPSS ver 20 statistical software.

4. Result

4.1. Respondent's characteristics

Respondents who participated in this study showed variety of characteristics. Respondents' ethnicity showed significant variation between sites ($p > 0.05$). In Debre Birhan Amhara (62.90%) was the highest and followed by Argoba and Tigre (2.90% each) but in Shewa Robit the highest respondents was Amhara (65.70%) followed by Argoba (20.00%) and Tigre (8.60%). Among from respondents in Debre Birhan; highest respondents were Orthodox (68.60%) followed by Muslim (17.10%) and Protestant (14.30%) and in Shewa Robit the highest respondents were Orthodox (57.10%) followed by Muslim (28.60%) and Protestant (14.30%). With respect to respondents Educational level in Debre Birhan; Primary school, Secondary school and Diploma had equal proportion (8.60%), Certificate (2.9 %), Bachelor (25.70%), Masters (20.00%), Doctorate (14.30%) and Others (11.40%). In Shewa Robit respondents educational background was Primary school (2.9%), Secondary school (11.4%), Diploma (11.40%), Certificate (31.40 %), Bachelor (40.00%) and Masters (2.90%).

Job of respondents were mostly government and merchant (20.00%), retired (11.4%), self-employed or students (17.10%) in Debre Birhan. But In Shewa Robit most of respondents were government employed (57.10%), self-employed and merchant (8.60%). There were the respondents' mean age was 42.3 in Debre Birhan and 44.3 in Shewa Robit. The gender balance was (57.10%) females and (42.90%) males in Debre Birhan and (68.60%) females and (31.40%) males in Shewa Robit. Average monthly house hold incomes of respondents were 4259 birr in Debre Birhan and 2470 birr in Shewa Robit.. There were significant differences ($p \leq 0.05$) with ethnicity, educational level, job of respondents and average monthly house hold income among study sites (Table 1).

Table 1. Characteristics of respondents (mean±SE)

Site	Age	House hold size	Monthly house hold income (Birr)
Debre Birhan	41.28±2.43	4.25±0.43	4259.28±436.58
Shewa Robit	44.34±1.70	4.6±0.31	2470.57±242.41
Total	42.81±1.48	4.42±0.26	3364.92±339.49

4.2. Vegetables and fish consumption pattern

Weekly household vegetables consumption (Kg per week) (Mean ± SE) was 7.7±0.5 where highest from DB 8.3±0.9 followed by SR 6.4±0.5. Similarly monthly household fish consumption (Kg per month) (Mean ± SE) was 0.9±0.2 where the highest from DB 1.02±0.18 followed by SR 0.53±0.11. Vegetables and fish consumption showed significant variation between sites with highest from DB ($P<0.05$). The significant variation is due to consumption size variation for onion and carrot between study sites (Table. 2). There were significant difference among onion and carrot consumption between study site ($p<0.05$).

Table 2. Weekly vegetables and monthly fish consumption level (Mean±SE) in the study sites

Site	Onion	Garlic	Spinach	Lettuce	Potato	carrot
Debre Berhan	2.71±0.24[a]	0.29±0.06	0.45±0.13	0.76±0.13	1.42±0.2	2.08±0.12[a]
Shewa Robit	1.74±0.13[b]	0.15±0.05	0.57±0.12	0.52±0.09	1.08±0.14	1.51±0.11[b]
Total	2.22±0.14	0.22±0.04	0.51±0.09	0.64±0.08	1.26±0.12	1.8±0.12

4.2.1. Weekly vegetables and fish expense (Birr per week) level (Mean ± SE) in Debre Birhan and Shewa Robit

Estimated weeklyvegetables expense (177.18 ± 36.63) and fish expense (19.63 ± 9.7) per household showed variation between sites; highest in DB (188.15±28.3) followed by SR (163.09±53.44) for vegetables and highest in DB (212.23 ± 40) followed by SR (172 ± 55.4) for general (vegetables and fish). The variation between sites was significant ($P<0.05$) and the posthoc analysis showed that there was a significance variation between sites on onion, garlic, lettuce and tilapia highest expense per households in DB and lowest spinach expense in DB ($p<0.05$). Pearson's correlation indicated that there was a significant positive correlation between weekly consumption of vegetables and fish with respondents level of education and monthly income ($P<0.05$)

From the total respondents significantly highest respondents purchase vegetables from vegetables shop in DB than SR; however significantly highest respondents purchase vegetables from open market than vegetables shop in SR than DB ($P<0.05$). Fish purchase site showed significant variation between sites; where in SR significantly highest fish purchase from fishing site than fish shop but the condition was opposite in DB ($P<0.05$).

Vegetables and fish consumption per household was not found significantly correlated with distance from market and production site ($p>0.05$). There was a significant variation between study sites on distance of fish and vegetables market from house and production sites ($p<0.05$). Significantly far mileage (Km) from market to household for vegetables observed from DB (0.94±0.08) than SR (0.72±0.1) while far mileage for vegetables from production site observed from DB (719±198) than SR (148±92) ($p<0.05$).

