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SHORT COMMUNICATION KISA MAKALE

THE FIRST SUBSTANTIATED RECORD AND NORTHWARD EXPANSION OF THE MERTENS' PRAWN-GOBY, *Vanderhorstia mertensi* (OSTEICHTHYES: GOBIIDAE) IN THE AEGEAN SEA

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Abstract:

The occurrence of the alien goby *Vanderhorstia mertensi*, off Akbük Cove, Anatolian coasts of Aegean Sea, is here well proven for the first time. On 12 August 2014, a single specimen was observed by visual census. This finding substantiate that its presence and also distribution is expanding northwards, along the Anatolian coasts of the Aegean Sea.

Keywords: *Vanderhorstia mertensi*, Aegean Sea, Alien species, Anatolian coasts

Introduction

A crucial factor heavily influencing the changes of Mediterranean biodiversity is the continuous introduction and rapid establishment of exotic newcomers of Erythraean origin (Zenetos et al., 2012). Alien biota in the Aegean Sea include 775 alien species of which 105 are exotic fish species consisting of more than 65 species of Indo-Pacific origin (Zenetos et al., 2012). Bilecenoğlu et al. (2014) stated 512 fish species belonging to 150 families along the Turkish coasts, where 55 non-indigenous fish species are reported (Ergüden et al., 2013).

Gobiidae is one of the largest fish family among marine fishes, found mainly in shallow waters in diverse habitats, including approximately 1900 species in all tropical and temperate regions (Golani et al., 2006). It is also the richest family in the Mediterranean more than 60 species, four of which are Lessepsian immigrant (Bilecenoglu et al., 2008; Goren, 2014).

The Erythraean slender shrimpgoby, *Vanderhorstia mertensi* Klausewitz, 1974, has been first recorded from the Fethiye Bay, Turkey (Bilecenoglu et al., 2008) and afterwards it was reported chronologically: in 2008 at Iskenderun Bay (Yokeş et al., 2009), in 2009 at Antalya Bay (Gökoğlu et al., 2011), in 2010 at Gökova Bay (Çınar et al., 2011) and in 2012 from the Haifa Bay (Goren et al., 2013) (Figure 1.).

Materials and Methods

On 12 August 2014, While SCUBA dive performed in order to determine marine biota in the Akbük Cove, SE Aegean Sea, Turkey (Figure 1.) (37°23′N - 27°25′E), some of the authors (A.T, Ü.A and F.Y) observed a single specimen of *Vanderhorstia mertensi* (Figure 2.) in shallow waters (approx. 6 m), on sand and muddy bottom and its photo was taken using Canon EOS550d Digital Camera with Ikelite Underwater Housing. The identification of the species was based on the description provided by Larson and Murdy (2001) and Bilecenoğlu et al. (2008) using high quality photos.

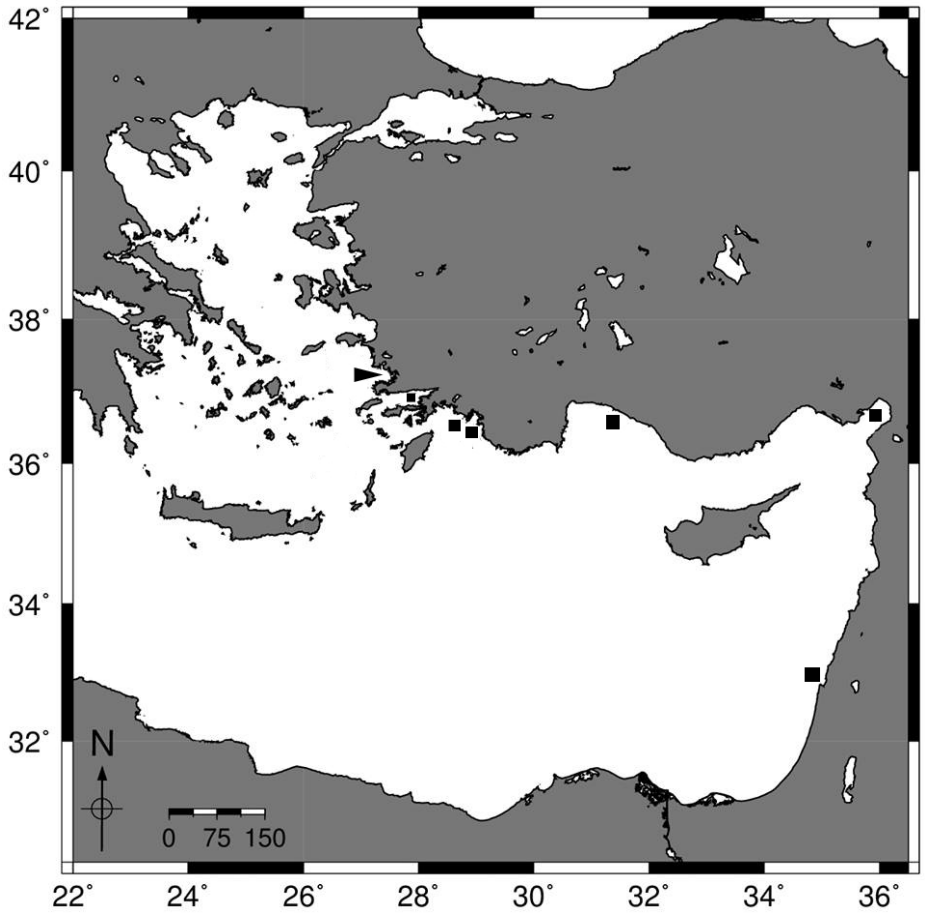

Figure 1. Locations of Mediterranean reported by *Vanderhorstia mertensi* (▲ Present study, ■ previous studies)

Figure 2. A general view of *Vanderhorstia mertensi* in front of its nest (Photo: Ali Türker).

Results and Discussion

Important diagnostic features of specimen were clearly visible and noticeable: Body colour white ventrally with spotless, beige and light grey dorsally; a mid-lateral line of well-distinguished vertical dark stripes (not reaching the belly). Dorsal and ventral zones were separated by dark strips with numerous irregular yellow/orange spots where exist on dorsal part of body and head. One dark spot on both the opercle and caudal peduncle and, three more below the second dorsal fin.

Identification of goby species requires more attention because the most important characters of species are visible generally under stereomicroscope. There are over 120 gobiid fish belonging to 20 genera known to live in association with Alpheid shrimps, there have been only two Erythraean associated gobiids, *Vanderhorstia mertensi* and *Cryptocentrus caeruleopunctatus*, in the Mediterranean (Rothman and Goren, 2015). This feature provides convenience for photographic identification of Red Sea gobies in the Mediterranean. These two species also are differentiated from each other by distinct and characteristic colorations.

The opening of the Suez Canal, which are formed artificially, have contributed to be invaded Mediterranean biodiversity by Erythraean fauna and flora (Coll et al., 2010). This phenomenon, called as Lessepsian influx, associated with anthropogenic actions and global warming have proceed the remodeling drastically biota of Mediterranean in the last century (Bianchi and Morri, 2003).

Most of Erythraean fishes that are quite common in the eastern Mediterranean have not yet been observed in the southeastern Aegean, probably due to difficulties in overcoming biotic and/or abiotic factors, such as temperature regime, substrate, currents, structure of the continental shelf, thermal tolerance of the colonizing species, food availability, competition with indigenous species, resistance to local pathogens, and extension of the spawning season (Corsini-Foka and Economidis, 2007; Mavruk and Avsar, 2007). However, cold water temperature has been considered as the most important restrictive factor in invasion/colonization processes of Erythraean fishes. Nevertheless, distributions of coastal littoral species, such as *V. mertensi*, seem to not affected by these unfavourable conditions because shallow sandy and/or muddy habitats that provide suitable conditions for their survival and establishment (Golani et al., 2007; Yapici et al., 2015). Additionally, substantial northward occurences of the previously-known *V. mertensi* may probably increase due to the fact that rise in seawater tem-

perature of approx. 1–2°C of the Aegean Sea (Pancucci-Papadopoulou et al., 2012; Bianchi et al., 2014). Moreover, its distribution may be wider from the known up to now due to it has no commercial value, a small size and cryptic behavior. Concerning alien fishes, Golani et al. (2011) highlighted the importance of both first records and additional records in new areas, because they indicate that previous occurrences were not just accidental and they provide information about their invasion pathways and zoogeographic range expansion.

Conclusion

The observation of the Erythraean alien goby *Vanderhorstia mertensi* here reported for the first time provably in the Turkish Aegean waters, shows a lightly expansion northern to the Anatolian coasts of Aegean Sea. Therefore, studies of non-indigenous new assemblages should focus more, and their interactions deeply investigated as well.

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ORIGINAL ARTICLE/ORİJİNAL ÇALIŞMA

FULL PAPER TAM MAKALE

COMPARATIVE STUDY OF THE TOXICITY OF OILS FROM SEEDS OF *Citrullus colocynthis* AND *Citrullus vulgaris* ON LARVAE OF *Dermestes Maculatus*

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Abstract:

Study was carried out in the Fisheries Research Laboratory, Ahmadu Bello University to evaluate the effect of *Citrullus colocynthis* (Eguisi) and *Citrullus vulgaris* (Watermelon) seed oils on the larvae of *Dermestes maculatus*, an important pest of smoke-dried *Clarias gariepinus* (African catfish). The effect of the oils at different tested concentrations against the larvae of *D. maculatus* was dose dependent as 3.33% and 81.11% mortality for *C. colocynthis* while 2.22% and 91.11% for *C. vulgaris* were recorded for 0.027 mLg^{-1} and 0.081mlg^{-1}respectively at 96 hours' exposure time. The interaction effect of 0.081mlg^{-1} watermelon seed oil and 96h exposure gave the highest kill compared to eguisi seed oil at the same concentration and time which was significantly ($p<0.05$) more than the percent kill of the other concentrations and exposure time. At 0.243 mLg^{-1} both oils killed 100% of *D. maculatus* larvae even at 24h exposure time. It is therefore concluded that 0.081mlg^{-1} and 0.243 mLg^{-1} of both *C. colocynthis* and *C. vulgaris* seed oil could be applied as botanical insecticides to prevent smoke-dried fish from *D. maculatus* larvae attack.

Keywords: *Citrullus colocynthis*, *Citrullus vulgaris*, *Dermestes maculatus* larvae, Larvicidal effect, Dried catfish

Introduction

Citrullus vulgaris and *Citrullus colocynthis* belongs to a large plant family called the Cucurbitaceae known for its great diversity and widespread adaptation in tropical and subtropical regions, arid deserts and temperate locations (Oluba, Adeyemi, Ojieh & Isiosio, 2008). It consists of nearly 100 genera and 750 species, known for their high protein and oil content. Seeds of curcubits are sources of oils and protein with about 50% oil and up to 35% protein (Achu, Fokou, Tchiégang, Fotso & Tchouanguep, 2005). Eguisi (*Citrullus colocynthis* L.) and watermelon (*Citrullus vulgaris* L.) belongs to the species of the genus *Citrullus* of curcubitaceae family, which usually consists of a large number of varieties that are generally known as melons (Mabaleha, Mitei & Yeboah, 2007). Seenivasan, Jayakumar, Raja & Ignacimuthu (2004) reported that *Citrullus colocynthis* showed highest repellent activity in lower concentration against *Callosobrochus maculatus*. Akpotu & Adebote (2013) reported that 1.38ml of *C. colocynthis* oil applied on 17g *Clarias gariepinus* dried fish gave 44% repellent protection while the same concentration of *C. vulgaris* seed oil gave a much better repellence (71.11%). Watermelon seeds have been observed to be mildly diuretic and its consumption may have antihypertensive effect (CBC News site, 2008) while its eguisi counterpart is heavily consumed for the food in the seeds and used both as condiment and thickener in various Nigerian local soups (Uruakpa & Aluko, 2004).

Stored products like grains, cheese, hide, fur, bacon, dried fish, meat, and other protein-containing concentrates, have been known to be destroyed by insect pests. Insect infestation of cured fish by blowflies and hide beetles is an important cause of post – harvest losses in many developing countries (Johnson & Esser, 2000). Fish is susceptible to attack by insect pests throughout processing and storage. The principal pests are blowflies (Diptera: Calliphoridae and Sarcophagidae) and hide beetles (Coleoptera: Dermestidae and Cleridae). Losses caused by infestation could be physical, economical and nutritional in nature (Johnson & Esser, 2000). According to Osuji (1974); Eyo & Awoyemi (1989), large scale deterioration in quality and quantity of dried fish is attributed to dermestid infestation. Prominent insecticide families Organochlorine hydrocarbons (e.g. DDT) have been used in the control of pest of stored products but they have been phased out because of their persistence and potential to bioaccumulate (Kamrin, 1997). They operate by disrupting the sodium/potassium balance of the nerve fibre, forcing the nerve to transmit continuously.

Unlike synthetic chemical insecticides that kill both pests and non – target organisms, natural insecticides including botanicals are relatively target specific (Isman, 1997). Plant materials such as spices, vegetable oils, extracts, powder or ash (Keita, Vincent, Schmit, Arnason & Bélanger, 2001; Akinkurolere, Adedire & Odeyemi, 2006; Adedire, Obembe, Akinkurolere & Oduleye, 2011) have been reported for their insecticidal efficacy. *Dermestes maculatus* is an important pest of dried fish and meat in many regions of the world (Integrated Information System, 2009). A comparative assessment of the biological performance of *D. maculatus* in various dietary media namely dried fish, fish meal, bone meal, palm kernel meal, blood meal and whole meal revealed that dried fish followed by fish meal were significantly superior to the commercial feeds (Osuji, 1978). Management of agricultural pests over the past half century has been largely dependent on the use of synthetic chemical pesticides both for field and post-harvest protection of stored products. Potential problems associated with continued long term use of toxic insecticides include pest resistance and negative impact on natural enemies (Abudulai, Shepard & Mitchell, 2001). For this reason, plants and their products are exploited for their benefits as possible control agents against pests of stored products, in this case *D. maculatus* larvae. Researchers have begun to assess plant essential oils as alternatives to fumigants and contact insecticides (Isman, 2000; Wang, Tasi, Ding, Zhao & Li, 2001).

The objective of the present study was therefore to determine the larvicidal effect of the oils on the late instar larvae of *D. maculatus* and compare their effects on the pest.

Materials and Methods

Culture of *Dermestes maculatus*

Adult *D. maculatus* was obtained from infested fishes at Sabon gari market in Zaria, Kaduna state, Nigeria. The beetles were reared in clean kilner jars containing whole and fragmented fishes. The jars were capped with muslin cloth and kept at ambient temperature (27 ±3ºC) and rela-

tive humidity of 75 ±%. The muslin cloth allowed for ventilation and also prevented entry or exit of beetles and other insects. The beetles were allowed for 5 days to oviposit on the fishes. At the end of five days, the beetles were removed by hand picking and added to another sterilized jar of fish to raise new generations of *D. maculatus* larvae. The culture was then maintained by continually replacing the devoured and infested fishes with fresh disinfested ones.

Collection and Processing of Plant materials

The seeds of *C. colocynthis* and *C. vulgaris* were purchased from seed marchants in Sabon gari market, Zaria. They were air-dried for three (3) days in the shade. The dried seeds were then pulverized into powder using mortar and pestle. The powder was put in cellophane bags and kept until needed.

Oil Extraction

40g of each powder was extracted using n-hexane with the help of a soxhlet apparatus. The extract was then transferred to a water bath to separate the solvent from the oil. The extracted seed oils from *C. colocynthis* and *C. vulgaris* were stored in separate labeled bottles and kept in a cool place until used in bioassay.

Bioassay

The smoke-dried fishes for the experiment were heat sterilized in the oven set at 60 ±2ºC for an hour and then allowed to cool. After cooling to room temperature, each fish was weighed and tagged. 0.003 mLg^{-1}, 0.009 mLg^{-1}, 0.027 mLg^{-1}, 0.081 mLg^{-1} and 0.234 mLg^{-1} crude seed oil of *C. colocynthis* and *C. vulgaris* were applied to the whole fish and placed in kilner jars. The toxicity of the seed oils was recorded after 24, 48, 72 and 96 hours. All the treatments including control were replicated three times and data collected were analyzed statistically at $p<0.05$. One Way Analyses of variance (ANOVA) was used to determine if there is significant difference between the various treatments and where differences exist means were separated by Duncan's multiple range test (DMRT). Probit Analysis was also used to determine the 96 hour LC_{50} of the seed oils.

Results and Discussion

The mortality result of this experiment is presented in Table 1 and 2.

