American Chemical Science Journal
4(6): 975-982, 2014

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Physico-Chemical Quality and Plankton Density of Water in Duck-Fish Production Systems

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Author's contribution

The sole author designed, analyzed and interprets and prepared the manuscript.

Original Research Article

Received 24th May 2014
Accepted 8th July 2014
Published 19th August 2014

ABSTRACT

This study was conducted to evaluate the effect of duck manure and spilled duck feed on water quality and production of *Oreochromis niloticus* in an integrated system with local duck breeds. Fish with an average body weight of 20.17±1.28g, were stocked into experimental ponds (area 72m^2 each) at a stocking density of 5 fish/m^2 in duplicate. Treatment 1 (T1) was integrated with 12 Mallard ducks *(Anas platyrhynchos*) while Treatment 2 (T2) was integrated with 12 Muscovy ducks (*Cairina moschata*). Treatment 3 (T3) was used as control, without integration. Fish in T3 was fed compounded feed of 30% crude protein content three times a day while those in T1 and T2 fed on duck manure and spilled duck feed (15% crude protein content). Water quality parameters of the fish ponds, growth parameters of fish and ducks were monitored. After a 12-week period, mean weight gain of fish were 140.68, 122.11 and 157.19g in T1, T2 and T3 respectively while percentage survival was highest in T3 and lowest in T2. The levels of physico-chemical parameters were generally favourable for fish production and dissolved oxygen (DO) was higher in the integrated treatments probably due to duck activity in the ponds. Plankton analyses shows that duck manure engenders the growth of plankton and this favours the growth of plankton-feeding fish species like *O. niloticus*. Mallard ducks are recommended for the duck-fish system since they performed better than Muscovy ducks both in survivability and in ability to stimulate physico-chemical and biological processes that engender fish growth.

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Keywords: Oreochromis niloticus; duck; manure; water quality; plankton.

1. INTRODUCTION

Integrated duck-fish farming involves the combination of duck and fish farming where the wastes (manure and spilled feed) from the duck system become inputs into the fish system. It is an old practice in Central Europe and South East Asia and it is pertinent to explore the feasibility of the system and extend the technology to poultry and fish farmers alike in other countries. Nigerian poultry farming is dominated by chicken [1] and the vast majority of poultry-fish farming studies have been on chicken-fish farming [2,3]. The combination of fish and duck farming is an inexpensive way of fertilizing ponds for fish production and advantages of ducks over chickens include their relatively high disease tolerance, hardiness and excellent foraging ability [4,5]. According to Ola [6] ducks survive better than the best laying strains of chicken even under adverse conditions like high rainfall, temperature, poor housing etc. However, duck meat and eggs generally command lower market prices than chicken and due to the shovel-shape of their bills, ducks are prone to spill and waste more feed than chicken when confined. Thus, this study was aimed to determine the effects of duck manure on water physico-chemical parameters, plankton production and growth performance of *O. niloticus* under integration with local Mallard and Muscovy ducks and the potential of duck-fish farming.

2. METHODOLOGY

2.1 Experimental Layout

The experiment was carried out at the fish farm site of the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa and six earthen ponds (each $72m^2$) were used for the study consisting of three duplicate treatments. Four duck sheds (each $7.5m^2$) were constructed over four ponds. The duck sheds were built directly over the ponds and ducks were sourced from the local markets. Treatment 1 involved integration with 12 adult Mallard ducks *(Anas platyrhynchos*) while Treatment 2 involved integration with 12 adult Muscovy ducks (*Cairina moschata*). The ducks in both treatments had an average age of 10 months (with initial mean weight of 1.02±0.21kg in T1 and 1.16±0.18kg in T2) and were stocked at a density of 1600 ducks/ha with 1:3 male to female ratio. Treatment 3 was the control and involved no integration. The ponds were stocked with juvenile *Oreochromis niloticus* at a stocking density of 5 fish/m^2. The integrated treatments were fenced so that the ducks were confined within the fish pond areas but adequate playground was provided for them and they were fed *ad libitum* with compounded feed (crude protein content, 15%) containing maize bran, millet and guinea corn in a 50:30:20 ratio. Fish in the integrated treatments fed on duck manure and spilled feed from the duck shed while fish in the control was fed with feed having 30% crude protein content. The study lasted 12 weeks.