Table 3. Weekly vegetables and monthly fish expense (Birr) level (Mean ± SE) in Debre Birhan and Shewa Robit

Site	Onion	Garlic	Spinach	Lettuce	Potato	Carrot	Cabbage	Tilapia	Catfish
Debre Birhan	35±4.4	18±3.09	25.23±3.77	47.85±8.28	15.229±1.92	15.29±1.68	11.06±1.58	63.62±12.3	32.67±8.13
Shewa Robit	16±1.2	8.85±1.5	15.29±1.68	23.97±2.73	11.68±1.15	11.06±1.98	16.23±2.15	17.31±364	18.38±4.38
Total	26±2.5	13.43±1.8	46.47±22.68	35.74±4.5	13.457±1.13	28.32±2.61	13.76±1.38	50.84±9.72	27.7±5.62

Table 5. Vegetables and fish market distance (Km) (Mean±SE) from respondents' house in Debre Birhan and Shewa Robit

Site	Onion	Garlic	Spinach	Lettuce	Potato	Carrot	Cabbage	Tilapia	Catfish
Debre Birhan	0.73±0.10	0.73±0.10	0.71±0.10	0.71±0.10	0.73±0.10	0.73±0.10	0.71±0.10	0.66±0.14	0.77±0.17
Shewa Robit	0.94±0.07	0.94±0.07	0.94±0.07	0.94±0.07	0.94±0.07	0.94±0.07a	0.94±0.07	3.34±0.96	3.34±0.96
Total	0.83±0.06	0.83±0.06	0.83±0.06	0.83±0.06	0.83±0.06	0.83±0.06	0.83±0.06	1.55±0.40	1.77±0.46

4.2.2. Product characteristics that Consumer's look to buy vegetables and fish in Debre Birhan and Shewa Robit

Consumers' look several selection criteria for buying vegetables and fish, specifically their general purchasing characteristics to aquaponics products was analyzed. Consumers' vegetables and fish selection criteria's showed difference with sites and consumers gave highest value for credibility of product (34.3%) followed by price (25%) but in SR highest value was for price and freshness (28.6%). In general consumers prioritize the characteristics they look to buy vegetables in both sites and highest value calculated for credibility and rice (27.1%) followed by freshness (24.3%), health (20%) and Taste (1.4%). From DB 54.5% respondents look for price followed by freshness (45.5%) to buy Tilapia and 60% (price) and 40% (freshness) to buy catfish but the trend was opposite for SR 87.5% (freshness) and 12% (price) for Tilapia and 87.5% (freshness) and 12.5% (price) for catfish. Generally, respondents from this study prioritize freshness (63.2; tilapia and 61.1%; catfish) than price (36.8%; tilapia and 38.9% catfish) characteristics to determine their preference during purchase.

Only 28.6% of respondents stated that they considered price and freshness to be the most important decision factor when buying vegetables and 87.6% of respondents decided for freshness of fish in Shewa Robit town (Table 7). There was no significant differences between characteristics that customers looks to purchase ($p<0.05$).

Table 6. **Vegetables and fish market distance (Km)** (Mean ±SE) **from production site in Debre Birhan and Shewa Robit**

Site	Onion	Garlic	Spinach	Lettuce	Potato	Carrot	Cabbage	Tilapia	Catfish
Debre Birhan	36±6.82	19.85±6.18	47.05±10.69	7.31±1.55	11.02±1.39	15.11±2.86	29.31±6.66	468.84±95.20	359.5±99.18
Shewa Robit	22.94±6.57	16.31±1.74	21.31±4.35	41.28±6.58	40.62±5.19	24.88±6.53	39.34±6.66	74.31±46.33	74.31±46.33
Total	29.47±4.76	18.08±3.19	34.18±5.93	24.30±3.93	25.82±3.50	20±3.58	34.32±4.71	318.54±74.08	232.75±66.85

Table 7. Product characteristics that Consumer's look to buy vegetables and fish in Debre Birhan and Shewa Robit

Site		Vegetables					Tilapia		Catfish	
		Health	Taste	Freshness	Price	Creditability	Freshness	Price	Freshness	Price
Debre Birhan	%within Site	20.00%		20.00%	25.70%	34.30%	45.50%	54.50%	40.00%	60.00%
	% within x-stics	50.00%		41.20%	47.40%	63.20%	41.70%	85.70%	36.40%	85.70%
	% of Total	10.00%		10.00%	12.90%	17.10%	26.30%	31.60%	22.20%	33.30%
Shewa Robit	% within Site	20.00%	2.90%	28.60%	28.60%	20.00%	87.50%	12.50%	87.50%	12.50%
	% within x-stics	50.00%	100.00%	58.80%	52.60%	36.80%	58.30%	14.30%	63.60%	14.30%
	% of Total	10.00%	1.40%	14.30%	14.30%	10.00%	36.80%	5.30%	38.90%	5.60%

4.2.3. Consumer's readiness to pay high price for vegetables and fish product quality

Despite the higher share of consumers decision making on product selection for purchase; price for consumers was considered as flexible criteria for purchase. With equal quality products consumers prefer to choose product with less price but they paid more for quality products. From respondents in this study 88.60% and 80% of respondents in Debre Birhan and Shewa Robit respectively ready to pay highest price for product quality but less than 20% of respondents were not ready to pay high price for product quality.