Table 1. Mortality effect of *Citrullus colocynthis* seed oil on *Dermestes maculatus* Larvae in 96 hours Exposure time

Seed oil conc.	Exposure Time in hours				
	24h	48h	72h	96h	**P-Value**
Control	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	**0.79**
0.003mlg^{-1}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	**0.79**
0.009mlg^{-1}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	1.11±0.33^{d}	**0.47**
0.027mlg^{-1}	2.22±0.67^{c}	2.22±0.67^{c}	2.22±0.67^{c}	3.33±0.58^{c}	**0.46**
0.081mlg-1	71.11±4.18^{b}	74.44±4.70^{b}	76.67±5.03^{b}	81.11±3.71^{b}	**0.06**
0.243mlg^{-1}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	**0.97**
P-Value	**0.00**	**0.00**	**0.00**	**0.00**	

Mean ±SEM with same superscript within columns are not significantly different from each other at $p<0.05$

Table 2. Mortality effect of *Citrullus vulgaris* seed oil on *Dermestes maculatus* Larvae in 96 hours Exposure time

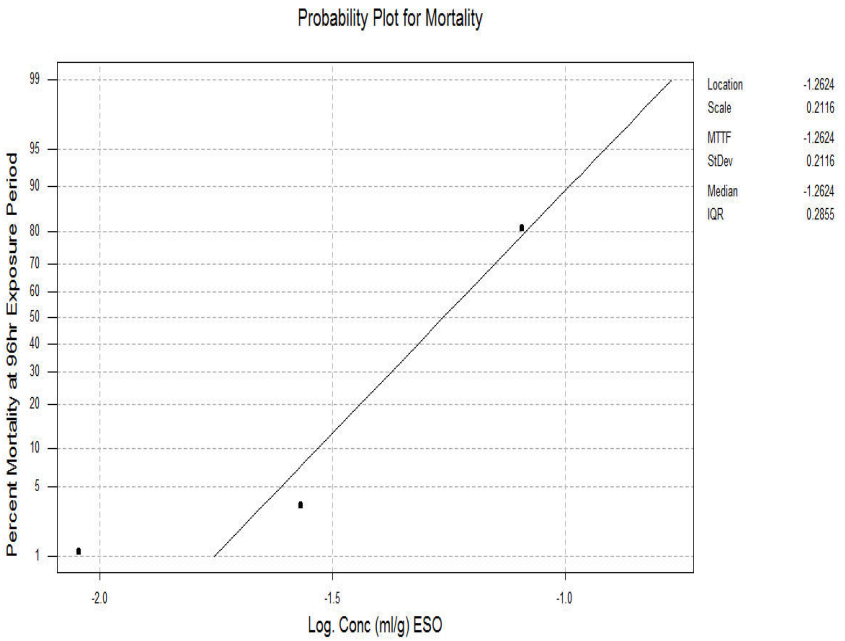
Seed oil conc.	Exposure Time in hours				
	24h	48h	72h	96h	**P-Value**
Control	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	**0.79**
0.003mlg^{-1}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	**0.79**
0.009mlg^{-1}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{d}	**0.79**
0.027mlg^{-1}	1.11±0.33^{c}	2.22±0.33^{c}	2.22±0.33^{c}	2.22±0.33^{c}	**0.01**
0.081mlg-1	78.89±1.45^{b}	86.67±0.58^{b}	87.78±0.88^{b}	91.11±0.88^{b}	**0.19**
0.243mlg^{-1}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	**0.97**
P-Value	**0.00**	**0.00**	**0.00**	**0.00**	

Mean±SEM with same superscript within columns are not significantly different from each other at $p<0.05$

Table 1 and 2 showed that *C. colocynthis* and *C. vulgaris* respectively at 0.243 mLg^{-1} concentration exhibited the highest efficacy against *D. maculatus* followed by 0.081 mLg^{-1}, 0.027 mLg^{-1}, 0.009 mLg^{-1} and 0.003 mLg^{-1}. This implies that the toxic effect of *C. colocynthis* and *C. vulgaris* seed oils against the test larvae were dose dependent and significantly different ($p<0.05$) from each other. There was no significant difference ($p<0.05$) in the toxicity performance of both oils at 0.027 mLg^{-1} in all time frames considered in this study but there was clear significant difference ($p<0.05$) at 0.081 mLg^{-1} in all the time frame implying that C. vulgaris oil is more effective than oil of *C. colocynthis* in killing *D. maculatus* larvae.

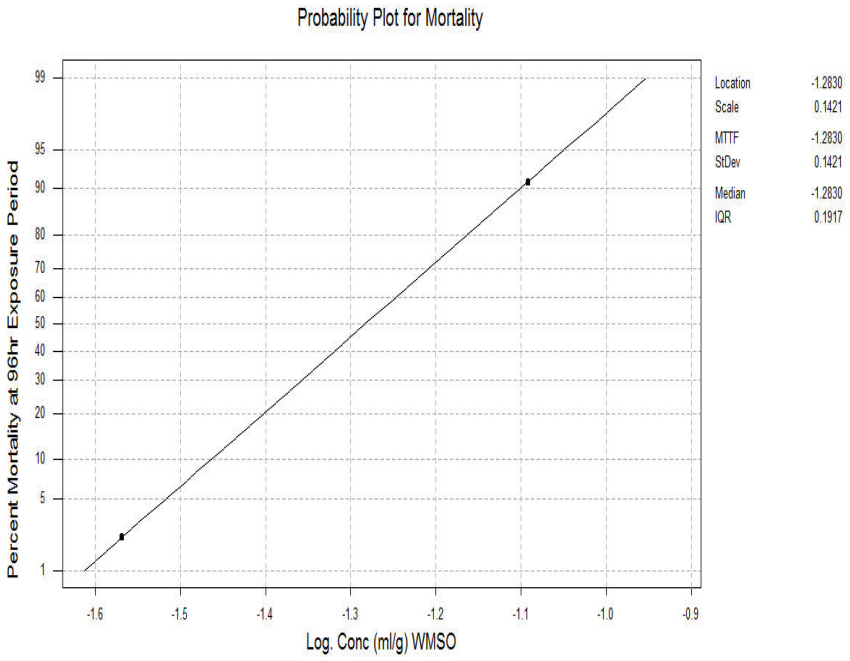
The LC_{50} (Figure 2.) of *C. vulgaris* at 24, 48, 72 and 96h exposure time was lower than that of *C. colocynthis* (Figure 1), implying that *C. vulgaris* seed oil was more effective than oil of *C. colocynthis* on *D. maculatus* larvae. The highest total mortality percentage (100%) was recorded at 0.243mLg^{-1} for both oils. The result also showed that there was positive interaction effect between treatments and exposure time but was also dose dependent. No mortality was observed in the control. The interaction effect of *C. colocynthis* oil at 0.081mLg^{-1} concentration for 72h showed that the 76.67% kill of the test insects was significantly more than that of 24, 48 and 72h at the same concentration but was significantly lower than that recorded for *C. vulgaris* oil which gave 87.78% kill at 72h and the same concentration.

The mortality of *D. maculatus* larvae caused by oils of *C. colocynthis* and *C. vulgaris* may be due to the effect of sterols and fatty acids on the cuticle of the insect or it may be due to the disturbance of hormonal regulations caused by sterols. This report is comparable to that of Kamel (2010) who attributed mortality of larvae and pupae of the Armyworm (*Spodoptera frugiperda*) to the whole components found in moringa oil. Ajayi (1929) also showed that the active compounds responsible for mortality of the insects are embedded in plant extracts. Asawalam, Emosairue, & Wokocha (2007) holds the view that insecticidal activity of any plant extract depends on the active constituents of the plant. These components could have worked synergistically to produce the mortality effect observed in this study.



ESO: Eguisi Seed Oil (*Citrullus colocynthis*)

Figure 1. Probit graph use to determine the LC_{50} of *Citrullus colocynthis* seed oil against *Dermestes maculatus* larvae



WMSO: Watermelon Seed Oil (*Citrullus vulgaris*)

Figure 2. Probit graph use to determine the LC_{50} of *Citrullus vulgaris* seed oil against *Dermestes maculatus* larvae

The result obtained in this study agrees with EL Nadi, EL Hag, Zaitoon & AL Doghairi (2001) who found that *Azadiracta indica* extract show a remarkable toxicity against *Trogoderma granarium* and that this toxic effect was found to be dose and exposure time dependent. Although *C. colocynthis* was comparatively less toxic than *C. vulgaris* seed oil against *D. maculatus* larvae, it was significantly more larvicidal to *D. maculatus* at all levels of concentrations compared to the control. This agrees with the report of Nadeem, Iqbal, Khattak & Shahzad (2012) who holds a similar view. Since most insects breathe through the use of spiracles, the high larval mortality recorded in this experiment could be as a result of blockage of spiracles or air chamber of the beetles causing death by suffocation. This agrees with Don-pedro (1989) who holds a similar view.

Conclusion

On the basis of results, it can be concluded that *C. colocynthis* and *C. vulgaris* are good control agents of *D. maculatus* larvae and are most effective at 0.243 mLg^{-1}. The larvicidal effects of both oils are dose and time dependent. Seed oil extract of *C. vulgaris* was a superior larvicide to *C. colocynthis* seed oil. It is therefore recommended that *C. colocynthis* and *C. vulgaris* at 0.081 mLg^{-1} and 0.243 mLg^{-1} could be utilized in the management of *D. maculatus* larvae in smoke-dried fish stores.

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SHORT COMMUNICATION KISA MAKALE

ACUTE EFFECTS OF GLYPHOSATE ON THE BEHAVIOURAL AND HEMATOLOGAL CHARACTERISTICS OF HETEROCLARIAS (HYBRID) FINGERLINGS

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Abstract:

The toxicity effect of glyphosate on fingerlings of Heteroclarias after series of range finding tests, the fishes were exposed to lethal concentration of 0.00 mg/L, 5.40 mg/L, 7.20 mg/L, 9.00 mg/L, 10.80 mg/L and 12.60 mg/L for 96 hours in a renewal bioassay procedure showed that the 96 hours LC_{50} was 6.838 mg/L. Respiratory disturbance, erratic swimming, loss of equilibrium, lethargies and sudden fish death were observed in the exposed fish and these varied greatly with differences in concentration of the toxicant and this shows that mortality increases with an increase in concentration. Also, as the concentration of glyphosate increased the beats of the tail and operculum increased in 12 and 24 hours. Also the toxicant led to significant changes ($P<0.05$) in hematological parameters as the toxicant concentration increased. Mean Red Blood Cells (RBC), Hemoglobin content (Hb), Packed Cell Volume (PCV), reduced as the concentration of toxicant increased while other parameters increased proportional with the toxicant concentration. Others, such as Basophils, Eosinophils and Monocytes were tested but not detected.

Keywords: Glyphosate, Heteroclarias, Round-up, Toxicology

Introduction

The major formulation is Round-up, in which glyphosate is formulated as isopropyl amine salt and a surfactant, polyethoxylene amine (POEA), is added to improve the quality of the herbicide (Tsui and Chu, 2004; Releya, 2005). The indiscriminate use of herbicides, careless handling, accidental spillage, or discharge of untreated effluents into natural water-ways have harmful effects on the fish population and other forms of aquatic life and may contribute long term effects in the environment (Ayoola, 2008). Most aquatic herbicides have undergone some toxicity testing to evaluate effects on non-target organisms (Urban and Cook, 1986). Okomoda *et al*. (2013) conducted research on hematological response of *Clarias gariepinus* fingerlings exposed to acute concentrations of sunsate®. This is because tests are rarely conducted on the early life stages of fish commonly found in water bodies in Nigeria being treated for 'weed control'.

Materials and Methods

The experiment was conducted at the Fisheries Laboratory Department of Biological Sciences Ahmadu Bello University Zaria, Kaduna, Nigeria. Fingerlings of Heteroclarias of mixed sexes and fairly uniform size (2.2 ±0.7g weight and 6.7±0.7cm standard length) were obtained from National Open University Nigeria (NOUN) Fisheries Unit Kaduna-Zaria express road, Kaduna and transported in plastic container to the laboratory in the Department of Biological Sciences, Ahmadu Bello University Zaria. They were acclimatized for two weeks in four oval/rectangular shaped bath tubs, separately containing water of about 150L. The fish were being fed twice daily at 5% body weight with 35% crude protein diet. Pilot studies were carried out to determine the definitive concentration range for testing Round-up following the methods of Solbe (1995). This was done by introducing three nominal concentrations into three separate test tanks (using pipette) containing 20 liters of dechlorinated water in triplicate. Five fish per concentration of toxicant was used with 3 replicates each for 96 hours. When the fish died in all the test tanks, lower range of concentrations of the toxicants were prepared until when 80 to 90% of fish died in the highest concentration test tank and 20 to 30% of fish died in the lowest concentration test tank. The five nominal concentrations were then range between the highest and the lowest concentrations geometrically (5.40, 7.20, 9.00, 10.80 and 12.60mg/L). The methods of acute toxicity tests as described by Sprague (1973) and APHA (1995) was employed. The range of concentrations of glyphosate (5.40, 7.20, 9.00, 10.80 and 12.60mg/L) obtained in the pilot tests were dispensed with a pipette into 20 liters of each test tank in duplicate. Ten fingerlings fish were exposed to five different concentrations of the toxicant in each test glass tank in duplicate and the control.

Fingerlings of fairly equal weight (2.2 ±0.7g), total length (6.7 ±0.7cm) and standard length (5.9 ±0.6cm) was selected randomly, weighed and distributed into 10 glass aquaria containing definitive concentration of the glyphosate and 2 controls with only distilled water without glyphosate. The bioassay test was carried out in 12 glass tanks each of size 30.5 x 30.5 x 92.5cm into which approximate quantity of glyphosate were taken and to give a final volume of 20.0L. The fish were starved for 24 hours before commencement of the experiment. The solutions were stirred for homogenous mixing before each aquarium were randomly stocked in duplicates with 10 fingerlings of fish while the test solution and control were renewed daily. The investigation of opercula ventilation counts and tail fin movement rate was carried out for 96 hours which were counted using stop watch at 12, 24, 48, 72 and 96 hours per minutes. Three fish were used for the counting per tank and the average.

Data was subjected to one-way analysis of variance (ANOVA) using SPSS software to test for the significant differences between means and where significant differences are found, the Duncan's Multiple Range Test (DMRT) was used to separate the significantly different means. Mini Tab 17 statistical software was used to determine LC_{50}.

The blood was sampled as described by Blaxhall and Diasely (1973) for the assessment of the various blood parameters and was collected by severance of caudal peduncle from the caudal artery at 2cm away from the caudal peduncle. This process was done on the surviving fish tanks. Hemoglobin concentration was estimated as cyanmethemoglobin (Brown, 1980), Packed Cell Volume (PCV) was determined using microhaematocrit. The Red Blood Cell (RBC) were counted using haemocytometer (Improved Neubauer Weber Scientific Ltd), according to Wintrobe (1978).

Also the total white Blood Cell Counts (WBC) was estimated with an improved Neubauer. The RBC indices that include Mean Corpuscular Hemoglobin Concentration (MCHC), Mean Corpuscular Hemoglobin (MCH) and Mean Corpuscular Volume (MCV) were calculated by using the formula mentioned by Dacie and Lewis (1968).

Results and Discussion

Heteroclarias exposed to glyphosate showed increased tail fin beat and opercular ventilation with increase in the concentration of the toxicant (glyphosate) for 5.40, 7.20, 9.00, 10.80, and 12.60 mg/L as present (Figure 1 and 2 respectively). The activity of the opercula was observed and counted, especially during the first 48 hrs. The result of opercula ventilation as presented in figure 1 showed that the opercula beats of the exposed fish to the toxicant at 12 and 24 hours were higher than the one in the control fish. Increase in toxicant concentration resulted in an increase in opercula beats rate at 12 and 24 hours, and at 48 hour beats rate decreased. Further duration of exposure led to more decrease in the opercula ventilation beat of the fish. By the 96 hours the opercula ventilation rates of the exposed fish were significantly lower than those of the control group.

The activity of tail fin beat was observed and counted, in particular during the first 48 hours of exposure, the result of tail fin beat as presented in figure 2 showed that the tail fin beat of the exposed fish to the toxicant at 12 and 24 hours were higher than the one in the control fish. The tail fin beat increased initially and started decreasing at the 48 hours. As the duration of exposure progresses, there was a continuous decrease in tail fin beat of the fish. There was significant difference between the tail fin beat of the treated fish as seen in the figure (P<0.05). The values were dose dependent.