2.2 Water Sampling and Analyses

Water samples were collected at a depth of 10cm with acid washed polyethylene bottles for the determination of physico-chemical parameters and plankton density. Temperature, pH, dissolved oxygen, nitrite and ammonia were determined on a weekly basis while transparency, total solids, total dissolved solids, alkalinity, hardness, conductivity, nitrate, phosphate, phytoplankton and zooplankton were determined monthly using standard methods [7]. Other parameters were analysed using standard methods used by several authors [8-15].

2.3 Sampling and Analysis of Fish and Duck Parameters

A total of 40 *O. niloticus* samples were collected monthly with a net from each pond and weighed with a weighing balance. Thick polyethylene sheets were used to cover the underneath of each duck shed for a period of 24 hours weekly. Faecal droppings and spilled duck feed were collected on different sheets and weighed to give the 24 hour manure and spilled feed loading rates. The average of these weekly measurements is the daily manure and spilled feed loading rates for each treatment. Proximate composition of duck manure was also analysed using standard methods described in FAO [8].

2.4 Statistical Analysis

Statistical analysis was done using the SPSS (version 13.0) for Windows software package. Mean concentrations and standard deviations were calculated for each parameter. The results were also subjected to analysis of variance (ANOVA) and means were compared using Duncan Multiple Range Test. ANOVA was used to assess the relationship between manure and spilled feed loading and water quality parameters.

3. RESULTS AND DISCUSSION

The relevant parameters of duck and fish which were determined are outlined in Table 1. Mallard ducks (under T1) survived better than Muscovy ducks (under T2). One Mallard and 4 Muscovy ducks died and were replaced in the course of the experiment. Mallard ducks produced significantly higher (P = .05) number of eggs than Muscovy ducks in the study. The higher mortality rate and lower egg laying performance of Muscovy ducks in the system is in line with the findings of Sonaiya and Swan [16] who stated that though female Muscovy is an excellent breeder, it thrives better on free range than in confinement. Mean spilled feed loading rate was also higher for Mallard ducks but manure loading rate was higher for Muscovy ducks. Fish production was significantly lower (P = .05) in T2 than in the other treatments. Compounded feed (T3) led to higher fish growth than duck manure (T1 and T2). This result is in contrast with the findings of many authors [17,18,19] who reported that fish growth was better in the duck-fish system than in the control where fish was fed compounded feed. However, there were no marked differences (P>.05) in fish survival in the treatments.

Proximate composition of duck manure is shown in Table 2. Moisture content was higher in Mallard duck manure compared to that of Muscovy duck but the major nutrients in manure viz., nitrogen, phosphorus and potassium were higher in Muscovy manure. In the same vein, crude protein, fat, fibre and ash contents were higher in dry Muscovy manure in relation to that of mallard duck. However, nitrogen free extracts (NFE) were higher in Mallard manure.

Table 3 shows mean values for physico-chemical parameters in the various treatments. Mean values for all the parameters except temperature and transparency were significantly lower (P = .05) in the control (T3) compared to the integrated treatments (T1 and T2). This is similar to the findings of Jha et al. [20] who reported that manure application significantly increased phosphate, ionized ammonia, nitrite and nitrate contents of pond water. Transparency is lower in the integrated treatments as a result of higher suspended solid content arising from the deposition of manure and spilled feed. The levels of physico-chemical parameters were generally favourable for fish production and dissolved oxygen (DO) was higher in the integrated treatments probably due to duck activity in the ponds. Duck movement disturbs pond water and leads to increase in dissolved oxygen content of water. This result is similar to the findings of Prisloo et al. [21]. In this study, mean nitrate, nitrite and ammonia concentrations in all the treatments were lower than the 2 – 10 mg L^{-1}, <0.3 mg L^{-1} and <0.1 mg L^{-1} benchmark values recommended for aquaculture [22].