Table8. Consumers readiness to pay high price for product quality

			Yes	No
Site	Debre Birhan	% within Site	88.60%	11.40%
		% within ready to pay	52.50%	36.40%
		% of Total	44.30%	5.70%
	Shewa Robit	% within Site	80.00%	20.00%
		% within ready to pay	47.50%	63.60%
		% of Total	40.00%	10.00%

4.3. Knowledge on mode of vegetables and fish production and aquaponics

Numerical variation observed between sites on knowledge on how vegetables and fish conventionally produced and made available for their consumption. In DB 80.0% of respondents and in SR 71.4% respondents know the mode how vegetables they consumed are produced, 48.60% of respondents in DB and 34.30% respondents in SR know the mode how fish they consumed are produced. Consumers' knowledge on synthetic fertilizers effect, showed variation between sites and 85.70% of respondents in DB and 68.60% respondents in SR think that synthetic fertilizer use has environmental impact. In addition, substantial percentages of consumers 45.70% (DB) and 17.10% (SR) suspect the presence of pesticide residue on fruits and vegetables consumed 54.3% (DB) and 82.9% (SR) suspect the presence of toxic chemical residues on fish consumed. Consumers' understandings correlated to their decisions making criteria for vegetables that are credibility of the providers.

More than 86.6% (DB) and 85.4% (SR) of respondents never heard of aquaponics, while only 13.40% (DB) and 14.6% (SR) respondents heard about Aquaponics. Knowledge about aquaponics reached them by various ways; by media (7.3%), training (2.6%), profession (2.9%) and workshop (0.7%) in DB and by media (3.3%), training (3.7%), profession (2.9%) and workshop (3.7%) in SR. After briefing about aquaponics technology 91.40% of respondents in DB and 81.80% respondents in SR prefer aquaponics products than hydroponics, aquaculture, and soil based farm. From entire respondents 97.10%in DB and 100% in SR showed willingness to support the idea of producing fish and vegetables without environmental pollution and without pesticide use.

Table 9. Knowledge about fish and vegetables production modes

	Debre Birhan		Shewa Robit	
Knowledge about fish and vegetables production modes	Yes	No	Yes	No
1. Do you know the mode of vegetables produced?	80	20	71.40%	28.60%
2. Do you know the mode of fish produced?	48.60%	51.40%	34.30%	65.70%
3. Do you know what aquaponics means?	13.40%	86.60%	14.60%	85.40%
4. Do you prefer aquaponics products than hydroponics, aquaculture, and soil based farm?	84.60%	15.40%	81.80%	18.20%
5. Are you aware of health and environmental hazard of pesticide used for vegetables production?	91.40%	8.60%	68.60%	31.40%
6. Can you state the severity level of pesticide?	88.60%	11.40%	65.70%	34.30%
7. Are you aware of the environmental pollution caused by the use of inorganic fertilizers?	80.00%	20.00%	60.00%	40.00%
8. Will you be able to support the idea of producing fish and vegetables without environmental pollution?	97.10%	2.90%	100.00%	-
9. Are you willing to use fish and vegetables produced without using pesticide?	97.10%	2.90%	100.00%	-
10. Do you think synthetic fertilizer use has environmental impact?	85.70%	14.30%	68.60%	31.40%
11. Do you think there are a pesticide residue on fruits and vegetables that you consumed before?	45.70%	54.30%	17.10%	82.90%
12. Do you think there are toxic chemical residues on fish that you consumed before?	45.70%	54.30%	17.10%	82.90%

4.3.1. Consumer's opinion of aquaponics products

In both sites most of respondents showed positive opinion for aquaponics products with respect to product quality and environmental friendness but there was significant variation between sites on price of aquaponics products

Table10. Opinion of consumers on aquaponics products

		Strongly disagree	Disagree	Agree	Strongly agree
Debre Berhan	Aquaponics technology is environmentally safe	2.90%	-	42.90%	54.30%
	Aquaponics products are Healthier	2.90%	5.70%	25.70%	65.70%
	Aquaponics products have no harmful impact	2.90%	2.90%	40.00%[a]	54.30%[a]
	Aquaponics products are supper quality	8.60%	5.70%	51.40%	34.30%[b]
	Aquaponics products are more expensive	-	-	20.00%	80.00%
Shewa Robit	Aquaponics technology is environmentally safe	-	2.90%	45.70%	51.40%
	Aquaponics products are Healthier	-	5.70%	42.90%	51.40%
	Aquaponics products have no harmful impact	8.60%	8.60%	71.40%[b]	11.40%[b]
	Aquaponics products are supper quality	11.40%	20.00%	65.70%	2.90%[a]
	Aquaponics products are more expensive	-	-	22.90%	77.10%

Consumer's preference on how to differentiate aquaponic products from conventional products (labeling, selling in special market, premium price ….)

The result of this study indicated that aquaponics products should be differentiated from conventional products by labeling (97.1%), selling in special market (2.9%) in both sites. There was statistically no significant difference between study areas ($p > 0.05$).

Consumer's scale of preference for aquaponics products (vegetables and fish)

From entire respondents aquaponics products scale of preference stated from excellent to poor in both sites but it was product specific. For vegetables highest 27.15 % (DB) and 28.60% in (SR) rated excellent preference followed by 23.58% (DB) and 25% (SR) rated very good. Only 9.28 % (DB) and 13.55% (SR) respondents rated their aquaponics products preference as poor.