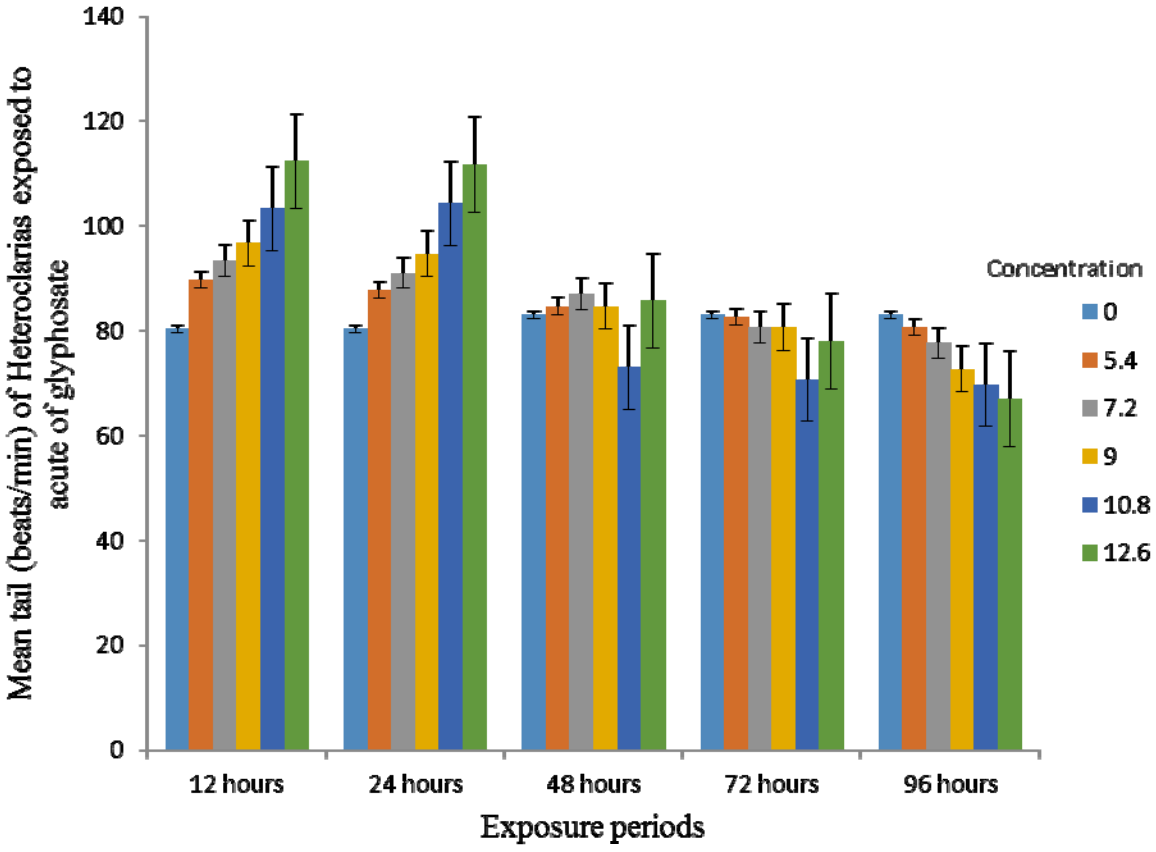

Figure 1. Mean (±SE) mean tail beat rate of Heteroclarias exposed to acute concentration of glyphosate

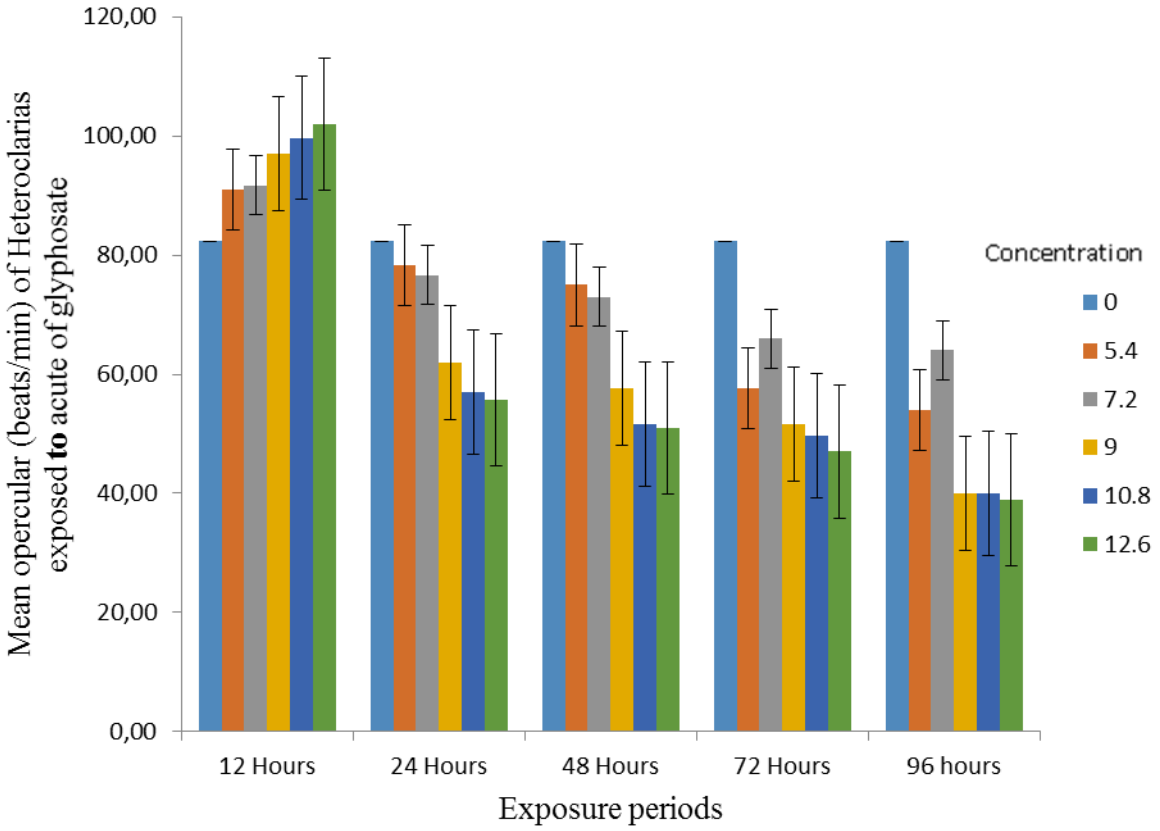

Figure 2. Mean (±SE) opercula beat rate of Heteroclarias exposed to acute concentration of glyphosate

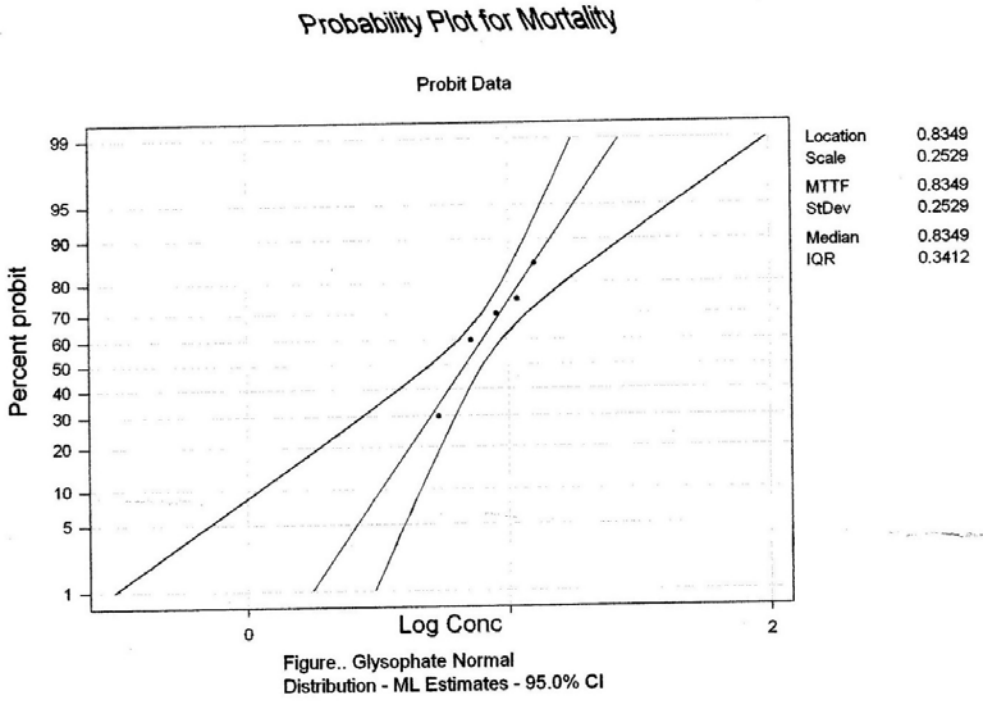

Figure 3. Probit Plot of LC_{50} at 96 hours' glyphosate herbicide exposure on fingerlings of Heteroclarias

The result of this study revealed that Heteroclarias exposed to various concentrations of glyphosate recorded decrease packed cell volume (mm^3), total red blood cell (RBC) and hemoglobin (Hb) but an increase in total white blood cells (WBC) as presented (Table 1). Neutrophil decreased with increase in glyphosate concentration while lymphocyte of test fish increased with increase in glyphosate concentration as presented (Table 2). The acute toxicity test showed hematological changes which is an indication of severity in the treated fish. The anemia effect could be due to an inhibition in erythrocyte production and haemodilution. Erythropenia (deficiency in the number of red blood cells) was reflected by the reduced hemoglobin content and hematocrit value as well as erythrocyte sedimentation rate (ESR) (Eisler, 1967). The findings were similar with anemia associated with erythropenia that was reported by Srivatava and Mishra (1979) in *Colisa fasciatus* after acute exposure to lead. Similar results have been reported for several freshwater fishes (Khalaf Allah, 1999; Balathakur and Bais, 2000; Rehulka, 2000; Gbem *et al*., 2003; Aderolu *et al*., 2010). The increase in white blood cell in acute bioassay studies could be associated with an increase in antibody production which help in survival and recovery in the fish exposed to sub-lethal concentration of glyphosate. Similar trend was also reported by Joshi *et al*. (2002) and Ekrem *et al*. (2013). The fluctuation in the mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) in the present study, clearly indicates that the concentration of hemoglobin in the red blood cells were much lower in the exposed fish than in the control fish, depicting anemic condition. Bhagwant and Bhikajee (2000) observed similar fluctuations. Figure 3 show mini tab LC_{50} probit plot at 96 hours, indicates the median value which gave an anti-log value of 6.838 mg/L which is the LC_{50} value at 96 hours.

Conclusion

In conclusion, acute concentrations of glyphosate are harmful and posed toxic metabolic stress to Heteroclarias and it is concentration and time dependent.

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Table 1. Effect of differential concentration of glyphosate on hematological parameters of Heteroclarias after 96 hours of exposure.

Conc. (mg/L)	RBCC ($x10^6mm^3$)	WBCC (x500mm3)	Hb (g/100mL)	PCV (%)	MCV ($x10^6$Pgcel)	MCH ($x10^6$Pgcel)	MHCH (g/100mL)
0	227.67±1.45^a	7552.00±73.90^e	10.50±0.12^a	31.67±0.33^a	1.39±0.01^c	0.46±0.03^c	32.49±0.66^b
5.4	222.67±1.45^b	6272.00±73.90^f	9.87±0.09^b	29.67±0.33^b	1.33±0.01^c	0.44±0.00^c	33.26±0.13^{ab}
7.2	187.67±1.45^c	8064.00±73.90^d	9.17±0.09^c	27.67±0.33^c	1.47±0.01^b	0.49±0.00^b	33.13±0.14^{ab}
9	137.67±1.45^d	9856.00±73.90^c	7.50±0.12^d	22.67±0.33^d	1.65±0.01^a	0.54±0.00^a	33.09±0.26^{ab}
10.8	122.67±1.45^e	10363.67±74.03^b	5.67±0.20^e	17.00±0.58^e	1.38±0.03^c	0.46±0.01^c	33.33±0.12^{ab}
12.6	112.67±1.45^f	10880.00±73.90^a	4.37±0.20^f	13.00±0.58^f	1.15±0.04^d	0.39±0.01^d	33.58±0.15^a

Means with the same superscript along the columns are not significantly different (P>0.05)

Table 2. Mean (±SE) of Heteroclarias exposed to acute concentration of glyphosate after 96 hours on some leucocytes differential count.

Conc.(mg/L)	Neutrophils (%)	Lymphocytes (%)	Basophils (%)	Eosinophils (%)	Monocytes (%)
0.00	19.00±0.58^b	45.00±0.58^f	Nd	Nd	Nd
5.40	15.00±0.58^d	51.00±0.58^e	Nd	Nd	Nd
7.20	22.00±0.58^a	61.67±0.88^d	Nd	Nd	Nd
9.00	20.00±0.58^b	66.00±0.58^c	Nd	Nd	Nd
10.80	17.00±0.58^c	70.00±0.58^b	Nd	Nd	Nd
12.60	13.67±0.58^d	75.00±0.58^a	Nd	Nd	Nd

Means with the same superscript along the columns are not significantly different (P>0.05).
Nd = Not detected

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BIOMETRIC RELATIONSHIP, FOOD AND FEEDING HABIT OF *Heterotis niloticus* (Cuvier, 1829) AND *Labeo coubie* (Ruppell, 1832) FROM LOWER RIVER BENUE

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Abstract:

This study investigated the length-weight relationship as well as feeding habit of two important commercial fish species from lower River Benue namely *Heterotis niloticus* and *Labeo coubie*. Fish samples were collected between November 2014 and January 2015 every fortnight for the recording of relevant data (length, weight and stomach content). The result obtained reveals significantly higher biometric parameters in *H. niloticus* compared to *L. coubie*. Many biometric parameters measured correlated significantly with the gut characteristics. The length-weight relationship revealed negative allometric growth for both species. However, sampled fishes were in good condition at the time of the study. Food item isolated in both species revealed an omnivorous feeding habit, hence these fish species may be considered as potential candidates for aquaculture.

Keywords: African bonytongue, African carp, River Benue, Length-weight relationship, Feeding habit

Introduction

The African bonytongue *Heterotis niloticus* is a large fish that is native and widely spread in many parts of Africa (Moreau, 1982, Micha, 1973). Its hardiness and high growth rate make it a possible candidate for aquaculture in Africa (Welcomme, 1988). It is currently estimated that 60% of the breeding and nursery habitat for this species has been lost due to environmental degradation caused by oil spillages, pollution, and destruction of mangrove swamps, (Bake and Sadiku 2005). Although it is currently listed by IUCN Red List Status, as least concern (LC) (IUCN 2012), it is important to make a conscious effort to conserve this fish species to prevent further depletion of stock. African carp *Labeo* is also another major fish genus found in many rivers of African countries such as Nigeria, Senegal, Gambia, Ivory Coast, Liberia, Zaire, and Gabon (Ayotunde *et al*; 2007). Four species of this genus (Labeo) are largely found in rivers, and they include *Labeo senegalensis, Labeo pseudocoubie, Labeo rhohita, and Labeo coubie* (Idodoumeh, 2005, Ayotunde *et al*., 2007). They are highly valued fish food in African countries and usually known for being rich in protein along with their sweet tastes (Rahman, 1989, Ayotunde *et al.,* 2007). They can grow up to very large sizes and are likely future aquaculture candidate if its biology is well understood.

Research on the exploitation of *H. niloticus* for aquaculture is ongoing in many African countries, notably among these are the works of Yao et al. (2003), Nguenga and Brummett (2003), Olanyan and Zwilling, (1963) and Akegbejo-Samsons et al., (2003). Despite these efforts, the realization of the full aquaculture potentials of this fish is still far in sight. The major setback preventing successful mass propagation of this fish in captivity include problems of artificial reproduction and larval rearing (weaning) (Froese and Pauly, 2012). To our knowledge, no reported accounts exist on the exploitation of *L. coubie* for aquaculture. It is important to note that realizing the full potential of fish for aquaculture purposes would require a good understanding of the biology of the fish. Studies on fish biology are an indispensible aspect of sustainable management and conservation of fish biodiversity (Solomon et al., 2012). Okafor et al. (2012) also stated that insufficient knowledge of the biology of commercially exploited fishes is the main reason for continuous failure experienced in the attempts to culture them in captivity. The continuous decline in fish catches due to lack of monitoring and poor regulation (Adeyemo, 2004, Solomon et al., 2012) makes it imperative to focus research on the biology of fishes in an attempt to provide information that will make domestication a success. This study was designed with the aim of investigating the length-weight relationship, condition factor, as well as food and feeding habit of two importantly exploited fish of River Benue (*H. niloticus and L. coubie*). This is to provide information necessary to understand the welfare and husbandry requirements in the wild so as to adopt same in captivity for a successful domestication program.

Materials and Methods

The study was conducted in Makurdi the Benue State capital (in Nigeria) located at Longitude 7°43°N and Latitude 8°32°E (Fig1). The town is divided into the North and the South Bank by the River Benue from which fish samples were collected. The river contains several species of fish which are of economic importance to the people of the State. This study, however, focused on two species namely *H niloticus* and *L coubie*. The fish samples for this study were obtained from fishermen at three major landing sites of lower River Benue in Makurdi. The fishing gears used by fishers in catching the fish includes; traps, seine nets, cast net, gill nets, clap nets, hook, and line while crafts were canoe and calabash. *H niloticus* and *L coubie* were randomly sampled at each site every fortnight over a period of three months (November 2014 – January 2015). Sampling time was between 6:00 am to 8:00 am, a time when fishermen would be returning to landing site after fishing through the night. Collected samples were fixed in an ice chest and moved to the Department of Fisheries and Aquaculture University of Agriculture Makurdi where data collection of biometric parameters and observation of the stomach content were carried out.

A total of 150 fish specimens each of *H. niloticus* and *L coubie* was obtained from fishermen. Total and standard lengths of each fish species were measured in centimeters (cm) using a meter rule while the weight was taken in grams (g) using an electronic weighing balance.

Figure 1. Map of Makurdi showing location of the study areas of sample collection (Source google maps 2016)

The length-weight relationship was calculated using the equation by Van Snik et al., (1997) as stated below;

Log W= log a + b log L

The condition factor (K) was calculated according to the equation by Pauly (1983) below:

$$(K) = \frac{100W}{L^3}$$

The ventral part of the fish was dissected, and the stomach immediately preserved in sterile bottles containing 5% formalin. Individual stomach fullness was determined, and the content emptied into separate Petri-dishes. While some stomach contents were identified macroscopically, others were identified microscopically using a light microscope. The component food items were identified using identification guide (Barnes 1980, Kaestner 1970) provided in the laboratory of the Department of Fisheries and Aquaculture University of Agriculture Makurdi. The food items encountered were analyzed using frequency of occurrence method (Hynes, 1950) as stated in the formulae below.

Frequency of occurrence =

$$\frac{\text{Total number of stomachs with the particular food item}}{\text{Total number of stomachs with food}} \times 100$$

The gut length and its equivalent weight were also recorded as appropriate.

Statistical Analysis

Data analysis was carried out using Minitab 14 software. Biological parameters were subjected to student t-test to determine if significant differences exist between the two species. Analysis of variance was used to determine monthly differences in parameters measured. When significant differences were observed, means were separated by Fisher's least significant difference. Correlation between various biometric and gut parameters was also done to determine the relationship between these parameters.

Results and Discussion

Table 1 shows some biometric parameters of *H. nilotocus* and *L. coubie* from lower River Benue. The result obtained reveal *H. nilotocus* to be significantly higher in standard length (31.57), total length (34.46), body weight (399.5) and condition factor (0.96) compared to *L. coubie* (23.98; 29.03; 216.7 and 0.84 respectively). However, gut length and weight were higher in *L. coubie* (251.3 and 10.34 respectively) compared to *H. nilotocus* (37.92 and 12.79 respectively). Statistically, stomach fullness was same among both species.