Table 1. Weight of ducks, manure/spilled, feed rates and fish production

Parameter	Treatments		
	T1	**T2**	**T3**
No. of ducks stocked	12.00	12.00	–
Initial mean weight of duck (kg)	1.02±0.21a	1.16±0.18a	–
Final mean weight of duck (kg)	1.36±0.16a	1.48±0.24a	–
No. of eggs produced	20.00	4.00	–
Manure loading rate (g/day)	153.49±8.72a	162.04±5.68b	–
Spilled feed loading rate (g/day)	18.26 ±0.32a	15.33±1.81a	–
No. of fish stocked	360.00	360.00	360.00
No. of fish at the end of the experiment	332.00	324.00	338.00
Survival of fish (%)	92.22	90.00	93.88
Initial mean body weight/fish (g)	20.17±1.28a	21.86±0.93b	22.63±0.88b
Final mean body weight/fish (g)	160.85±12.29a	143.97±15.87b	179.82±20.44c
Mean weight gain /fish(g)	140.68	122.11	157.19

Means in the same row with different letters are significantly different (P = .05)

Table 2. Proximate composition (%) of fresh duck manure

Parameter	Treatments	
	T1 (Mallard)	**T2 (Muscovy)**
Moisture	74.80	70.59
	Dry matter basis	
Potassium	0.84	1.06
Nitrogen	4.25	4.73
Phosphorus	1.89	2.01
Crude Fat	7.15	8.83
Crude Protein	22.60	21.45
Crude Fibre	9.33	10.61
Ash	14.92	16.40
NFE	32.96	29.62

Table 4 shows species composition and mean abundance of phytoplankton in the different treatments. A total of 15 phytoplankton species were identified in the treatments during the study. Phytoplankton abundance was significantly higher (P = .05) in the integrated treatments (T1 and T2) than in control with *Anacytis sp.* being the most abundant. Similar results were obtained by other authors such as [23,24]. Duck manure stimulated the production of high quantities of phytoplankton compared to the control. Higher phytoplankton abundance in the integrated treatments may also be a factor in the higher DO values obtained for these treatments compared to the control. Higher phytoplankton abundance results in higher photosynthetic activity and higher oxygen production especially in daytime. However, T2 had significantly higher mean total phytoplankton abundance than T1 but DO was higher in T1. These may be due to higher rate of respiration in T2 as a result of higher phytoplankton abundance. The phytoplankton species observed in this study were among the useful planktons listed by Pradhan et al. [25]. They reported that the planktons not only enhanced fish production but also facilitates the bioremediation of toxic substances like heavy metals.

Table 3. Mean (± SD) values of physico-chemical parameters of water in the integrated system

Parameter	Treatments		
	T1	T2	T3
Temperature (^oC)	28.23±0.25a	28.50±0.20a	27.92±0.35a
pH	8.85±0.21a	8.78±0.13a	6.25±0.27b
Electrical Conductivity (μScm^{-1})	87.58±4.72a	96.45±3.18b	79.05±2.15c
Total Solids (mgL^{-1})	3.50±2.89a	3.22±1.03a	2.16±0.93b
Total Dissolved Solids (mg/l)	2.17±10.74a	1.95±0.63a	1.06±0.55b
Transparency (cm)	10.08±0.95a	11.70±1.34a	15.16±1.72b
Dissolved Oxygen (mg/l)	8.27±1.84a	7.10±1.93b	5.80±0.87c
Hardness ($mgCaCO_{3/}$ l)	140.77±11.24a	127.90±14.30b	109.26±7.53c
Alkalinity (mg/l)	323.40±3.81a	429.28±9.07b	280.17±5.49c
Nitrate (mg/l)	1.64±0.58a	1.45±1.07a	0.30±0.13b
Nitrite (mg/l)	0.06±0.01a	0.04±0.02b	0.03±0.01c
Ammonia (mg/l)	0.06±0.03a	0.05±0.01a	0.03±0.02b
Phosphate (mg/l)	0.62±0.81a	0.50±0.24a	0.30±0.15b

Means in the same row with different letters are significantly different (P = .05)