Highest proportion of consumers rated their aquaponics fruity vegetables preference as very good (28.55%) followed by excellent (26.43%) in DB and excellent (22.85%), very good (17.88%), in SR,aquaponics fish products excellent (20.00 %), very good (22.9%), very poor (5.7%) in DB and excellent (11.4%), very good (14.3%), poor (25.0%) in SR (Table 12). There was statistically significant variation in cucumber and eggplants consumers' preference between study areas ($p < 0.05$).

When consumers had intention to purchase aquaponics products the majority of consumers indicated that they have positive intention to buy fruity vegetables expressed by rating excellent 75.75% (DB) and 58.85% (SR), very good 10.27% (DB) and 23.55% (SR) and poor 15% (DB) and 1.45% (SR). With regard to fish aquaponics products consumers demonstrated highest level of intention to purchase by rating excellent 27.15% (DB) 28.23% (SR).

Table 12. Scale of preference for aquaponic products (Leafy vegetables, fruity vegetables and fish)

Site		Very poor	Poor	Fair	Good	very good	Excellent
Debre Birhan	Leafy vegetables	-	9.28%	18.58%	21.43%	23.58%	27.15%
Shewa Robit		-	13.55%	17.85%	14.98%	25.00%	28.60%
Debre Birhan	Fruity vegetables	4.30%	7.63%	17.15%	17.85%	28.55%	26.43%
Shewa Robit		-	16.43%	24.30%	18.58%	17.88%	22.85%
Debre Birhan	Fish	5.70%	5.70%	25.70%	20.00%	22.90%	20.00%
Shewa Robit		-	25.70%	28.60%	20.00%	14.30%	11.40%

Table13. Level of intention to purchase for aquaponic products (Leafy vegetables, fruity vegetables and fish)

Site		Very poor	Poor	Fair	Good	very good	Excellent
Debre Birhan	Leafy vegetables	18.58%	23.58%	30.00%	15.00%	12.13%	75.73%
Shewa Robit		18.55%	17.88%	47.88%	33.33%	-	100.00%
Debre Birhan	Fruity vegetables	12.88%	22.15%	29.28%	23.55%	8.58%	52.85%
Shewa Robit		21.40%	18.10%	56.43%	38.55%	-	100.00%
Debre Birhan	Fish	-	5.70%	22.90%	65.70%	5.70%	-
Shewa Robit		-	-	14.30%	85.70%	-	-

4.3.2. Consumer's perception on relative advantage of aquaponic products (vegetables and fish) over conventional products

In both study sites there is a tactical variation on the reason of consumers to choose aquaponics products. From all respondents the relative advantage of aquaponics vegetables products over conventional vegetables products with respect to quality, mileage, price, trust and health found to be 12.3%, 11.59%, 16.58%, 20.88% and 38.59% respectively. Whereas the relative advantage of aquaponics fish product as compared to conventional fish products with respect to quality, mileage, price, trust and health found to be 11.4%, 11.4%, 15.7%, 21.4% and 40% respectively. From those figures it is understood that the consumers gave highest priority for their health and trust aquaponics products for their health. There was no significant variation between sites with relative advantages ($p>0.05$.).

Table 14. Relative advantage of aquaponic products over conventional products

Site		what are relative advantage of aquaponic products vegetables					what are relative advantage of aquaponic products fish				
		Quality	Mileage	Price	Trust	Health	Quality	Mileage	Price	Trust	Health
Debre Birhan	% within Site	16.08%	3.25%	18.91%	16.05%	45.71%	14.30%	2.90%	17.10%	17.10%	48.60%
	%within relative advantage	64.90%	13.71%	56.88%	38.39%	59.28%	62.50%	12.50%	54.50%	40.00%	59.30%
	% of Total	8.01%	1.59%	9.48%	8.04%	22.89%	7.10%	1.40%	8.60%	8.60%	24.30%
Shewa Robit	% within Site	8.60%	20.00%	14.30%	25.70%	31.40%	8.60%	20.00%	14.30%	25.70%	31.40%
	%within relative advantage	35.10%	86.29%	43.13%	61.61%	40.73%	37.50%	87.50%	45.50%	60.00%	40.70%
	% of Total	4.30%	10.00%	7.10%	12.90%	15.70%	4.30%	10.00%	7.10%	12.90%	15.70%

4.3.3. Social acceptance of aquaponics technology and its products

Consumers (20%) of respondents in both study area; showed a slightly negative image for aquaponics technology and its products. These negative images indicated that lack of knowledge (consumers not heard) of aquaponics products. Consumers do not distinguish aquaponic products from conventional products. They generally believe that the products they buy have conventional products. Thus, the issue at stake is to understand whether to promote farmed products as such or to promote the combined fish and vegetables production without soil use. For those who had never heard of aquaponics, a description of aquaponics that provides the main value propositions that can be read in commercial materials about aquaponics technology: "Aquaponics is a combination of aquaculture (fish farming) and hydroponics (growing plants using water rather than soil). In aquaponics, the waste produced by farmed fish supplies the nutrients for plants grown hydroponically, which in turn purifies water for the fish. This secures a closed-loop sustainable food production system. Very few pesticides and herbicides are non-toxic for fish so this ensures that aquaponics production uses organic pest and weed control. After these description respondents answers aquaponics technology and products were acceptable 80% and unacceptable 20% in both study area.