Monthly variations in morphometric parameters of *H. nilotocus* and *L. coubie* are shown in Table 2. The result obtained shows that samples of *H. nilotocus* collected in November were higher in body weight (455.4), condition factor (1.05), gut length (39.19), gut weight (14.05) and stomach

fullness (0.49) compared to other months. However, no significant difference was observed for standard length and total length across the months of the experiment. In *L. coubie,* however, samples collected in November were significantly higher in standard length (24.76), total length (29.38), gut length (314.9) and stomach fullness (0.49) compared to other months. The highest body weight and gut weight for this species during the study were observed in December (223.4 and 13.15 respectively).

Correlation of morphometric parameters of *H. niloticus* and *L. coubie* as shows in table 3 reveals high positive and negative correlation between several parameters.

Length-weight relationship of *H. niloticus* and *L. coubie* are shown in Figures 1 and 2. The result indicates that both species have negative allometric growth pattern. However, R^2 value of *H. niloticus* was higher (0.71) compared to *L. coubie* (0.52).

Food and feeding habit of *H. niloticus* and *L. coubie* using the frequency of occurrence method is represented in Fig 3. The result shows the presence of mud (26.25%), digested food (13.75%), detritus (15%), insect larvae (18.75%), algae (26.25%), plant part (15%) and some unidentified food items (6.25) as the dietary composition of *L. coubie.* However, the gut of *H. niloticus* consisted of detritus (6.25%), insect larvae (20.00%), algae (18.75%) plant part (22.5%) sand (35.0%), copepods (17.5%) and unidentified items (1.25).

Table 1. Morphometric parameters *H. nilotocus* and *L. coubie* from lower River Benue

Parameters	***H niloticus***	***L. coubie***	**P-Value**
Standard length	31.57 ±0.59^a	23.98 ±0.61^b	0.001
Total length	34.46 ±0.61^a	29.03 ±0.68^b	0.011
Body weight	399.5 ±22.9^a	216.7 ±18.6^b	0.012
K	0.96 ±0.04^a	0.84 ±0.05^b	0.035
Gut length	37.92 ±0.75^b	251.3 ±13.10^a	0.035
Gut weight	12.79 ±0.41^b	10.34 ±0.88^a	0.035
Stomach fullness	0.43 ±0.04	0.44 ±0.04	0.135

Mean in the same column with different superscripts differ significantly (P<0.05)

Table 2. Monthly morphometric parameters *H. nilotocus* and *L. coubie* from lower River Benue

		H. niloticus		
Parameters	**November**	**December**	**January**	**P-Value**
Standard length	31.52 ±1.12	31.47 ±0.35	31.72 ±1.39	0.098
Total length	34.77 ±1.01	34.16 ±0.43	34.45 ±1.48	0.121
Body weight	455.4 ±46.3^a	345.1 ±12.6^c	398.1 ±47.3^b	0.012
K	1.05 ±0.08^a	0.86 ±0.02^c	0.96 ±0.09^b	0.05
Gut length	39.19 ±0.99^a	37.43 ±0.79^b	37.13 ±1.86^b	0.05
Gut weight	14.05 ±0.82^a	12.57 ±0.34^b	11.78 ±0.80^c	0.035
Stomach fullness	0.49 ±0.07^a	0.40 ±0.06^b	0.39 ±0.06^b	0.002
		L. coubie		
Standard length	24.76 ±1.24^a	23.94 ±1.17^b	23.24 ±0.72^b	0.01
Total length	29.38 ±1.34^a	29.29 ±1.32^b	28.42 ±0.89^c	0.03
Body weight	217.2 ±38.3^b	223.4 ±33.3^a	209.6 ±25.5^c	0.02
K	0.81 ±0.09^c	0.83 ±0.07^b	0.88 ±0.09^a	0.05
Gut length	314.9 ±14.70^a	269.00 ±23.3^b	170.2 ±16.1^c	0.05
Gut weight	9.60 ±1.27^b	13.15 ±2.04^a	8.26 ±0.85^c	0.05
Stomach fullness	0.49 ±0.07^a	0.50 ±0.08^a	0.32 ±0.06^b	0.02

Mean in the same column with different superscripts differ significantly (P<0.05)

Table 3. Correlation matrix of the morphometric parameters of *H. niloticus* and *L. coubie*

Correlations	*H niloticus*	*L. coubie*	Correlations	*H niloticus*	*L. coubie*
TL/SL	0.93**	0.88**	**K/BW**	0.45**	0.12
BW/SL	0.76**	0.83**	**GL/ BW**	0.34**	0.53**
K/SL	-0.06	-0.17	**GW/ BW**	0.57**	0.79**
GL/SL	0.54**	0.67**	**SF/ BW**	0.34**	0.51**
GW/SL	0.66**	0.73**	**GL/ K**	-0.18	-0.29**
SF/SL	0.49**	0.41**	**GW/ K**	-0.05	-0.14
BW/TL	0.72**	0.85**	**SF/ K**	-0.09	0.12
K/TL	-0.17	-0.37**	**GW/ GL**	0.39**	0.69**
GL/TL	0.54**	0.68**	**SF/ GL**	0.37**	0.29**
GW/TL	0.67**	0.81**	**SF/ GW**	0.58**	0.35**
SF/TL	0.49**	0.43**			

(**=P<0.01)

Where TL= Total length, SL= Standard length, BW= body weight, K= condition factor, GL= gut length, SF= Stomach fullness, GW= gut weight

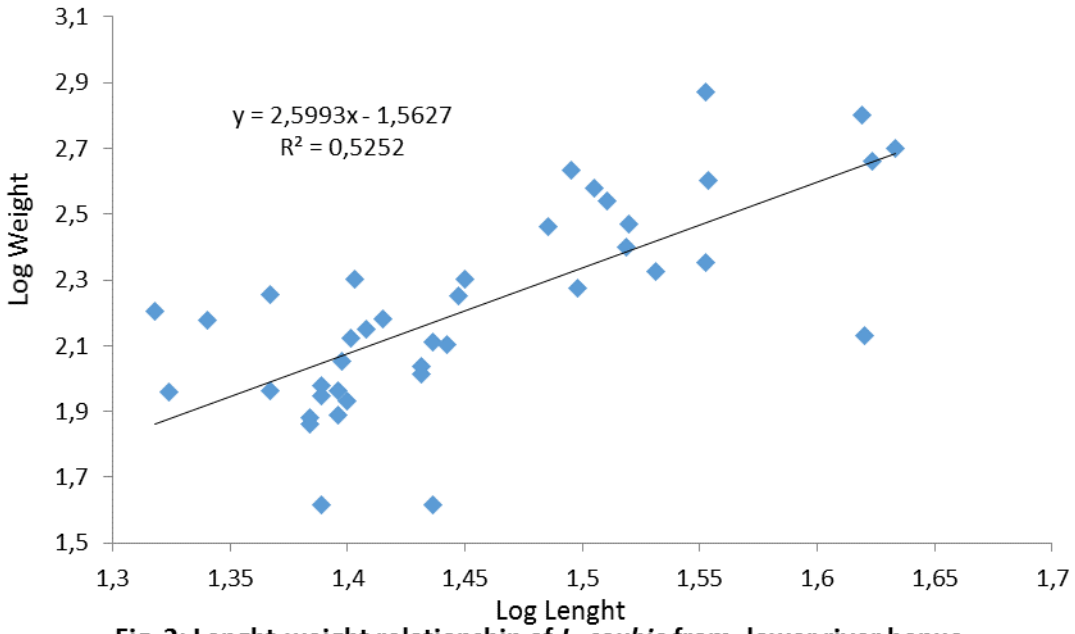

Fig. 2: Lenght-weight relationship of *L. coubie* from lower river benue

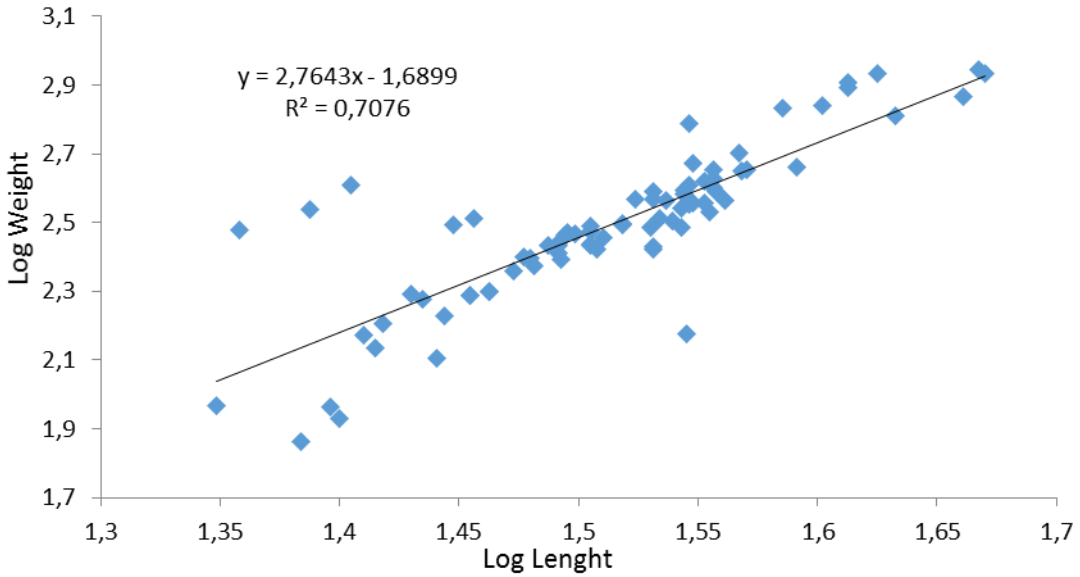

Fig.3: Lenght-weight relationship of *Heterotis niloticus* from lower river benue

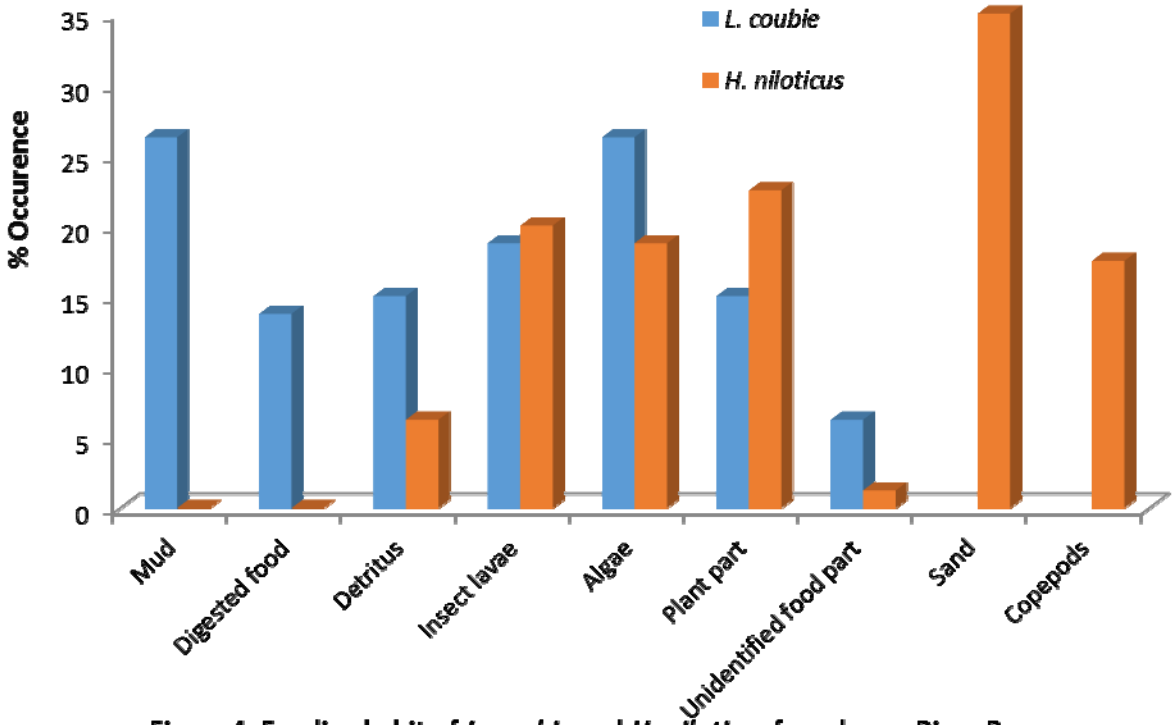

Figure 4: Feeding habit of *L. coubie* and *H. niloticus* from lower River Benue

Dietary habits based on stomach content analysis is widely used in fish ecology as an important means of investigating trophic relationship in the aquatic communities (Ekwu 2006 and Arendt et al. 2001). It is also important in the creation of trophic models as a tool for understanding complex ecosystems (Lopez and Arcila 2002). Numerous studies have shown that natural food tends to vary quantitatively and qualitatively within a year (Ekpo 1993, Ugwuba and Adebisi 1992), hence the need to continually study this concept over a period. From the shape of the mouth and the gills arrangement of *H niloticus,* it could be concluded that filter-feeding habit is aided by the possession of a fine gill raker (Bake and Sadiku 2002). Hence, it is capable of filtering planktons and other food substances in the water. Although this species has earlier been described as more of plankton feeder (Reed et al. 1967 and Bake and Sadiku 2002), this study has shown that it is an omnivore. Larger (1977) had also earlier describe it has more of an omnivore. While Edoghotu et al. (2014) based on their observation which isolated macrophytes, plankton, insects and worms in the gut of the fish also concluded it is omnivorous in feeding habit. Insect larvae and detritus have been previously reported to be significant in the food of *H. niloticus* by Fagbenro *et al*., (2000). However, the observed food types in this study for *H. niloticus* suggest that aside filter feeding, the fish probably grazed on other benthic community species by scraping, nimble or nipping plants off their substrate. Hence, the presence of the muddy substance, detritus, and sand in the food composition isolated in this study. However, the variety of food items present in the diet of *L. coubie* showed that it explores all the major biotopes for food, hence indicating *L. coubie* to be an omnivorous or euryphagous feeder. Euryphagy is an important characteristic of culturable fish species. This means that *L. coubie* have brighter prospects for culture in ponds where production of planktons can be significantly influenced by fertilizer application. This result is similar to the findings of Idodo-Umeh (2003) who reported that the diet of *L coubie* was mainly epipelagic algae and mud. Lagler (1977) had earlier described the stomach of an omnivore as a food grinder which requires a long gut length. The gut length and weight recorded in this study (mean of 251.3cm) suggests a long gut transit time for the food of this fish which is typical of omnivores.

Variation in condition factor (K) reflects information about the physiological state of the fish in relation to changes in its environment (King 1996). *H. niloticus* were observed to be in the best condition in November with the mean condition factor of about 1.00. This is an indication that the environmental conditions of the water body are at optimum level, giving the fish the best condition of growth and development than the other month of the study. However, the mean value of condition factor observed in *H. niloticus* was higher than those observed for *L. coubie*. This may be due to their feeding on a broad range of material compared to the *L. coubie* as observed in their feeding habit. Results of the length–weight relationship indicated that specimens of *H. niloticus* and *L. coubie* exhibited negative allometric growth in the study. Hence, both populations can, therefore, be considered as having homogenous groups with body weights varying indifferently from the cube of total length. The negative allometric exhibited by the species may be as a result of the hydrological, ecological and human factors. Many authors have reported both isometric and allometric growth for different fish species from various water bodies. Allometric growth patterns for *Tilapia* species from Umuoseriche Lake have been reported by King (1991). Also, isometric growth for *Pseudotolithus elongatus* from QuaIboe estuary was reported by King (1996). Isometric growth pattern for *E. fimbriata* had also been reported from Cross River estuary in Nigeria by Pervin and Mortuza (2008). The b value for *L. coubie* (2.599) is the same with the report of Ikpi et al. (2012) on the same specie. This study is also in accordance with the study by Offem (2006) on *L. mrigala* (2.657) in Kaptai Lake, Bangladesh. It is however, different from the isometric value (3.08) recorded for *L. coubie* in the tributaries of the Volta River, Ghana (King 1996). The differences observed in this study, and those of cited authors are based on the difference in the study area, species and spectrum of food available in the environment at the times these studies were conducted.

Conclusions

This study has shown that both *L. coubie* and *H. niloticus* are omnivorous feeders and are in good condition in the lower river Benue during the time of the study. Based on the assertions of this study it is recommended that other aspect of the biology of these important species be the focus of future research. In addition, wild fingerlings of

these species can be collected for nutrition trials based on their observed feeding habit reported in this study.

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THE INTEGRATION OF FISH AND PLANT PRODUCTION: NILE TILAPIA (*Oreochromis niloticus*) AND BASIL (*Ocimum basilicum*) CULTURE IN RECIRCULATING AND AQUAPONIC SYSTEMS

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Abstract:

In the present study, tilapia and basil production was performed in an aquaponic system developed with the integration of fish and plant production in the same culture environment. The variation of elements in the water was monitored and their effects on fish growth performance and feed utilization together with the plant growth were recorded. Triplicate groups of fish tanks were used in two different culture systems (recirculating-RS and aquaponic system-AS). The RS consisted of a water filtration unit whereas the AS was set with the incorporation of basil (*Ocimum basilicum*) production with the roots in water instead of soil, absorbing the discharge water from fish tanks through their roots. Nile tilapia (*Oreochromis niloticus*) with an initial mean weight of 5.65 g were introduced into both RS and AS systems and fed a commercial diet (50% protein) for a period of 75 days. At the same time basil was set into the AS with roots in water, a photoperiod of 12:12 dark:light regime was applied for the monitoring of plant growth. Water physico-chemical parameters were recorded in both culture environments throughout the study period. Based on the findings in both culture systems, at the end of the experiment, it was found that the variations of amonium (NH_4), nitrite (NO_2) and nitrate (NO_3) recorded in the AS were lower then those measured in the RS culture unit.

