J. Agric. Sci. Mansoura Univ., 32 (7): 5225 - 5244, 2007

STUDIES ON INTEGRATED FISH/DUCK PRODUCTION SYSTEM:
I- On WATER QUALITY AND FISH PRODUCTION

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ABSTRACT

A study was conducted in earthen ponds in an integrated system (fish-cum-ducks), for 120 days. The tested water parameters (temperature, pH, dissolved oxygen, salinity and phytoplankton numbers) did not significantly influence by the experimental treatments. Yet, total number of zooplankton and most of its classifications was lower significantly in water of non-integrated ponds. The 3rd treatment (40 duck/pond and fish feeding rate of 5, 4, and 3% daily during 1st two months, 3rd month, and 4th month, respectively) was the best concerning the final fish body weight, body weight gain, final body length, average daily body weight gain, specific growth rate, total fish production, and super and 1st class fish production. The worst treatments were those not integrated with ducks.
Keywords: Tilapia – Duck – Integration – Water quality – Performance– Composition – Productivity.

INTRODUCTION

Increasing aquaculture activity led to the competition on the conventional feed resources among various animals species. However, feed stuffs are the most expensive items in production process, particularly in case of fish. So, recycling of animal wastes in form of non conventional feed stuff for different animal species was and still one of the important aims of the nutritionists all over the world (Abdelhamid *et al.*, 2001-b). Yet, these wastes may threat the public health (Skovgaard, 1978). Therefore, the objectives of the present study were to investigate the effects of integrated Nile tilapia fish cultured in earthen ponds with Pekin ducks on pond's water quality, fish performance and productivity, as well as fish quality and fish production economy.

MATERIALS AND METHODS

This field experiment was conducted during season 2004/2005 in a private farm in Tolombat 7 at Al-Reiad belonging to Kafr El-Sheikh governorate. It aimed to reduce feed costs of fish production under semi-intensive production system via fish/duck integration system.

Experimental Animals:

Three hundred and fifty one-day old Pekin ducklings (each of .90 g average body weight) were purchased on 16/6/2004 from a private duck hatchery at Al-Reiad (Kafr El-Sheikh governorate). The ducklings were reared for 2 weeks in a closed pen before the swimming learning. Thereafter, they were divided (when reached about 225 g each) onto the earthen ponds on 29/6/2004 at variable stocking densities (being 80, 40, 20 and zero on ponds No. 1-2, 3-4, 5-6 and 7-8, respectively) as illustrated in Table 1. The rest of the ducklings (350 – 280 = 70) were reared in the previous pen as a control and for replacing the death cases from pond's ducklings. Hormone-sex reversed (mono-sex) Nile tilapia (*Oreochromis niloticus*) fry (4-5 g) from the hatchery of the same farm were distributed onto the experimental earthen ponds at stocking rate of 4 fish/m^2 as given in Table 1 too.

Table 1: Scheme of the experimental work.

Pond No.	Pond area, m^2	No. of fish/pond	No. of ducks/pond	Feeding rate, % of biomass daily
1	1529	6116	80	1st 2 months : 4 3rd month : 3 4th month : 2
2	1394	5574	80	1st 2 months : 3 3rd month : 2 4th month : 1
3	1129	4916	40	1st 2 months : 5 3rd month : 4 4th month : 3
4	1186	4744	40	1st 2 months : 4 3rd month : 3 4th month : 2
5	1547	6188	20	1st 2 months : 5 3rd month : 4 4th month : 3
6	1662	5548	20	1st 2 months : 4 3rd month : 3 4th month : 2
7	1860	7440	--	1st 2 months : 5 3rd month : 4 4th month : 3
8	1650	6600	--	---

Experimental Rearing System:

Fish: Eight earthen ponds were sun dried, reformed, and watered. Tolombat 7 drain (agricultural drainage station on the drain which surrounding Borolus lake) was the source of irrigation for a water column in the ponds of 1 m height. Six pens wee constructed on one hand, each on a bank of ponds No. 1, 2, 3, 4, 5, and 6; whereas ponds No. 7 and 8 were offered artificial diet and fresh duck manure (from the control ducklings pen abroad of the fish ponds), respectively. Each pair of ponds was tidily separated using nets to prevent interference of duckling and fish of both ponds with each other. Fish were stocked into the experimental ponds on the 7th of June 2004. Fish of the first 7 ponds were fed on a commercial fish diet (25% crude protein, from Teotrade Co., Cairo-Ismailia road) in a sinking pellets form (3 mm) at variable rates as shown from Table 1. Whereas, the 8th pond's fish were given fresh duck manure only at 10% of the biomass daily for 2 months, 8% for the following month, and 6% at the 4th month. Daily feed quantity offered to the ponds' fish was modified biweekly according to the actual fish body weight changes.