Table 15. Socially unacceptability issues with regard to aquaponic products technology and products

			Yes	No
Site	Debre Birhan	% within Site	20.00%	80.00%
		% within is there any socially unacceptability issues with regard to aquaponic products technology and products	46.70%	50.90%
		% of Total	10.00%	40.00%
	Shewa Robit	% within Site	22.90%	77.10%
		% within is there any socially unacceptability issues with regard to aquaponic products technology and products	53.30%	49.10%
		% of Total	11.40%	38.60%

4.4. Willingness to pay

Consumers were found to be willing to pay premium prices for both vegetables and fish produced aquaponically (67.1%) while few are not willing to pay premium prices (32.9%). Significantly highest percentage of consumers are willing to pay more for aquaponicsproducts as compared to conventional products ($p<0.05$) but there was no significant variation between sites ($p>0.05$).

Consumers had different reasons to pay premium prices for aquaponics products. Generally, 43.9% of consumers were ready to pay premium price for vegetables for their health followed by freshness (29.3%), trust 17.2%, mileage 6.9% and environment (3.4%). Similarly fish consumers were ready to pay premium prices and among from respondents 32.2% were ready to pay premium price for their health followed by freshness (29.31%), Trust (18.95%), Mileage (10.3%) and Environment 3.4%).

The level of premium price estimated by the consumers showed numerical variation; the estimated premium in percentage from the existing price for conventional product reported for lettuce, cabbage, spinach, basil, pepper, tomato, cucumber, eggplant, catfish and tilapia to be 7.11 ± 0.5, 5 ± 0.41, 5.42 ± 0.4, 4.27 ± 0.44, 8.56 ± 0.75, 9.43 ± 0.78, 5.89 ± 0.48, 6.66 ± 0.63,

and 8.5 ± 0.71 respectively. There was statistically significant difference on premium price for lettuce, cabbage, spinach and pepper between study areas ($p < 0.05$).

Table16. Willings to pay the premium price for aquaponics products

Site		Vegetables		Fish	
		Yes	No	Yes	No
Debre Birhan	% within Site	62.90%	37.10%	62.90%	37.10%
	% within willing to pay premium price	46.80%	56.50%	46.80%	56.50%
	% of Total	31.40%	18.60%	31.40%	18.60%
Shewa Robit	% within Site	71.40%	28.60%	71.40%	28.60%
	% within willing to pay premium price	53.20%	43.50%	53.20%	43.50%
	% of Total	35.70%	14.30%	35.70%	14.30%

Table 17. Reason to be willing to pay the premium price in Aquaponics of products

Site		premium price in Aquaponics products of vegetables					premium price in Aquaponics products of fish				
Debre Birhan		Health	Environment	Mileage	Trust	Freshness	Health	Environment	Mileage	Trust	Freshness
	%within Site	43.09%	3.40%	6.90%	17.20%	29.31%	37.90%	3.40%	10.30%	18.95%	29.30%
	%within reason willing pay	43.09%	3.40%	6.90%	17.20%	29.31%	37.90%	3.40%	10.30%	18.95%	29.30%
	% of Total	43.09%	3.40%	6.90%	17.20%	29.31%	37.90%	3.40%	10.30%	18.95%	29.30%
Shewa Robit	%within Site	43.09%	3.40%	6.90%	17.20%	29.31%	37.90%	3.40%	10.30%	18.95%	29.30%
	%within reason willing pay	43.09%	3.40%	6.90%	17.20%	29.31%	37.90%	3.40%	10.30%	18.95%	29.30%
	% of Total	43.09%	3.40%	6.90%	17.20%	29.31%	37.90%	3.40%	10.30%	18.95%	29.30%

Table18. State level of premium level that you are willing to pay in percentage compared to conventional products

site	Lettuce	Cabbage	Spinach	Basil	Pepper	Tomato	Cucumber	Egg plant	Cat fish	Tilapia
Debre Birhan	6.14±0.69	3.68±0.46	4±0.4	4.71±0.72	6.85±0.9	9.86±1.33	5.64±0.69	6.03±0.92	7.76±1.14	8.89±1.21
Shewa Robit	8.07±0.61	6.40±0.58	6.96±0.60	3.81±0.50	10.33±1.13	9±0.81	6.14±0.69	5.82±0.64	5.53±0.4	8.1±0.74
Total	7.11±0.47	5±0.41	5.42±0.40	4.27±0.44	8.56±0.75	9.43±0.78	5.89±0.48	5.92±0.48	6.66±0.63	8.5±0.71

DISCUSSION

According to present study existing fish and vegetables access, consumption level and preference level was measured by using incremental value of the product in a way to understand the consumers' acceptance about the aquaponis product. Vegetables and fish consumption pattern and consumption size per week (kg) per house hold showed that there were significant difference on onion, carrot and potato between study area ($p<0.05$). The variation associated with income of respondents, educational level and climatic factor of the study site. Further access to the market, distance to producers and purchase characteristics lost on the product were other decisive factors to affect the consumption size. Consumption size of vegetables and fish indicated the presence of substantial volume for additional products produced with in the study site like by Aquaponics technologies. Respondents mention the market distance from producers (km) purchase different vegetables and fish. Vegetables and fish purchase from open market, super market, vegetables shop, fishing site and fishing shop had vegetables and fish came from various producers distance. The highest respondents were buying vegetables from open market in study area. There were significant difference on market distance from producers (km) to the market forspinach, lettuce, potato, tilapia and cat fish between study area ($p<0.05$). These affected the quality of the products and increase the price of the products therefore consumers can be benefited through aquaponics technology dissemination in the study area.