Keywords: Aquaponic system, Recirculating system, Sustainable aquaculture, Soil-free agriculture

Introduction

The world population is in a rapid growth period with a total of about 7.4 billion people (Worldometer, 2016). Acording to the estimations of FAO, the world population over the next 34 years is expected to reach about 9.6 billion by 2050 (FAO, 2012). The daily birth of around 265000 a day (Worldometer, 2016) links to a challenge in food supply forcing the global food industry for increase their capacity with new investments. However, considering the limited resources in terms of soil and water suitable for food production is another important problematic issue. Eventhough, rich marine and inland water resources in Europe with its increasing aquaculture industry seems to be capable to meet the increasing demand for food with high quality protein from aquaculture (Yigit et al., 2016), freshwater resources are also vital for drink water. Hence it is an important approach to use water in a rational way with new technology or production systems that minimize the use of water for food production. Aquaponics is a new approach for fish farming with the integration of vegetable production. This new technique can utilize the outflow water from the fish farm in a hydroponic system with the production of vegetables, herbs or flowers. Aquaponics is a culture system with the integration of fish and plant production in a closed recirculating system. Practically, nutrient elements, excreted by the fish or supplied by the microbial breakdown of organic waste materials are directly absorbed by plants produced in the same system without the use of soil. In the fish farming environment, almost all reqired nutrients for plant growth can be provided by the postprandial waste material excreted by the fish into the water environment. Since the aquaculture effluent flows through the hydroponic structure of the recirculating system, waste metabolites from fish are removed by nitrification and then absorbed by the plants, acting as natural biological filtration in the system that afterwards flows back for reuse in the fish culture ponds. In a traditional fish farm, the nutrients provided by fish feeding are normally discharged into the water environment that contributes to water pollution in a long term acumulaiton effect. Recirculating aquaculture systems (RAS) are minimizing this effluent effect with the reuse of water flowing through a biofiltration unit. However, with the integration of plant production, a separate biofilter is not necessary and the removal of nutrients by plants may prolong the use of water with a minimized discharge to the environment. The other advantage of aquaponics to the hydroponic system is that it requires less monitoring for water quality in both fish and hydroponic plant production units. In general, a cost effective production is generated due to the elimination of nutrient cost for plants production, and the elimination of separate biofilter units, less water requirements, and the share of operation costs in the entire system. Basil is a fast growing herb with a high economic value, is widely being produced commercially and suitable for aquaponic systems (Rackocy and Hargreaves, 1993). Besides, basil is accepted as a medicinal herb with various health benefits, such as reduction of inflammation and swelling, anti-aging properties, effective antioxidant activities (Nordqvist, 2016). The present study describes the integration of fish and plant production, where Nile tilapia (*Oreochromis niloticus*) and basil (*Ocimum basilicum*) production was performed in recirculating and aquaponic systems. This research focused on the suitability of the new integrated production system for fish farmers, with the aim comparing fish growth performance and plant productivity in aquaponic and in traditional recirculating aquaculture systems.

Materials and Methods

The present study was conducted in the laboratories of Tokyo University of Marine Science and Technology, Faculty of Marine Science, Department of Marine Biosciences in Tokyo – Japan. Two different culture systems were designed and deployed for the experimentations. One was prepared as a traditional recirculation aquaculture system (RS) with water filtration, and the other was designed as an aquaponics system (AS) using plant roots as a biofiltration of the water effluent from fish culture tanks. Triplicate groups of fish tanks were stocked with Nile tilapia (*Oreochromis niloticus*) (initial mean weight: 5.65 g) in both culture environments (RS and AS). For the plant production in the AS, basil (*Ocimum basilicum*) absorbing the discharge from fish tanks through their roots was used. Commercial diet with a protein content of 50% was fed to the experimental fish for a period of 75 days.

System Design and Operation

The experimental setup used in the present study has been given in Figure 1, which consisted of (a)

recirculating aquaculture system (RS) set with fish tanks and filtration equipments, and (b) aquaponic system (AS) set with fish tanks and the plant production units serving as bio-filtration. A factorial design of 2 x 3, with 2 groups and triplicate tanks of 30 L volume (44 x 28 x 26 cm) (6 tanks in total) were used in the experiment. Group 1 (RS) consisted of triplicate groups of fish tanks made of glass aquariums with plastic bottom layers and was designed to have a filtration unit (Figure 1), whereas Group 2 (AS) consisted of triplicate groups of plastic containers of 26 L volume (59 x 37 x 12 cm) and used a plant production unit serving as the filtration system (Figure 2). Different then the RS, the outflow water from the fish culture tank in the AS system was linked to the plant culture tanks settled above the fish tanks for the bio-filtration of the waste water, which then was directed back to the fish tanks for re-use. A water pump (EHEIM; 100 V, 50/60 Hz, 5/6 Watt) was used for water circulation and the photoperiod was arranged using fleurosant light sources. Aeration was maintained using an aerator SLL-40 (40 L/min, 11,8 kPa, 100 V, 50/60 Hz, 30/35 W) and air stones set in to the experimental tanks. Water temperature was controlled using an aquarium heater (100 V, 50/60 Hz, 100~300 W) and set to 23 °C. Inorder to ensure an effective plant growth, constant and suitable environmental conditions such as room temperature and humidity were controlled with an air conditioner.

Figure 1. Experimental setup and design of the resirculating system

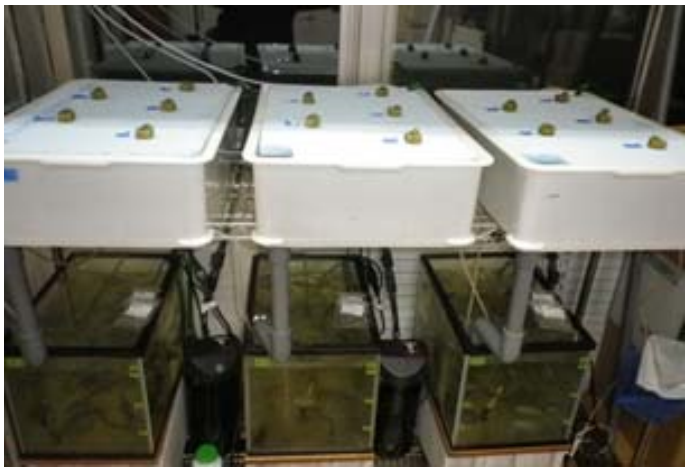

Figure 2. Aquaponic system setup used in the experiement

Basil seeds were placed into stone wool peaces with 3 seed planting in each hole (Figure 3) and left for germination of 10 days' period. After having reached an average weight of 20 g, plants were set into the culture environment, consisting of styrofoam layers (37 x 59 cm) set into plastic containers where the roots of the plants were met with water. The styrofoam layer were drilled with holes each within a distance of 20 cm, ensuring propper plant growth in the system. Five plants were inserted into each tank of the triplicate groups of plastic water containers through the styrofoam layers on the water surface (3 tanks x 5 plants with a total number of 15 basil roots in the AS system) (Figure 4).

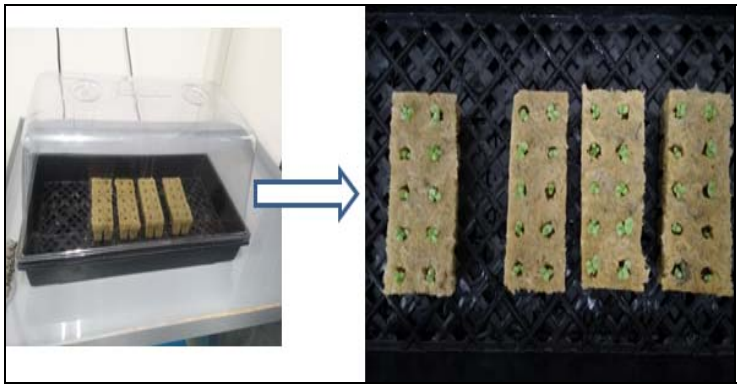

Figure 3. Basil (*O. basilicum*) germination

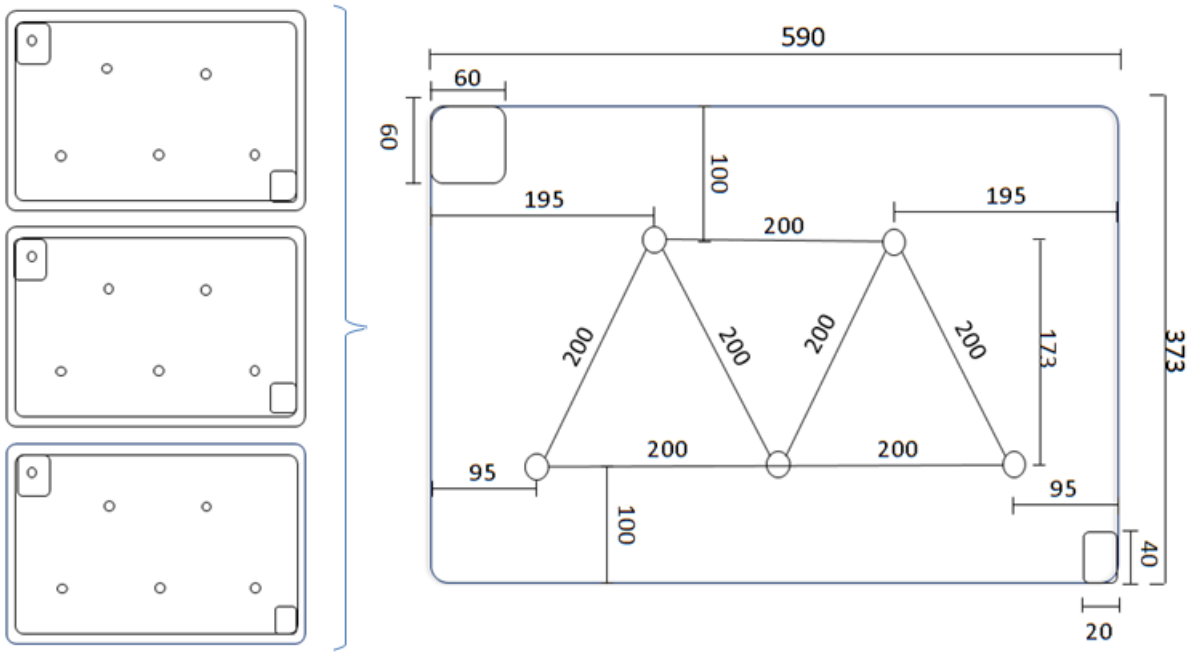

Figure 4. Planting design on styrofoam layers set on plastic water containers

After preparation of the plant production unit, Nile tilapia (*O. niloticus*) with initial mean weights of 5.0-6.0 g were stocked into the glass aquariums located below the plant growing tanks (Figure 2). Prior to fish stocking, all experimental fish were deprived from feed for 3 days. With the beginning of the feding trial, all experimental fish were fed a commercial diet with 50% protein at 80 % of the biomass level. A photoperiod regime of 12:12 dark:light was controlled with an automatic timer and measured using a LI-COR (LI-1400) data logger. The humidity in the experimental area was measured by EXTECH Humidity and Temperature Recorder (RH-520).

Water Quality and Analyses

During the course of the 75-day experimental period, pH, oxygen and water temperature were measured daily using multi-probe water analyser. Furthermore, water samples (initial and final) were taken from both culture systems (RS and AS) for measuring ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4), color and turbidity tests. Ammonia, nitrite, nitrate, and phosphate were measured by the phenol-hypochlorite method of Strickland and Parsons (1977).

Color and turbidity in the fish tanks and the plant production containers were measured using a UV-Spectrophotometer (SHIMADZU UV-1800, JAPAN). For the color tests, water samples from both fish tanks and plant containers were filtered through Whatman GF/A filters prior to the spectrophotometer readings, whereas water samples for the turbidity were directly read in the spectrophotometer without any treatment. Water temperature and humidity were controlled and daily measurements were performed at four intervals (10:00, 13:00, 16:00, 18:00 hour) using a multi-probe water analyzer.

Light intensity was measured using a LI-COR (LI-1400) data logger, and the humidity in the experimental area was measured by EXTECH Humidity and Temperature Recorder (RH-520). Light intensity for the plants was measured at 5 different area of the AS system and at the daylight area.

Fish Growth Performance and Calculations

Growth performance of experimental fish and feed utilization have been calculated using the following equations as described by Yiğit and Yiğit (2003), Yigit et al. (2006, 2010), Bulut et al. (2014a,b), Kesbic et al. (2016a,b):

RGR (relative growth rate, %) = (W2 - W1 / W1) x 100

SGR (specific growth rate, % growth per day) = ((lnW2 - lnW1) / (t2-t1)) x 100

FCR (feed conversion rate) = FC (g) / WG (g)

where; W2: final weight, W1: initial weight, t2-t1: days in total, FC: feed consumtion, WG: weight gain.

Results and Discussion

In the present study, survival was 100 % for all experimental treatments, showing that the culture system had no effect on fish survival. Growth performance of Nile tilapia was satisfactory in both culture systems (RS and AS). There were no significant differences (*p>0.05*) between the experimental groups in terms of wet weight gain (WWG), relative growth rate (RGR), specific growth rate (SGR) or feed conversion rate (FCR) (Table 1). Growth rates and feed utilization data recorded for Nile tilapia in the present study were comparable to those of previous reports (Fasakin et al., 1999; Cremer et al., 2002; Rakocy et al., 2004; Rakocy et al., 2006; Ogunji et al., 2008; Yıldırım et al., 2009; Chowdhury, 2011; Antache et al., 2013; Madalla et al., 2013; Mensah et al., 2013; Ferdous et al., 2014; Githukia et al., 2015; Kaya and Bilgüven, 2015; Day et al., 2016).

Variations of amonium (NH_4; 0.14-2.21 mg/L), nitrite (NO_2; 0.09-0.28 mg/L), nitrate (NO_3; 3-175 mg/L) and phosphate (PO_4; 2.25-40.1 mg/L) recorded in the aquaponic system (AS) were lower then those recorded in the recirculating system (RS; 0.08-0.39 mg/L, 0.05-0.21 mg/L, 11-106 mg/L, 0.41-22.7 mg/L, respectively) throughout the study period. With the incorporation of plant production in the fish culture system, water quality was increased that might have led to an improved growth performance of fish in the AS system compared to the RS, however the differences were not significant (p>0.05) (Figure 5-8).

Overall the concentrations of NH_4, NO_2, NO_3 and PO_4 in the water of both culture environments (RS and AS) were recorded within safe limits (0-2.5 mg/L, 0.05 mg/L, 100-200 mg/L, 1-20 mg/L, respectively) stated by Bregnballe (2015) for aquaculture operations, except for phosphate in the RS culture environment, which increased two-fold of the preferable level (40.1 versus 20.0 mg/L). In the AS culture environment, however phosphate concentration (1.41-22.7 mg/L) remained lower then that of the RS, and did not increase over the acceptable limits reported as 1-20 mg/L by Bregnballe (2015) (Table 2).

Table 1. Growth performance and feed utilization of Nile tilapia in the experimental conditions of recirculating- and aquaponic systems.

	Recircualting System	Aquaponic System
Initial weight (g)	21.99 ± 0.55[a]	22.16 ± 0.52[a]
Final weight (g)	36.47 ± 1.36[a]	36.82 ± 0.94[a]
WWD (g)	14.48 ± 1.25[a]	14.65 ± 0.43[a]
RGR (%)	62.46 ± 2.08[a]	66.10 ± 0.55[a]
SGR (%/day)	1.80 ± 0.13[a]	1.81 ± 0.01[a]
FCR	1.31 ± 0.09[a]	1.30 ± 0.03[a]

WWG (wet weight gain, g) = (Wfinal – Winitial)
RGR (relative growth rate, %) = (Wfinal – Winitial / Winitial) x 100
SGR (specific growth rate, % growth/day) = ((lnWfinal - lnWinitial) / (total time in days)) x 100
FCR (feed conversion rate) = feed consumption (g) / weight gain (g)

Table 2. Acceptable limits for different physico-chemical water quality parameters in a recirculating system and data recorded in the present study.

Parameter	Formula	Unit	Normal condition	Present study	
			RS (Bregnballe, 2015)	RS	AS
pH	-	-	6.5-7.5	5.56-7.09	5.72-7.28
Temperature	-	°C	Species specific	24-25	25
Oxygen	O_2	%	70-100	80	86
Ammonium	NH_4	mg/L	0-2.5 (pH influenced)	0.14-2.21	0.08-0.39
Ammonia	NH_3	mg/L	< 0.01 (pH influenced)	N/A	N/A
Nitrite	NO_2	mg/L	0-0.5	0.09-0.28	0.05-0.21
Nitrate	NO_3	mg/L	100-200	3-175	11-106
Phosphate	PO_4	mg/L	1-20	2.25-40.1	0.41-22.7

RS: Recirculating system, AS: Aquaponic system

The levels of pH in both experimental setups (RS and AS) were between 5.56 and 7.28, with an average rate of 6.3 and 6.5, respectively. The pH levels in the AS tanks were higher then the RS tanks throughout the study period (Figure 9), but pH in both culture systems were within acceptable limits of 6.5-7.5 as described by Bregnballe (2015).

Dissolved oxygen level in both experimental setup was recorded as 7.13 mg/L, initially, which than showed fluctuation throughout the study, and were recorded as 6.53±0.29 mg/L (80 %) and 7.08±0.14 mg/L (86 %) for the RS and AS culture environments, respectively and remained within acceptable limits (70-100 %) reported by Bregnballe (2015) for recirculating culture systems. The fluctuation of oxygen in the culture environments during the course of the study was possibly due to feeding and excretory end-products from fish into the water environment. Similar to the pH values, dissolved oxygene and temepature levels were also higher in the AS tanks then those of the RS environment (Figure 10, 11).