Ducks: The ducks were offered their feed in their pens, two times daily (3/2 morning and 1/3 evening) the morning meal was moisten, rough sand was offered once every 2 days; whereas they spent most of the day time on the fish ponds. The ducks were offered 50% of their initial body weight as daily feeding rate, which gradually reduced thereafter. Their diets (starter, grower and finisher, 21 – 17% crude protein), were mash and bought from Cairo Co. for Poultry. From 15/8/2004, their feed was mixed with trash fish from the same farm.

Criteria Measured:

Averages of initial live body weight and length of a fish sample (70 fish) were measured, then biweekly fish weight (0.01 g) and total length (0.01 cm) of each pond (average of 10 fish/pond) were measured. However, the following parameters were calculated after Abdelhamid (2003):

Condition (K) factor = W_F x $100/(L_F)^3$

Average gaily gain (ADG, mg/fish) = W_F (mg) – Wo (mg)/experimental period (days),

Specific growth rate (SGR, %/day) = (log W_F – log W_o) x 100/experimental period (days),

Feed conversion ratio (FCR) = feed consumption (g)/body weight gain (g),

Protein efficiency ratio (PER) = body gain (g)/dietary protein consumption (g),

Protein productive value (PPV, %) = retained protein (g) x 100/consumed protein (g), and

Energy utilization (EU, %) = retained energy (Kcal) x 100/consumed energy(Kcal) (Jobling, 1983).

Where, W_F = final weight

W_o = initial weight

L_F = final length

Log = natural logarithm.

Water samples of each pond were measured weekly for temperature, pH, dissolved oxygen (DO) and salinity (Table 2). Also, DO was measured 3 times daily (dawn, 5 am; afternoon, 2 p.m and at night 10 p.m) for each pond every 3 days. Nitrate, nitrite, and ammonia were estimated using test kits No. HI 3874, HI 3873, and HI 3824 for fresh water from HANNA instruments, respectively. All Another water samples were collected from the experimental ponds (3 samples / pond) for phyto-and zooplankton examination, mid the experimental period, according to APHA (1985) and Boyd (1992). All water samples were collected from 50 cm depth of the ponds' water column. Proximate chemical analysis for fish was carried out using the standard methods of analysis (A.O.A.C., 2000).

Statistical Analysis:

All numerical collected data were statistically analyzed using S.A.S. (2001) and Duncan (1955) for analysis of variance and least significant differences, respectively.

RESULTS AND DISCUSSION

1- Water Quality Criteria:

1.1- Physico-chemical parameters:

All values obtained for NO_3, NO_2, and NH_3 in the pond's water were lower than the detectable levels, i.e. 10, 0.2, and 0.5 mg/l. Table 2 presents ranges of some water quality criteria including temperature (°C), pH values, dissolved oxygen concentration (DO, ppm) and salinity level (ppm) throughout the 4-month fish rearing period (June – October). The temperatures ranged generally (regardless to ponds No., i.e. treatments) between 22.3 and 29.3°C. Also, pH, DO and salinity took the ranges of 8.37 – 9.34, 4.41 – 7.05 ppm and 2.86 – 4.85 ppm, respectively. Although there was no remarkable ($P \geq 0.05$) effect of the treatments on these water parameters; yet, it seams that fish ponds integrated with ducks (ponds No. 1 to 6) reflected warmer water with lower pH values and salinity levels but with higher DO contents comparable with ponds No. 7 and 8 (without ducks). Also, these changes were dependent on the duck intensity, so they were slightly stronger in ponds No. 1 and 2 (80 duck / pond) than ponds No. 3 and 4 (40 duck / pond), than ponds No. 5 and 6 (20 duck / pond). These differences may be due to ducks movements on the water surface which help in enrichment of water with DO from the air. Moreover, the ducks excretion (with its uric acid) lowered the pH values. The movement of ducks on water surface improved the transfer of ambient temperature from and to water, so led to elevating the water temperature. However, all these water criteria limits were within the suitable ranges recommended for Nile tilapia rearing (Abdelhamid, 2003).

Table 2: Ranges of some water quality criteria of the experimental fish ponds throughout the 4-months experimental period (June – October, 2004) as affected by the integration system (fish/duck).