This study showed that consumers preference decision for vegetables and fish in decreasing pattern were depend on taste, price, freshness and health respectively for vegetables and freshness and price for fish. These were associated with the existing trade practice which lacks on provision of information like mileage, producers, harvest date, size metrics, lable and packaging's. Because of these, consumers in both sites assumed equal quality on products, mileage and other factors and their decision mainly depend on minimum price. Purchase intention is directly interrelated with purchase characteristics; it is the main index to forecast whether the consumer will purchase (Zheng *et al*, 2010). Therefore informed citizen creation through eastablishing a model farm and market for vegetables and fish is needed. Consumers buy vegetables from open markets, vegetables shop depending on their existing living condition. Conciderable volume of products merchandised on open market which brought several health, social, and economic challenges. Respondents claimed that they can considered freshness, taste

and price to be the most important decision factor when buying vegetables and fish in study area in the future.

From respondents 88.60% and 80% in Debre Birhan and Shewa Robit respectively informed that they are ready to pay aquaponics products in higher price if the customer informed information and quality parameters considered by providers. This indicated that there were acceptance of aquaponics technology and products in the study sites. In general, consumers would insert new more aquaponics products: if there was a quality label, prices were more affordable and they had a better knowledge of the quality of these products. Consumers have a positive overall image of aquaponics products. In general, they think they are good for health, and that they are fresh products. Highest respondent'sproportion was willing to support the idea of producing fish and vegetables without environmental pollution using no pesticide and synthetic fertilizer aquaponically. Consumers' perceived aquaponics as free from pesticide and toxic chemical residues o on fruits, vegetablesand fish.

Consumers' Knowledge about Aquaponics is limited in the study area but there was limited knowledge in Europe up to 2017 (Milicic *et al*, 2017). Likewise, consumer's knowledge about the mode how and where the vegetables and fish they consumed are produced is found to be limited in both sites.

According to Milicic *et al.*, (2017), more than 50% of respondents had never heard about aquaponics and only 5.5% of respondents were in some way involved in aquaponics themselves in Europe. The results indicate, however, that willingness to pay when buying food is mainly based on price and whether the products are free of antibiotics, pesticides and herbicides (Milicic *et al*, 2017).

According to Hilverda *et al.*, (2017), more knowledge about aquaponics products needs to reach consumers through interactive learning practices and examples of existing good practices. Various training courses and summer schools have been carried out, including media games, flyers, social media, etc., but promotion of and education about aquaponics systems needs to continue further in the future. This will be the way to promote this healthy and sustainable system of food production (Hilverda *et al.* 2017). In Ethiopia, knowledge and technical support for aquaponics operation is provided by the knowledge center established through joint effort of Addis Ababa University, Debre Birhan University, Wageninigen University and TGS business development of the Netherlands (www.aquaponicsethiopia.com).

According to present study relative advantage was measured by using incremental value of the product in a way to understand the consumers 'acceptance about the product. The results showed that relative advantage has a positive and significant effect on intention to purchase Aquaponic products. More of the respondents were worried about their health, price, and quality of vegetables and fish respectively in both study area.

According to Flight *et al.,* (2011); relative advantage on innovation characteristic has been studied by to examine the intention of consumer adopting aquaponics products. On the other hand, relative advantage of the product can be extended to other factors such as the environmental impacts of the product (Lea and Worsley, 2008). Aquaponic products are expected to be environmental friendly to protect and preserve a better environment. On behalf of the relative advantage; some researchers' also defined relative advantage as the consequences after using the products to the consumer. In this study consumers were willing to pay the premium price for aquaponics products (vegetables and fish). The willingness to pay premium prices for aquaponics products in comparison to the conventional products due to the

Conclusions

From this research we can conclude that, aquaponics technology products have potential consumer's acceptance which can induce substantial market volume for aquaponics products as compared to conventional products. Aquaponics products consumers acceptance depend on the quality of products, label of product and mileage. Consumers are willing to pay apremium price in percentage from conventional product of 7.1% (Lettuce), 5% (Cabbage), 5.42% (Spinach), 4.27% (Basil), 8.56% (Pepper), 9.43% (Tomato) and 8.5% (Tilapia) for their health, mileage and trust of product.

Reference

Amadori, M. & Daley, D. (2012).An Engineered Ecosystem for Waste Management and Food Production.In *Environmental Science and Forestry*, Vol. Master's, 44 NY, USA,: State University of New York.

Beaulac, J., Kristjansson, E., & Cummins, S. (2009). A Systematic Review of Food Deserts.Prev Chronic Dis, **6**(*3*), 1-105.

Beaulieu, J. C. and Gorny, J. R. (2004).Fresh-cut fruits. In: Gross K. C., Wang, C.Y., Saltveit, M.E. (eds.), D.C.: Agricultural Research Service, pp. 66 Accepted (In Public review)

Bennett, J.W. &Klich,M.(2003) Mycotoxins.Clinical Microbiology Reviews 16:497-516.