In the present study, water color was more constant in the aquaponic system compared to the recirculating culture environment, where the change in water color increased to more than two-fold over the value measured in the aquaponic system (Figure 12). The change in water color might due to the accumulation of refractory organic compounds (e.g., tannic acid) as described by Rakocy et al. (2004). Water condition in the AS group was more clear compared to the RS group, which could be explained with a low level of suspended solids in the water environment of the AS culture environment.

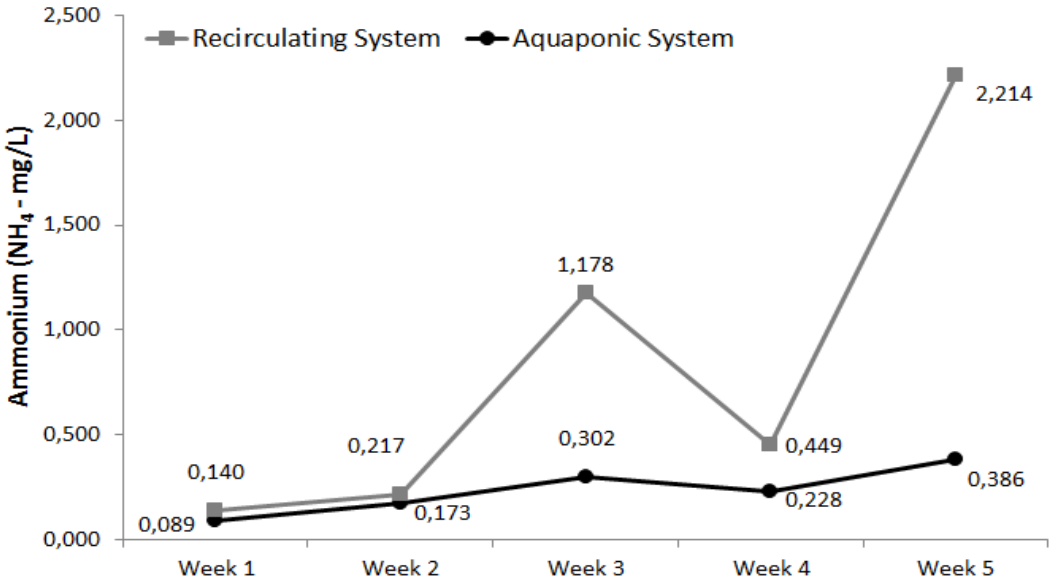

Figure 5. Weekly variations (06 January 2015 – 03 February 2016) of ammonium (NH_4) in the aquaponic system integrated with basil culture

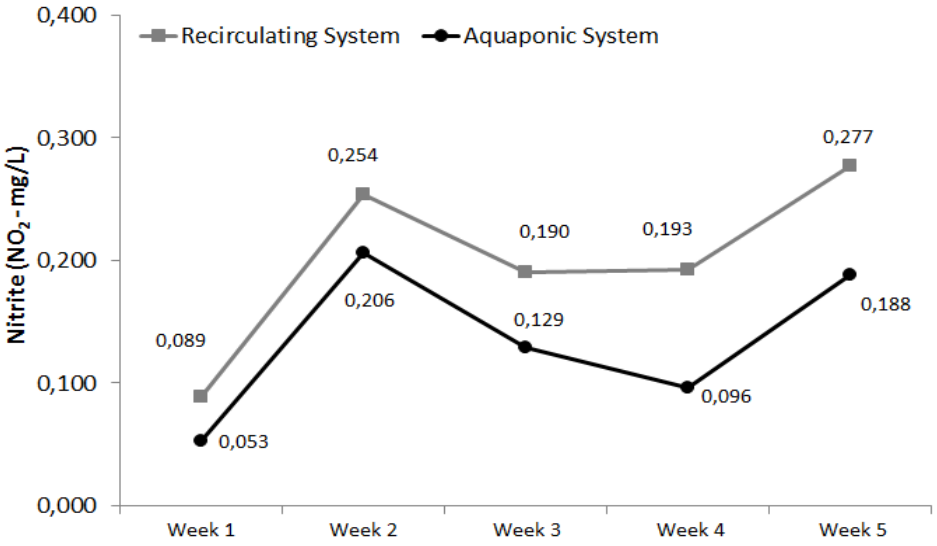

Figure 6. Weekly variations (January 2015 – February 2016) of nitrite (NO_2) in the aquaponic system integrated with basil culture

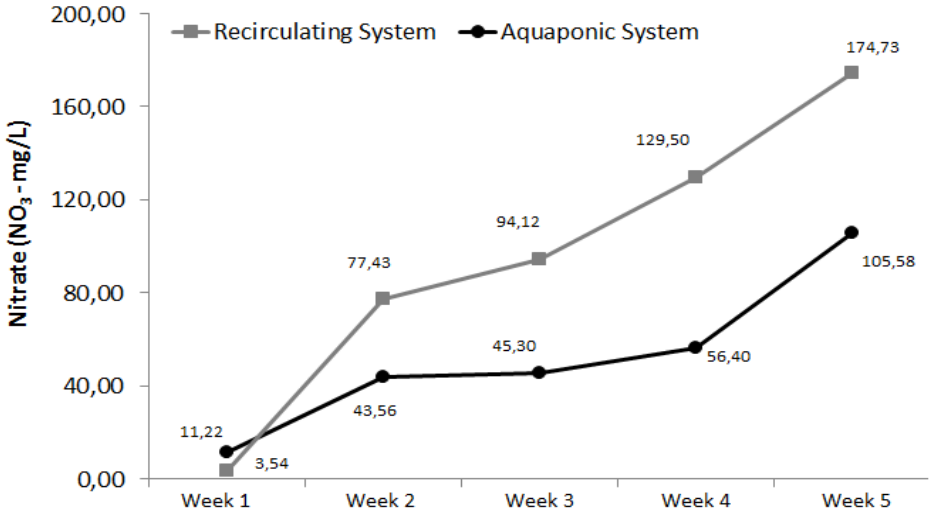

Figure 7. Weekly variations (January 2015 – February 2016) of nitrite (NO_3) in the aquaponic system integrated with basil culture

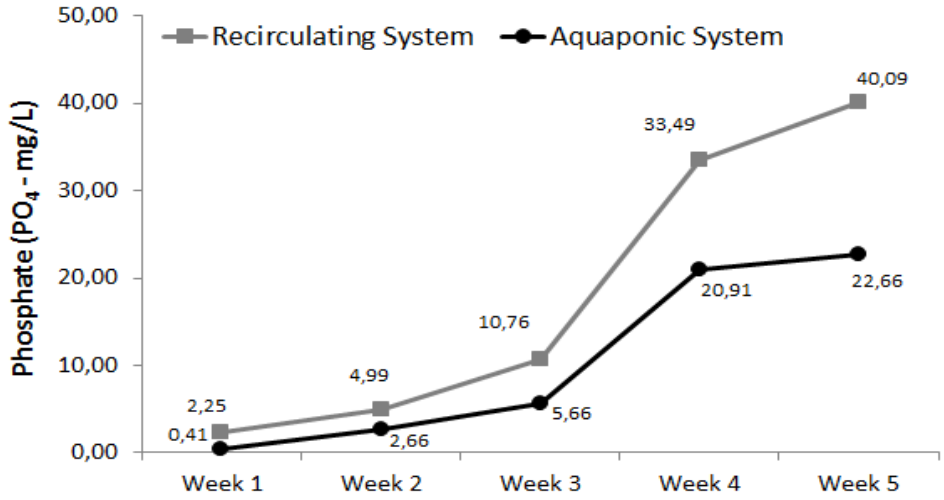

Figure 8. Weekly variations (January 2015 – February 2016) of phosphate (PO_4) in the aquaponic system integrated with basil culture

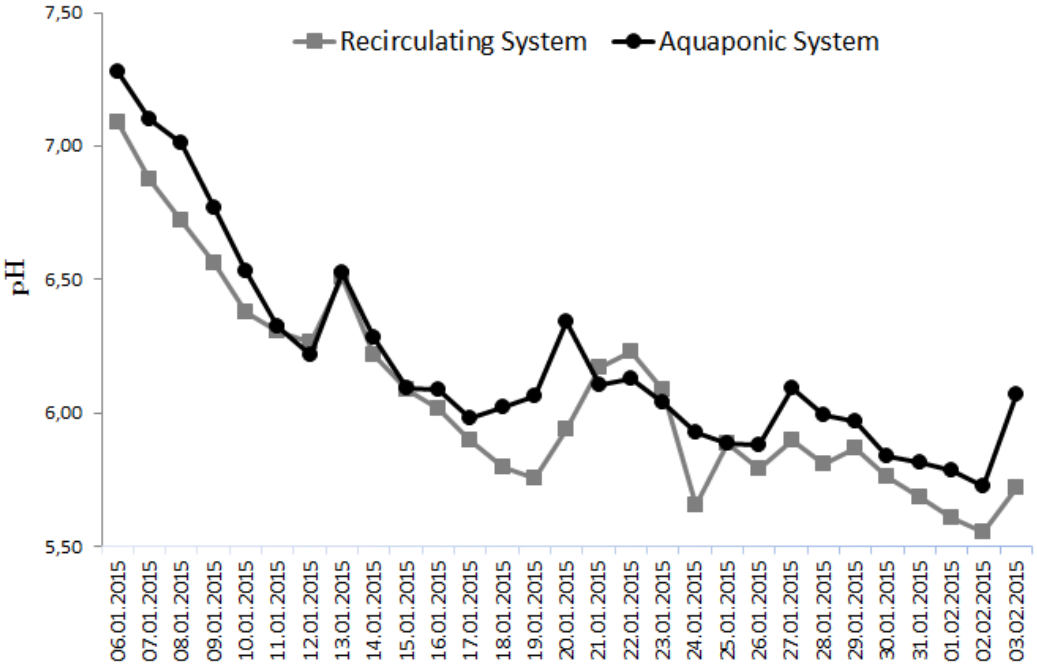

Figure 9. Daily measurement of pH levels in the experimental tanks

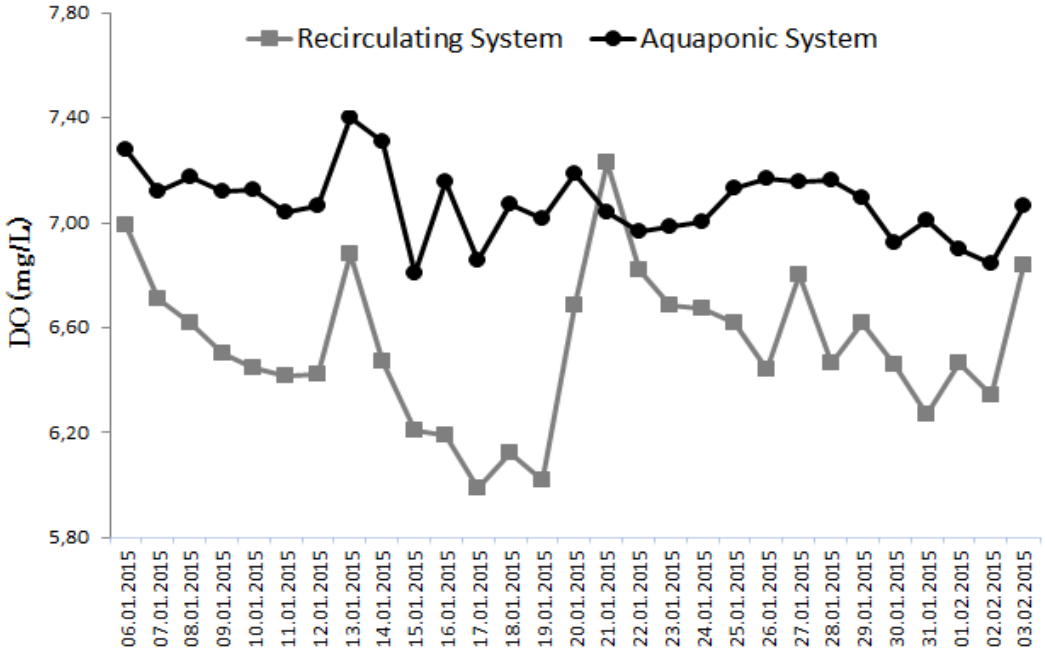

Figure 10. Dissolved oxygene (mg/L) levels in the experimental tanks

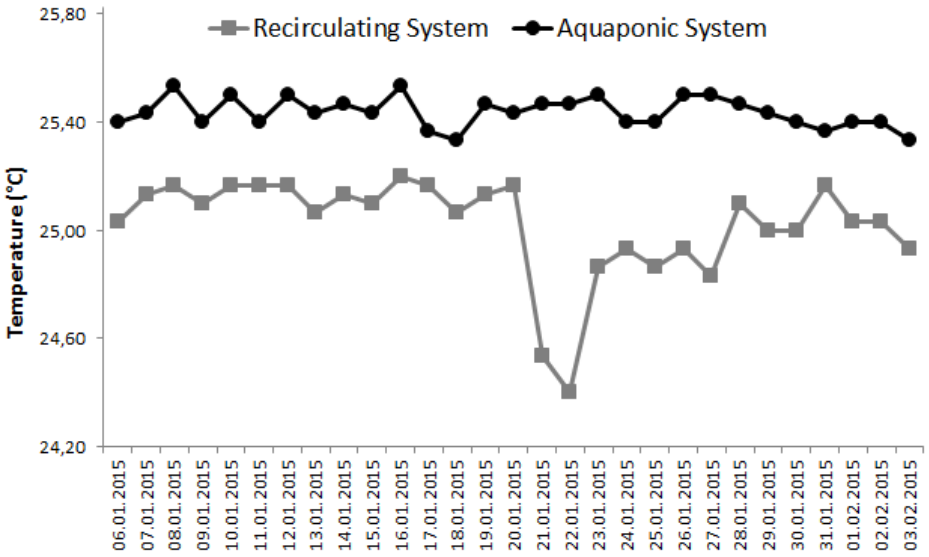

Figure 11. Daily water temperature (°C) variations in the experimental tanks

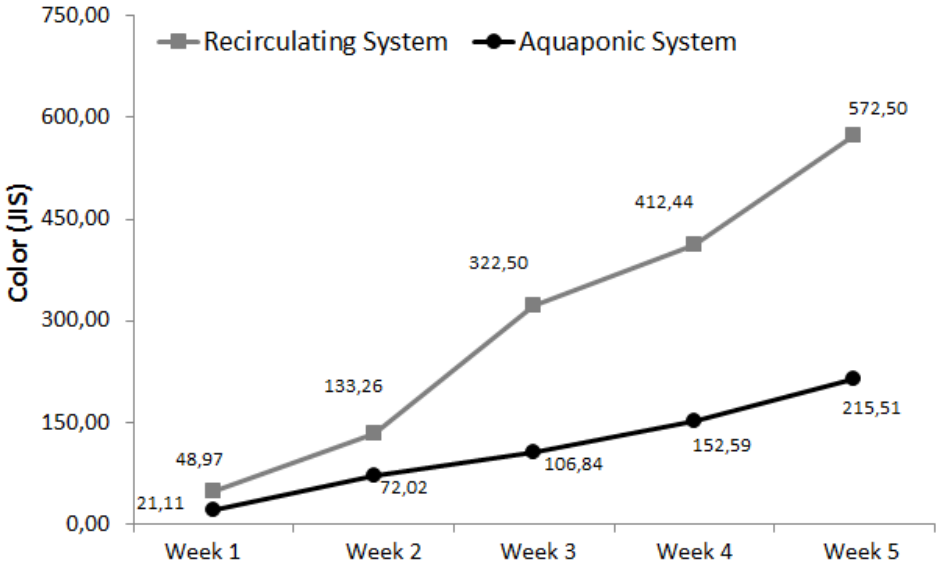

Figure 12. Weekly variations (January 2015 – February 2016) of water color in the aquaponic system integrated with basil culture

Turbidity, a measure of the strenth of water clarity, may decrease the amount of light that can penetrate the water body, hence the rate of photosynthesis might be decreased. Turbidity in natural waters such as lakes and reservoirs can range between 1-20 mg/L (ANZECC, 2000), which can also be acceptable for carp or tilapia culture operations. In the present study, turbidity measurments in the aquaponic system were within the range of the values reported by ANZECC (2000) for lakes and resevoirs, while the turbidity in the recirculating system increased to almost threefold of the aquaponic culture environment (Figure 13). Higher turbidity in the RS group resulted in a lower dissolved oxygen concentration in the water, which might be attributed to a reduced photosynthetic activity due to a reduced light penetration. Similar results were reported by Rakocy et al. (2004), where dissolved oxygen levels in the rearing tanks decreased when water became turbid in an aquaponic system integrated with basil and tilapia culture.

Despite the room temperature of the experimental setup remained constant, outside ambient weather conditions affected temperature and humidity and variations in these parameters were observed at different time intervals during the course of this study. Negative correlation was observed between room temperature and humidity rate. The temperature values in the morning and noon hours were higher than those recorded in the afternoon and evening hours. Humidity however showed contrast results, compared to the temperature values, with lower humidity in the morning and noon hours, but higher rates of humidity in the afternoon and evening hours. It was also recorded that humidity rates in the experimental room environment lowered during rainy or cloudy days and vice versa (Figure 14 and 15).

Light intensity through penetration from outher environment (sun light) was visibly higher than those each plant was exposed to in the morning and noon hours. However at afternoon and evening hours, light pentration from outher environment dropped and was equal to those measured in the plant growth area. Eventhough the light intensity in the experimental setup was controlled by fleurosent lights, sun light penetrated from outher environment fortified the light effect during the morning and noon hours, which were consequently higher than those measured in the afternoon and evening periods (Figure 16).