Table 4. Mean (± SD) phytoplankton abundance in the different treatments

Composition	Abundance (cells /ml)		
	T1	T2	T3
Microcytis sp.	1205.36±3.22a	0.00±0.00	160.54±0.53b
Anacytis sp.	17250.11±4.95a	28500.11±19.25b	1100.95±3.28c
Fragillaria sp.	100.51±0.66	0.00±0.00	0.00±0.00
Chlorella ellipsoidea	513.70±0.81a	2405.37±5.84b	200.55±1.10c
Athrospira sp.	340.22±1.20a	9000.48±6.10b	128.74±0.59c
Nitzchia sp.	203.16±0.51a	311.18±3.92a	0.00±0.00
Scenedesmus incassatulus	60.02±1.88a	3302.49±12.71b	20.14±0.35c
Scenedesmus quadricanda	120.73±1.29a	2400.66±9.43b	20.99±0.26c
Hormidium sp.	24.65±0.73a	310.84±2.80b	0.00±0.00
Anabaena spirodes	40.47±1.31a	1825.60±10.77b	25.72±0.84a
Stanrastrum rotula	20.33±0.47a	0.00±0.00	20.16±1.73a
Closterium sp.	0.00±0.00	300.88±3.62	0.00±0.00
Pediastrum simplex	0.00±0.00	0.00±0.00	20.48±0.55
Tetraspora sp.	0.00±0.00	0.00±0.00	0.00±0.00
Navicula digitoria	0.00±0.00	0.00±0.00	0.00±0.00
Total	19879.26±17.03a	48357.61±74.44b	1698.27±9.23c

Means in the same row with different letters are significantly different (P = .05)

Table 5 shows the species composition and abundance of zooplankton in the different treatments. A total of 13 zooplankton species were identified in the treatments. *Brachionus angularis* was the dominant zooplankton in all the treatments and abundance was significantly higher (*P* = .05) in the integrated treatments (T1 and T2) than in the control (T3). Abdel-Tawwab et al. [26] reported significantly higher zooplankton abundance in earthen ponds fertilized with organic and inorganic fertilizers compared with unfertilized ponds. The phyto- and zooplankton species produced in this study are similar those found by Bwala et al. [27] in a study of NIFFR Reservoirs. They concluded that these species were good feed resources for fish culture. Plankton analyses shows that duck manure engenders the growth of plankton and this favours the growth of plankton-feeding fish species like *O. niloticus*. This result is similar to the findings of Islam et al. and Little and Edwards [28,29].

Table 5. Mean (± SD) zooplankton abundance in the different treatments

Composition	**Abundance (cells /10 ml)**		
	T1	**T2**	**T3**
Brachionus falcatus	200. 11±3.25a	100.33±4.28b	60.59±1.84b
Brachionus angullaris	6198.04±8.30a	10105.22±35.90b	1900.17±10.55c
Cyclopoid copepods	400.25±3.98a	200.55±3.72b	80.77±5.20c
Copepodites	511.71±1.42a	211.50±5.41b	160.31±12.34b
Asplanchna sp.	223.60±2.95a	122.57±6.90b	20.88±0.59c
Lecane decipens	414.00±4.81a	0.00±0.00	20.45±1.22b
Nauplii	409.60±5.66a	98.10±4.36b	340.56±5.37c
Trichocerca cylindrical	100.27±1.73a	101.63±7.88a	142.19±2.94b
Moina micrura	100.19±3.44a	112.09±3.67a	125.61±8.05a
Brachionus Calyciflorus	516.70±6.52a	0.00±0.00	260.44±2.57b
Bosmina sp.	0.00±0.00	110.52±2.30a	20.17±1.55b
Diaphanosoma exicusm	0.00±0.00	100.35±5.86a	20.93±5.18b
Branchionus diversiconis	0.00±0.00	0.00±0.00	20.41±0.96
Distance trawled (m)	10.00	10.00	10.00
Total zooplankton / 10ml	9074.47±42.06a	11100±80.28b	3140±58.36c

Means in the same row with different letters are significantly different (P = .05)

4. CONCLUSION

The experiment shows that integrated duck-fish farming is a feasible and potentially profitable venture. Wastes from the duck sheds stimulated favourable levels of water physico-chemical parameters for fish growth. In addition, plankton density and composition was favourable for the growth of fish. Adequate awareness creation is needed for the adoption of this system since duck farming in Nigeria and other African countries is generally at a low level and integrated duck-fish farming is not widely practiced among duck farmers. Integration of Mallard ducks with fish production is highly recommended, while Muscovy ducks are not recommended for the system since they do not stay long in water and easily get sick when confined. More research is also needed on the performance of other duck breeds and fish species in the system.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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