Blackburne, R., Vadivelu, V., Yuan, Z. & Keller, J. (2007). Kinetic characterisation of an enriched Nitrospira culture with comparison to Nitrobacter. *Water Res***41**: 3033-3042.

Blidariu, F. & Grozea, A. (2011).Increasing the Economical Efficiency and Sustainability of Indoor Fish Farming by Means of Aquaponics. *Reviewof Scientific Papers Animal Science and Biotechnologies*. **44** (*2*): 1–8.

Brook, L. (2012). Report on the Value Chain Assessment of the Fishery Sector in Ethiopia. . Vol. 131Addis Ababa: Food and Agriculture Organization Sub-Regional Office for Eastern Africa

Caplow, T. (2009). Building Integrated Agriculture: Philosophy and Practice.In Urban Futures 2030.Urban Development and Urban Lifestyles of the Future.Publication Series on Ecology.

Christian, B., Laurence, G., Olivier, K., Girardin, P. and Galan, M., (2009).Comparison Systems to Improve Sustainability, Increase Productivity, and Reduce Environmental

Cometti, N., Martins, M., Bremenkamp, C. & Nunes, J. (2011). Nitrate concentration in lettuce leaves depending on photosynthetic photon flux and nitrate concentration in the nutrient solution. *Horticultura Brasileira***29**: 548-553.

Devereux S. (2000). Food Insecurity in Ethiopia. A discussion paper for DFID.

Doualle,B., Medini, K., Boucher, X. and Laforest V (2015).Investigating sustainability assessment methods of product-service systems. *Procedia CIRP*, **30**: 161-166.

Edwards, P. (2015). Aquaculture Environment Interactions: Past, Present and Likely Future Trends. Aquaculture, Research for the Next 40 Years of Sustainable Global Aquaculture**, 447**: 2–14.

Francis, C., Lieblein, G., Gliessman, S., Breland, T., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D. & Salvador, R. (2003). Agroecology: The Ecology of Food Systems. *J. Sustain. Agric***22**: 99-118.

Fujiwara, K., Iida, Y., Iwai, T., Aoyama, C., Inukai, R., Ando, A., Ogawa, J., Ohnishi, J., Terami, F., Takano, M. & Shinohara, M. (2013). The rhizosphere microbial community

in a multiple parallel mineralization system suppresses the pathogenic fungus Fusarium oxysporum. *Microbiologyopen***2**(6): 997-1009.

Genschick S, P. M. J., Thilsted S.H, Thorne-Lyman A.L and Subasinghe, R. (2015). Aquaculture and fisheries for nutrition: towards a nutrition sensitive approach. . *Info fish International* 5(26): 14-17.

Goddek, S., Delaide, B., Mankasingh, U., Ragnarsdottir, K., Jijakli, H. & Thorarinsdottir, R. (2015). Challenges of Sustainable and Commercial Aquaponics. *Sustainability***7**(*4*): 4199-4224.

Haase, Dagmar. (2015).Reflections about Blue Ecosystem Services in Cities. Sustainability of Water Quality and Ecology,Modelling ecosystem services: Current approaches, challenges and perspectives, **5**: 77–83.

Hilverda, F.; Kuttschreuter, M.; Giebels, E. Social media mediated interaction with peers, experts and anonymous authors: Conversation partner and message framing effects on risk perception and sense making of organic food. Food Qual. Preference 2017, 56, 107–118. 39-244, Apr.-June

Jatoba, A., Vieira Fdo, N., Buglione-Neto, C., Mourino, J., Silva, B., Seiftter, W. & Andreatta, E. (2011). Diet supplemented with probiotic for Nile tilapia in polyculture system with marine shrimp. *Fish Physiol Biochem***37**(4): 725-732.

Jones, B. (2005). *Hydroponics - A Practical Guide for the Soilless Grower* Washington, USA: CRC Press.

Jorgensen, C. J., Jacobsen, O. S., Elberling, B. & Aamand, J. (2009). Microbial oxidation of pyrite coupled to nitrate reduction in anoxic groundwater sediment. *Environ Sci Technol***43**(13): 4851-4857.

Junge, R., Sandra W., and Urs H. (2014).Aquaponics in Classrooms as a Tool to Promote Systems Thinking.In Proceedings of the Conference VIVUS on Agriculture, Environmentalism, Horti-culture and Floristics, Food Production and Proces-sing and Nutrition, **1**:234–44.

Kiss, G., Hermen J., Veronica L., Lydia O. (2015).The 2050 City International Conference on Sustainable Design, Engineering and Construction. *Procedia Engineering*,**118**: 326 – 355.

Klinger, D. & Naylor, R. (2012). Searching for Solutions in Aquaculture: Charting a Sustainable Course. *Annual Review of Environment and Resources***37**: 247-255.

Lennard, W. & Leonard, B. (2004). A comparison of reciprocating flow versus constant flow in an integrated, gravel bed, aquaponic test system. *Aquaculture International***12**(6): 539-553.

Love, D. C., Uhl, M. S. & Genello, L. (2015). Energy and water use of a small-scale raft aquaponics system in Baltimore, Maryland, United States. *Aquacultural Engineering* 68: 19-27.