In the present experiment, basil with an initial mean weight of 20.54±0.73 g reached a final marketable size of 131.02±16.77 g with a weight gain of 110.48±17.02 g after a 75 days growth period. Specific growth rate was recorded as 6.16±0.47 %/day. Growth performance of basil in the aquaponic system during the course of the trial has been given in Table 3, and weekly harvest has been shown in Figure 17.

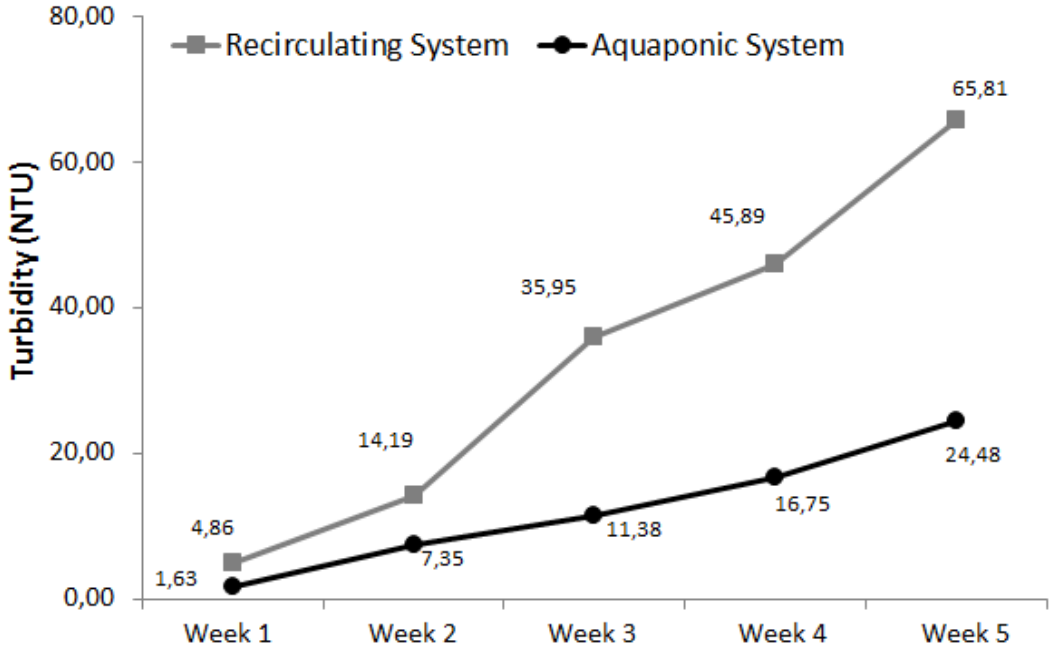

Figure 13. Weekly variations (January 2015 – February 2016) of water turbidity in the aquaponic system integrated with basil culture

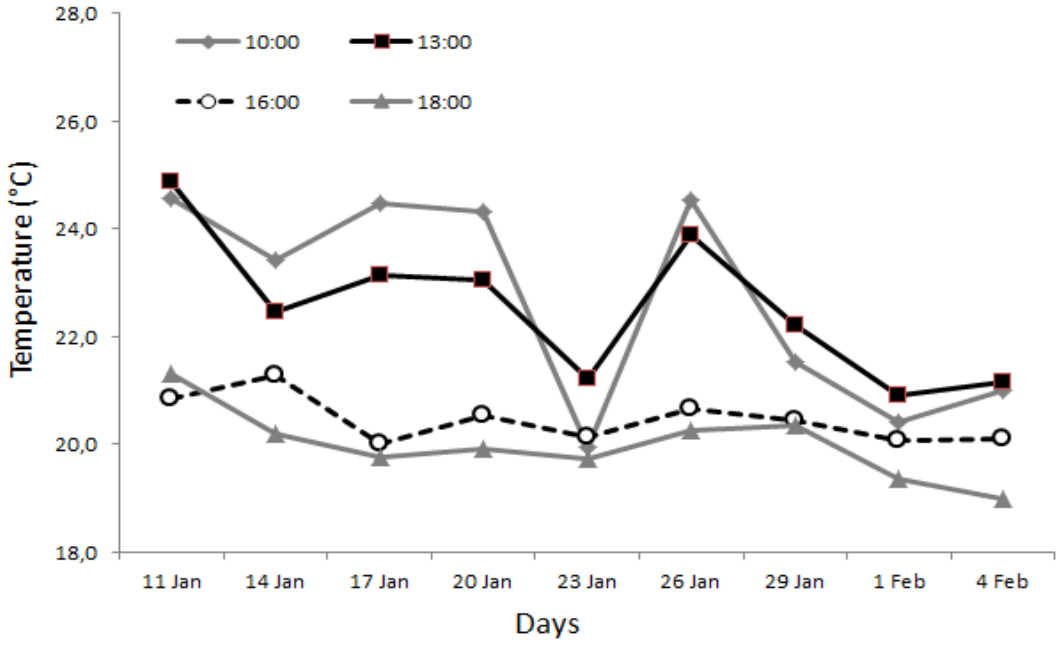

Figure 14. Tertian variations of room temperature in the experimental area at four time intervals during the trial

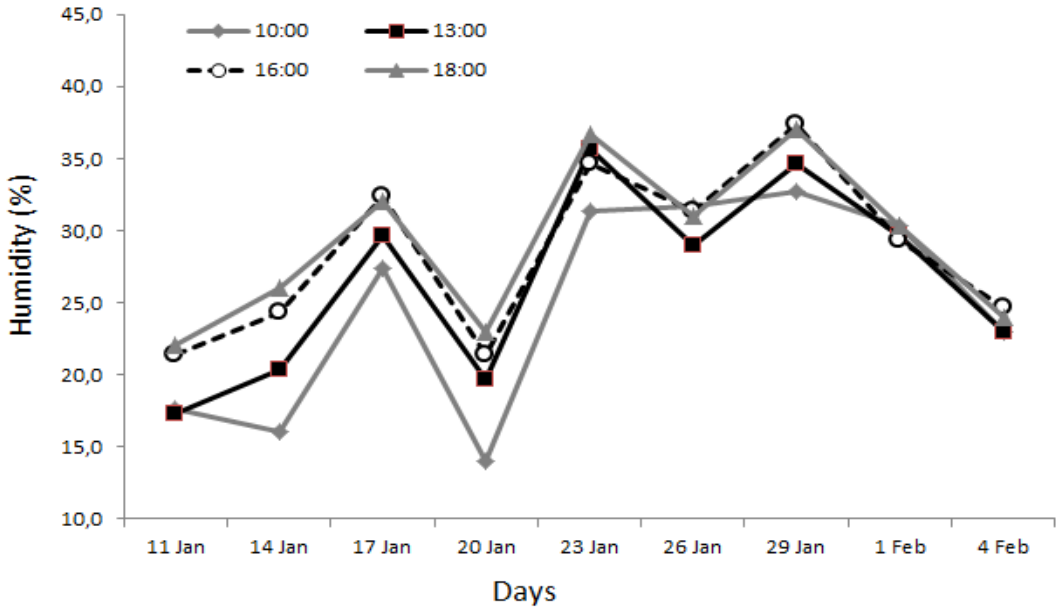

Figure 15. Tertian variations of room humidity in the experimental area at four time intervals during the trial

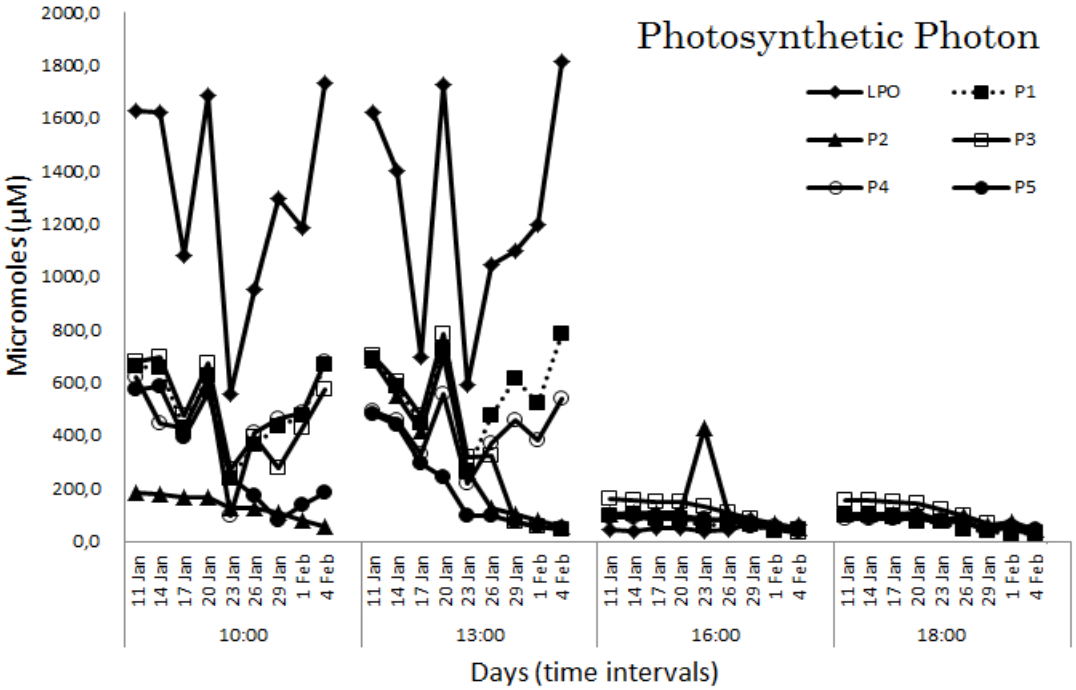

Figure 16. Tertian variations of light intensities (Photosynthetic Photon) in the plant culture environment (LPO: light penetration from outside; P1-5: positioning of planted basil on syrofoam layers in the aquaponics system)

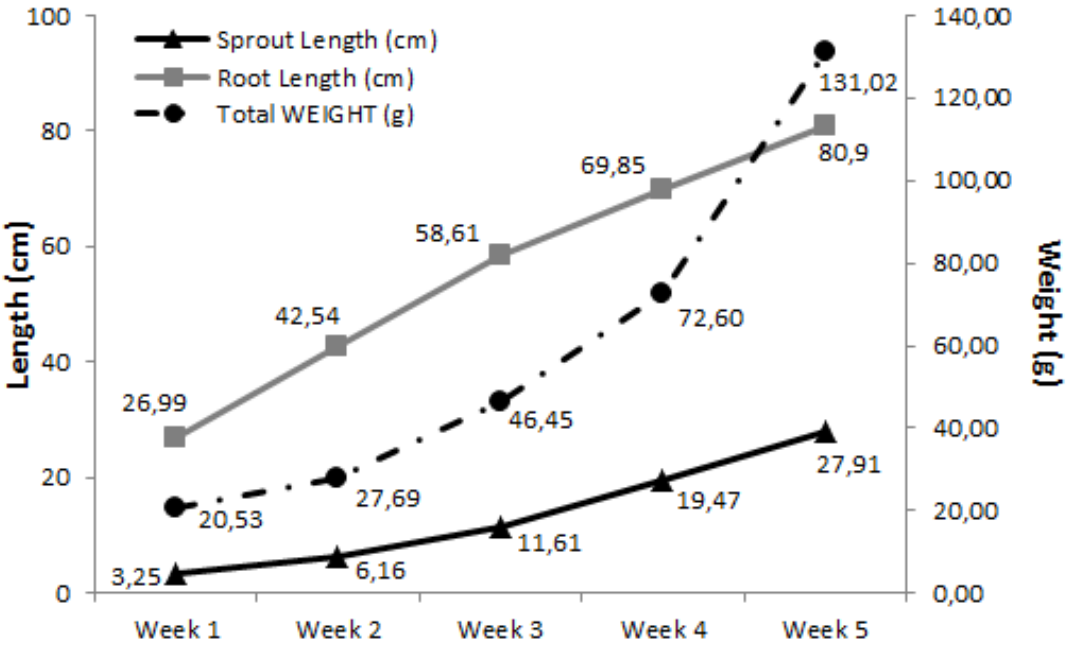

Figure 17. Increase of root and sprout length (cm) and harvest yield (g) of Basil (*O. basilicum*) (January 2015 – February 2016) in the aquaponic system integrated with tilapia culture

Basil harvest steadily increased during the trial and the end production per plant averaged 131 g with a yield of 5 kg/m^3 (600 g/m^2) (Table 3). Weight of basil doubled over the initial value 3 weeks after the start of the experiment, and at the final harvest basil showed a weight increase of more than 6 times over the initial value. Cummulative relative growth rate of basil increased from 34 % in the first week to 539 % at the end of 5-week experimental period (Table 3). Initially, basil showed a slow growth one week after the start of the trial and reached a mean weight gain of 28 g compared to the initial weight of 21 g. The first harvest gave a yield of 127 g/m^2 (28 g), while the yield almost doubled to 213 g/m^2, tripled to 330 g/m^2 and became 5 times higher over the first harvest at the second, third and last harvest, respectively.

Harvest results for basil in the present study are comparable with earlier reports. The harvest rate of 600 g/m^2 in the present study was lower then that reported by Rakocy et al. (2004) (1.8 kg/m^2) for basil production (8 plants/m^2) in an aquaponic system integrated with tilapia culture. Higher yield of basil was recorded at a rate of 6.25 kg/m^2 by Bradley and Marulanda (2001) in a hydroponic system. Our findings are in agreement with the yields of basil in field production (0.6 kg/m^2, mean weight of 104.4 g) that was reported by Rakocy et al. (2004). In the study of Bradley and Marulanda (2001), the number of basil planted into the production system was reported as 25 plants/m^2 which was more than the planting density of 23 plants/m^2 applied in the present study. The discrepancies between the reults of the present and earlier studies in terms of the harvest amount of basil in a square meter might be attributed to several factors, such as different diet composition used for fish feeding, protein level and digestibility of the diet, which may affect the diurnal pattern of ammonia excretion in fed fish, nutrient availability and amount of nutrients in the production system, culture conditions such as water quality, temperature fluctuations, length of growth period, or any combination of all these factors. However, from the results of the present study and those of earlier reports, it can be suggested that a higher planting density of basil might be applied in aquaponic culture systems.

The results in the present study shows the efficient use of water resources in an aquaponic system, in terms of the integration of plant production with tilapia culture that created a sustainable and eco-friendly food production system through the uptake of nutrients excreted postprandially into the water environment.

After the end of 5-weeks experimental period, there was no sign of nutrient deficiency as no chlorosis of the leaves was seen. Rakocy et al. (2004) reported nutrient deficiencies by the fourth harvest in a batch production system, due to a possible reduction of some nutrients as water passed through a long distance pipe between two sets of hydroponic tanks. Furthermore, the authors assumed that a batch production of basil might have exceeded the nutrient production capacity in their water system.

Table 3. Growth of Basil in the Aquaponic system integrated with Tilapia culture

	Aquaponic System
Initial weight (g)	20.53 ±0.73
Final weight (g)	131.02 ±16.76
Weight gain (g)	110.49 ±17.02
Specific growth rate (%/day)	6.16 ±0.46
Relative growth rate (%)	539.22 ±91.78
Final Harvest (kg/m^3)	5.002 ±0.64
Final Harvest (g/m^2)	600.18 ±0.08

SGR (specific growth rate, % growth/day) = ((lnWfinal - lnWinitial) / (total time in days)) x 100

Conclusion

Results in the present study reveal lower variations of amonium, nitrite and nitrate in the aquaponic system compared to the recirculating fish culture system. Different from traditional flow-through fish culture facilities, aquaponic systems can operate with lower amount of water. Hence, the reuse of freshwater in the aquaculture facility may support less water usage for food production, but more for drink water supply. The results in the present study shows the efficient use of water resources in an aquaponic system, in terms of the integration of plant production with tilapia culture that created a sustainable and eco-friendly food production system through the uptake of nutrients excreted postprandially into the water environment.

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REVIEW ARTICLE DERLEME MAKALE

SUSTAINING CONSUMER CONFIDENCE IN MIDDLE EAST AQUACULTURE SECURED BY TRACEABILITY SYSTEMS

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Abstract:

In recent years, aquaculture is the fastest growing protein supply for consumers in the Middle East countries. The aquaculture production in the region increased by 111% from 837 247 to 1 768 917 tons between 2005 and 2014. Egypt, Iran and Turkey are the leading countries in aquaculture production but Saudi Arabia, Oman and United Arab Emirates have vast investment plans for future aquaculture projects as the others in the region. Middle East aquaculture still need to grow by nearly 20% to match the regional demand for seafood which is average 12,55 kg fish per capita. This huge necessity for growth raises doubts in regional consumers on the sustainability of aquaculture production.

Sustainable aquaculture systems are being accepted as environmental friendly, profitable, productive and social. But the sustainability is not a measurable entity itself and its analysis relies on indirect criteria or indicators. Traceability is an important indicator that sustains consumer confidence on aquaculture products.

There's an increasing trend on the market for traceability of capture and aquaculture products. Therefore, many countries are developing various solutions for monitoring the aquaculture market. Turkey is one of these countries who's developing computer-based monitoring systems for fisheries and aquaculture production.

In this study, acceptance, progress, and the difficulties in transition to new monitoring system and the prospective contribution of traceability systems on consumer confidence have been investigated in example of Turkey.

Keywords: Sustainable aquaculture, Traceability, Middle East, Consumer confidence, Turkey

Introduction

Aquaculture is the fastest growing protein supply for the consumers in the Middle East countries in recent years. The aquaculture production in the region increased by 111% from 837 247 to 1 768 917 tons between 2005 and 2014 (FAO, 2015) (Figure 1). Aquaculture production across the region is predicted to reach 2.46 million tons as the year 2020. The majority of aquaculture production is supplied from freshwater species like Nile tilapia and rainbow trout. However, the huge consumer demand for shrimp, oysters, crab and mussels is encouraging aquaculture sector to produce such marine species.

Egypt, Iran and Turkey are the leading countries in the Middle East aquaculture production with more than 95% of total share (Table 1). Egypt is producing nearly 65% of total aquaculture production (GLOBEFISH, 2011).

In 2014, the value of aquaculture production reached to nearly 4.4 billion USD by 134% increase in ten years (Figure 2). While the major players continue to grow in Middle East aquaculture industry, the others like Saudi Arabia, Oman and United Arab Emirates (UAE) have started vast investments in aquaculture sector from the last quarter of 2013. Saudi Arabian Ministry of Agriculture has plans to support aquaculture projects with an additional 10.6 billion USD to produce one million tons of fish in next 16 years. Oman also has plans to invest 1.3 billion USD in aquaculture development up to the year 2020. Another potential producer United Arab Emirates, announced multi-billion USD aquaculture investments for its new aquaculture farms. Aquaculture is expected to be the fastest growing food industry in the Middle East (GLOBEFISH, 2011).

Food and Agricultural Organization (GLOBEFISH, 2011) reported seafood consumption in the Middle East as already above the world average and increasing rapidly. Per capita consumption of seafood in the United Arab Emirates (UAE) is at 51.1 kg, four times the world average and one of the highest worldwide. It is followed by the other fastest growing seafood markets in the region as Oman (36.7kg/per year), Bahrain (16.9 kg/per year), and Qatar (16.5 kg/per year). However, the Middle East aquaculture still needs to grow by nearly 20% to match the regional seafood demand which is average 12.55 kg per capita.

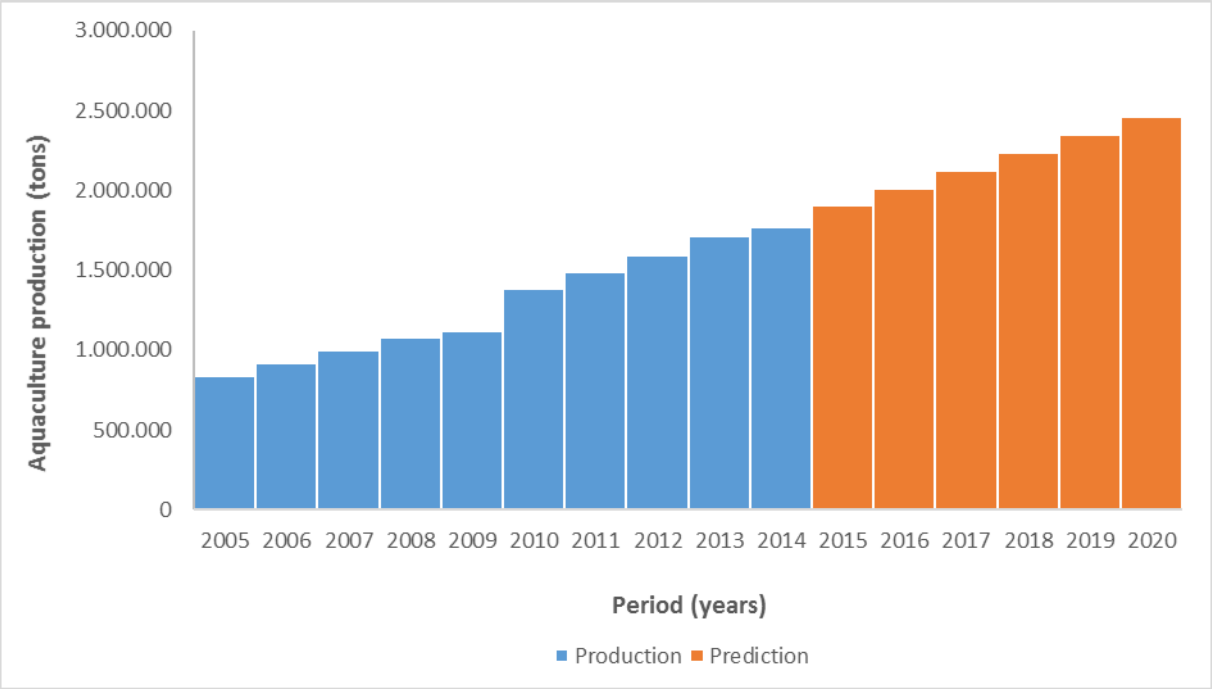

Figure 1. Aquaculture production and prediction in the Middle East countries between 2005 and 2020 (FAO, 2015).

Table 1. Aquaculture production and share of the Middle East countries in production between 2005-2014 (FAO, 2015)

Countries	2005-2014 total aquaculture production (tons)	Share in total aquaculture (%)
Egypt	8 328 377	64.56
Iran	2 143 365	16.61
Turkey	1 739 760	13.49
Israel	208 626	1.62
Iraq	188 931	1.46
Saudi Arabia	185 486	1.44
Syria	72 462	0.56
Lebanon	10 644	0.08
Jordan	5 931	0.05
United Arab Emirates	5 918	0.05
Kuwait	3 344	0.03
Oman	1 754	0.01
Yemen	1 680	0.01
Palestine	1 506	0.01
Qatar	375	0.01
Bahrain	24	0.01

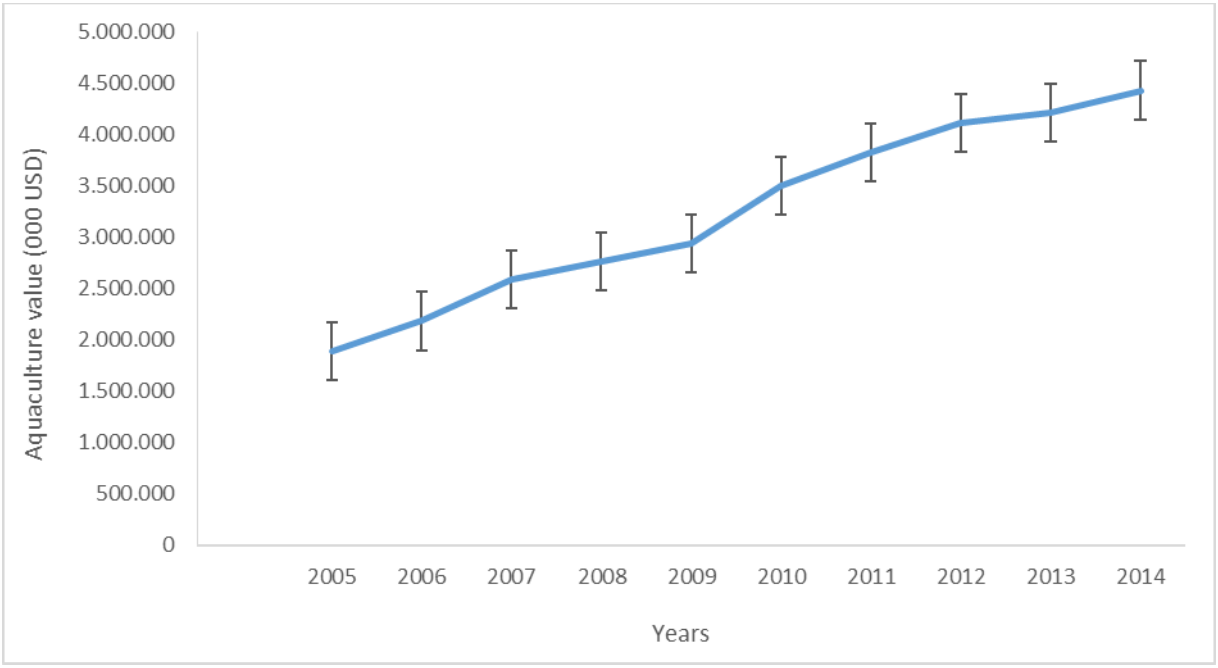

Figure 2. Total aquaculture value in the Middle East between 2005-2014 (FAO, 2015)

In terms of preferences, Middle Eastern consumers take into consideration whether a product is farm raised or wild caught. Many consumer prefers wild fish due to the perceptions that they are more natural, fresher, tastier and healthier than the farmed ones. But the fact is that the wild stocks have reached their limits and no more increase is expected in the amount of Middle East fisheries in the future. While the governments are investing in aquaculture, negative perceptions are the main limiting factors on the consumption of farmed fish in the region.

Sustainability Perceptions of the Consumers

Consumers attention to sustainability is an emerging trend in the region. This trend offers significant advantages to local authorities in promoting safe and sustainable aquaculture products. Nielsen (2014) reported that 63% of consumers are willing to pay more for products and services from companies that are committed to positive social and environmental impact covering sustainable production in the Middle East region. The government of UAE launched a campaign entitled “Choose Wisely” which is aiming to educate consumers on the sustainability of fish. The campaign provides consumers with a color coded system to provide information about which species are over exploited, considered sustainable or good alternatives (WWF, 2011). Such encouraging campaigns and efforts to inform consumers on sustainability of seafood are also being carried out in Turkey, Iran, Saudi Arabia, Kuwait and Egypt. The growing consumer interest in sustainability would be a good promotion tool for aquaculture (Parreño-Marchante, Alvarez-Melcon, Trebar & Filippin, 2014).

Sustainable aquaculture systems are being accepted as environmental friendly, profitable, productive and social. The principles of sustainable aquaculture cover legal production, respect to environment, sustainability of species, technological improvement, research and development, environmental ethics, labelling and traceability.

Traceability as an Indicator for Sustainable Seafood

Sustainability is not a measurable entity itself and its analysis relies on indirect criteria or indicators. Traceability is an important indicator and tool that sustains consumer confidence on aquaculture production. In 2002, European Commission introduced food and ingredient traceability systems through General Food Law to ensure consumer confidence in European Union (van Rijswijk, Frewer, Menozzi & Faioli, 2008). The regulation (EC) Nº 178/2002 defines traceability as: "The ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution". The aim of the commission was to promote and use traceability as a tool for proving food security inside the European Union. This regulation was also willing to force consumers to ask for traceability in food supply chains for imported products. The main advantage of traceability is giving confidence to suppliers and consumers that what they are buying is legal, safe and fairly traded. It also helps to motivate consumers to buy more domestic products and support domestic production (Fisher, 2015).

Food safety and ecological problems are affecting consumers’ confidence and arousing suspicion about the origin and the condition of food all over the world (Moretti, Turchini, Bellagamba & Caprino, 2003; Thompson, Sylvia & Morrissey, 2005). Aquaculture is a complicated production method based on many scientific and biological procedures. The high-level production systems include many ingredients and ecological factors which are not easy to understand by the most consumers. Moreover, not only ingredients but also environment problems like pollution, pesticide and antibiotics residues affect the quality and safety of aquaculture products (Hsu, Chen & Wang, 2008). Today, consumers tend to find out more information about the ingredients, the origins, processing procedures and transportation of aquaculture products.

Traceability in Aquaculture

Traceability in aquaculture allows consumer to get all high-level information from seed to plate (Figure 3). Those information includes feed types and ingredients, origin of the broodstock, hatchery procedures, harvest date, storage conditions, processing, transport and trade which are also present in traceability database of the farms. Labels are extrinsic cues that can assist consumers inferring product quality and forming quality expectations, which in turn influence a whole range of attitudes and behaviors related to food purchasing, meal preparation, satisfaction and future purchase decisions (Brunsø, Fjord & Grunert, 2002; Verbeke & Ward, 2006).

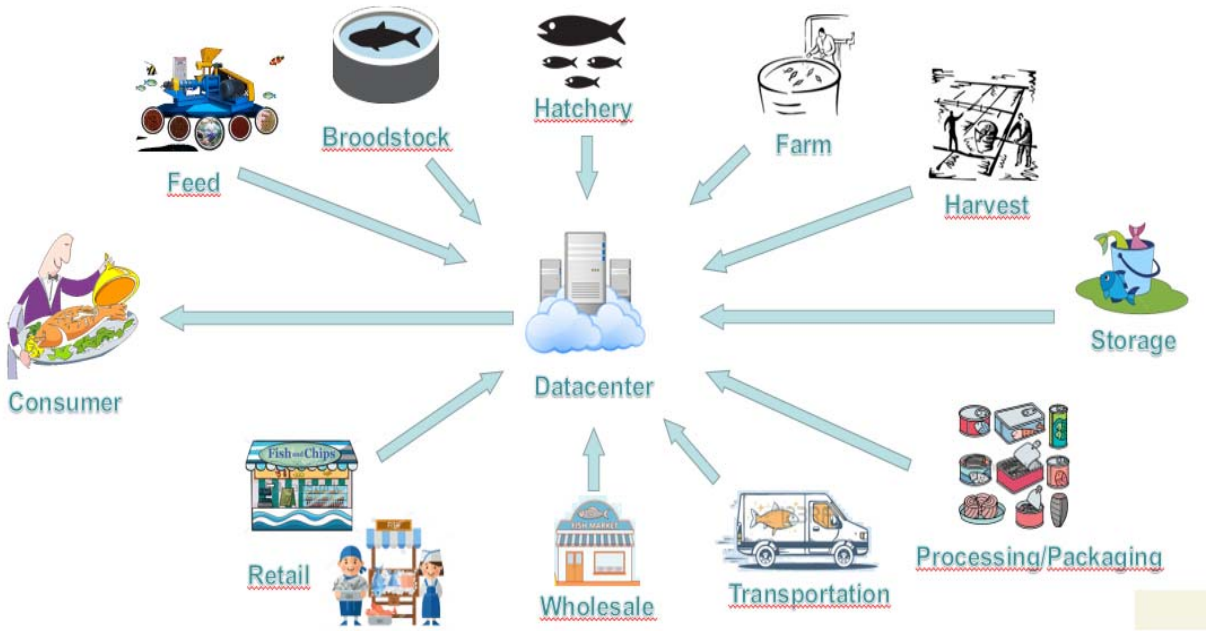

Figure 3. Information chain from seed to plate in aquaculture

The information collected on the database of aquaculture farms like commercial and scientific names of produced species, production methods, geographic location, harvest date, type (fresh, frozen or defrost product), best before date, nutritional values and other additional information are presented to the consumers through the product labels. QR and barcodes on the labels allow supply chain professionals to instantly know everything about the products they buy and sell. Also, these barcodes are essential tools for tracing products through electronic information systems.

Aquaculture Traceability in Turkey

There's an increasing trend on the market for traceability of capture and aquaculture products. Many countries of the world have started to implement traceability systems and compose new regulations on fisheries and aquaculture to sustain consumer confidence on seafood security. Turkey is one of these countries who's developing computer-based monitoring systems for fisheries and aquaculture production.

Turkey has started to implement monitoring applications for fisheries and aquaculture in order to ensure the traceability of fishery products from the source to the consumer. In this context electronic information systems and its infrastructure are being improved since 2007. A new regulation for recording, control, audit and ensuring traceability of aquaculture and fisheries products was also accepted. The efforts on determining quality criteria of fisheries and aquaculture products, control and supervision of traceability and consumer information has gained legal support by the new "Seafood Marketing Standards and Consumer Information Regulation".

The "Aquaculture Register System", developed for monitoring aquaculture operations and production is managed by Ministry of Agriculture and Livestock, General Directorate of Fisheries and Aquaculture and production information of all aquaculture enterprises are being kept on the system. These enterprises are obliged to enroll in the Aquaculture Registry System to get insurance, credit support, best agriculture production certificate and other legal procedures.

The best advantages of Aquaculture Registry System are:

- Traceability of cultured products back to broodstock and eggs,
- Keeping records of all life stages of reared fish like biomass, production unit, production amount and species,
- Movement traceability of aquaculture species including all life stages,

- Keeping records of all treated fish according to national legislations,
- Traceability of harvested fish until processing,
- Detection of production sites with all geographic coordinates

In this context, the system fills an important gap for monitoring of aquaculture operations. Currently, all aquaculture farms have not yet completed their registration process but input of information into the system is intensively in progress.

Turkish aquaculture sector fully integrated into the latest processes and quality management systems as BRC, IFS, Global GAP and HACCP certification process and all production process from broodstock to processed product are being entirely monitored by inner traceability infrastructure of the enterprises. These certificates determine the reliability level of the companies' products in the commercial sense. But highly complex information and terms included in such certificates are not informative for the regular consumer level. Moreover, certification procedures only monitor products until the processing and packaging stage whereas consumers need a fully tracing process from egg to plate which is common in all over the world.

There are intensive studies supported by the Seafood Marketing Standards and Consumer Information Regulations on labelling and barcoding which are an important part of traceability in aquaculture. In addition to labelling, an infrastructure that allows consumers to monitor whole production stages of seafood will be functional by these studies.

At this stage, many companies have started initiatives to ensure traceability of their products by consumers in order to increase their effectiveness on the market. Consumers can get detailed information about the production site, production stages, feeds and packaging date by entering the serial number on the label of the fish into the web page of the farms. Such individual initiatives are very positive approaches to gain consumer confidence on aquaculture products. But a centralized Aquaculture Registry System covering the whole aquaculture production would be more effective on overall consumer perceptions.

Conclusion

The traceability provides confidence to suppliers and customers about purchased seafood is legal, safe and fairly traded. On a positive aspect, having improved traceability encourages and promotes the consumption of aquaculture products thereby helping the economy of aquaculture farms to improve. It helps to induce a sense of confidence in farm grown fish. Moreover, better traceability also helps facilitate national and international trade by taking the domestically produced fish to markets inside and outside the region and creating a demand for it.

Conclusion

In conclusion, there is a growing concern on sustainable fisheries and aquaculture around the world. While more consumers demanding sustainable, organic and non-genetically modified foods increasing, traceability is the only tool that can certify a product that meets these claims.

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