Lovell, R. T. (1991). Nutrition of aquaculture species. *J Anim Sci***69**(10): 4193-4200.

McAndrew, B. J., Turner, G. F., Robinson, R. L., Beveridge, M. C. M., Baird, D. J., Ross, L. G., Lowe-McConnell, R. H., Lorenzen, K. & Penman, D. J. (2000). *Tilapias: Biology and Exploitation.* Heidelberg, The Netherlands: Springer.

Milicic; v., Ragnheidur; T, Maria; Dos S. and Maja Turnšek Hančič (2017). Commercial Aquaponics Approaching the European Market: To Consumers' Perceptions of Aquaponics Products in Europe. *Water research* 2017, 9(2) 80

Million, A., Grit B., Anja S., and Wolf R.(2014).Roof Water Farm.Participatory and Multifunctional Infrastructures for Urban Neighbor-hoods.In Finding Places for Productive Cities. Leeuwarden, the Netherlands.

Neori, A., Chopin, T., Troell, M., Buschmann, A., Kraemer, G., Halling, C., Shpigel, M. & Yarish, C. (2004). Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture***231**(1–4): 361-391.

NRC (1999). *Nutrient Requirements of Fish.* Washington, USA: National academy press.

Nyamangara, J., Mtambanengwe, F., Musvoto, C. (2009) Carbon and nitrogen mineralization from selected organic resources available to smallholder farmers for soil fertility improvement in Zimbabwe. *African J Agric Res***4**: 870-877.

Ochsenbein, G., Wachter, D. (2004) Sustainability assessment: Conceptual framework and basic methodology. *Fed Off Spat Dev,***1**: 1-62.

Ragnarsdottir, K. V., Sverdrup, H. U. & Koca, D. (2011). Challenging the planetary boundaries I: Basic principles of an integrated model for phosphorous supply dynamics and global population size. *Appl. Geochem.***26**: 303-306.

Rakocy, J. & Hargreaves, J. (1993). *Integration of vegetables hydroponics with fish culture.* USA: American Society of Agriculture Engineers..

Rakocy, J. (1997). *Integrating Tilapia culture with vegetables hydroponics in recirculating systems.* Baton Rouge, Louisiana: World Aquaculture Society.

Rakocy, J. (2012).Aquaponics. **In**: *Aquaculture production systems*, pp415 (J. Tidwell,ed.).: John Willey & Sons, Ltd Lowa, USA.

Rakocy, J., Masser, M. & Losordo, T. (2006). Recirculating Aquaculture Tank Production Systems: Aquaponics - Integrating Fish and Plant Culture. *Southern Regional Aquaculture Center (SRAC)***454**: 1-16.

Roosta, H. & Mohsenian, Y. (2012). Effects of foliar spray of different Fe sources on pepper (*Capsicum annum* L.) plants in aquaponic system. *Scientia Horticulturae***146**: 182–191.

Roostaa, H. & Hamidpour, M. (2011). Effects of foliar application of some macro- and micro-nutrients on tomato plants in aquaponic and hydroponic systems. *Scientia Horticulturae***129**: 396–402.

Savidov, N., Hutchings, E. & Rakocy, J. (2007). Fish and plant production in a recirculating aquaponic system: a new approach to sustainable agriculture in Canada. *Proceedings of the International Conference & Exhibition on Soilless Culture* 7(42): 209-221.

Seawright, D., Stickney, R. & Walker, R. (1998). Nutrient dynamics in integrated aquaculture–hydroponics systems. *Aquaculture***160**(3-4): 215-237.

Shu, L., Schneider, P., Jegatheesan, V. & Johnson, J. (2006). An economic evaluation of phosphorus recovery as struvite from digester supernatant. *Bioresour Technol***97**(17): 2211-2216.

Somerville, C., Cohen, M., Pantanella, E., Stankus, A. & Lovatelli, A. (2014). Small-scale aquaponic food production. *Food and Agriculture Organization of the United Nations. Rome: FAO.*

Tokunaga, K., Tamaru, C., Ako, H. & Leung, P. (2015). Economics of small-scale commercial aquaponics in Hawai'. *J. World Aquac. Soc.***46**: 20-32.

Turcios, A., Papenbrock, J. (2014). Sustainable treatment of aquaculture effluents-What can we learn from the past for the future? Sustain **6**: 836-856.

Tyson, R., Simonne, E., Treadwell, D., White, J. & Simonne, A. (2008). Reconciling pH for Ammonia Biofiltration and Cucumber Yield in a Recirculating Aquaponic System with Perlite Biofilter. *HORTSCIENCE* 43(3): 719–724.

Tyson, R., Treadwell, D. & Simonne, E. (2011). Opportunities and Challenges to Sustainability in Aquaponic Systems. *Hortitechnology***21**(1): 6-13.

Vadiee,A. and Viktoria, M. (2012).Energy Management in Horticultural Applications through the Closed Greenhouse Concept, State of the Art. Renewable and Sustainable Energy Reviews,**16**(*7*): 5087–5100.

Vermeulen, T. & Kamstra, A. (2013). The need for systems design for robust aquaponic systems in the urban environment. **104**: 71-78.

Viljoen, A., Katrin B,, and Joe H. (2005). Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities. Architectural Press