Ponds No.	Temperature, °C	pH – value	DO, ppm	Salinity, ppm
1	23.1 – 29.0	8.37 – 8.93	6.41 – 7.00	2.86 – 4.11
2	23.3 – 28.6	8.62 – 9.00	6.37 – 7.04	2.86 – 4.15
3	23.0 – 29.3	8.63 – 9.22	5.00 – 6.91	2.89 – 4.83
4	22.9 – 28.4	8.64 – 9.34	5.02 – 7.05	2.91 – 4.85
5	23.3 – 29.2	8.59 – 9.25	4.47 – 6.78	2.87 – 4.48
6	23.5 – 28.3	8.71 – 9.16	4.41 – 6.80	2.86 – 4.50
7	22.3 – 28.5	8.78 – 9.21	5.73 – 7.00	3.03 – 4.64
8	22.3 – 28.2	8.88 – 9.22	5.72 – 6.89	3.04 – 4.73

Meske (1985) reported that water temperature must be kept above 24°C for optimal growth of tilapia. Winfree and Stickeny (1981) revealed that *O. niloticus* can tolerate a wide range of temperature being 8 – 42°C. *O. niloticus* were found in the great Bitter lakes of Egypt (Kirk, 1972) at salinities between 13.5 and 22.4 ppt. An excellent aquacultural attribute of tilapia is their tolerance to low DO concentration. Magid and Babiker (1975) stated that the lowest DO limit of *Tilapia niloticus* was 0.1 ppm. Teichert-Coddington and Green (1993) revealed that *O. niloticus* survived at 0.1 mg/l DO, for up to 6 h and their pH tolerance ranged from 5 to 11, but optimal results can usually be obtained only between pH 6 and 9. Chervinsky (1982) cited that the recommended pH for tilapia culture was 7 to 8.

As shown from Table 3, there was no effect (P ≥ 0.05) on DO due to the experimental treatments in water measurements of dawn, midnight and the general mean of the three sampling times. Yet, at afternoon, this measurement was significantly (P ≤ 0.05) affected, where the lowest OD concentration was recorded for pond No. 4 comparing with the pond No. 1. Otherwise, there were no significant (P ≥ 0.05) differences among all other ponds. Generally this table clearly illustrates the very low DO levels at dawn (2.08 – 2.63) followed by at midnight (3.44 – 4.66) and at highest at afternoon (7.10 – 10.28 ppm). This is a fact because at dawn most of the DO is totally consumed and depleted by breathing of all kinds of alive organisms. At midnight, photosynthesis stopped and DO in water begins to be consumed; whereas at afternoon, all photocells consume CO_2 and produce O_2 which surpasses the breathing requirements of all aquatic organisms. Therefore, the highest DO levels are measured often at afternoons. These findings are in good accordance with those given by Brune *et al.* (2003).

Table 3: Means ± standard errors of the dissolved oxygen level (ppm) in ponds water as affected by the experimental treatments and time of sampling.

Ponds No.	Sampling times			General mean
	Dawn	afternoon	Midnight	
1	$2.20^a \pm 0.294$	$10.28^a \pm 1.256$	$4.57^a \pm 0.913$	$5.69^a \pm 0.815$
2	$2.09^a \pm 0.341$	$8.53^{ab} \pm 1.034$	$3.72^a \pm 0.572$	$4.78^a \pm 0.641$
3	$2.63^a \pm 0.312$	$9.99^{ab} \pm 1.364$	$4.66^a \pm 1.086$	$5.76^a \pm 0.913$
4	$2.20^a \pm 0.040$	$7.10^b \pm 0.202$	$3.44^a \pm 0.676$	$4.24^a \pm 0.225$
5	$2.26^a \pm 0.202$	$9.28^{ab} \pm 1.260$	$4.31^a \pm 0.687$	$5.28^a \pm 0.716$
6	$2.60^a \pm 0.231$	$7.39^{ab} \pm 0.572$	$3.68^a \pm 0.381$	$4.56^a \pm 0.381$
7	$2.08^a \pm 0.167$	$8.35^{ab} \pm 0.421$	$4.45^a \pm 0.734$	$4.96^a \pm 0.433$
8	$2.23^a \pm 0.248$	$7.22^{ab} \pm 0.184$	$3.72^a \pm 0.352$	$4.39^a \pm 0.196$

a–b: Means in the same column superscripted with different letters significantly (P ≤ 0.05) differ.

1.2- Plankton:

Although there were no significant (P ≥ 0.05) differences among the experimental ponds in the phytoplankton count as a total and as euglena and green and blue green algae (Table 4); yet, there were remarkable (P ≤ 0.05) changes in zooplankton number whether as a total, nauplii, rotifers, cladocerans, copepods or larvae (Table 5). Where ponds No. 7 and 8 contained the lowest total numbers of zooplankton, rotifers, cladocerans and larvae per liter of fish rearing water. However, poultry manures are easy to rot and its nitrogen is chiefly in uric acid form, which could not be absorbed directly by plants, accordingly it is better to be used after fermentation. As for each fowl, the yearly amount of excrements in average being 7.5 – 10 Kg dry weight or 52 – 70 Kg fresh weight for duck and can be converted into Kg of fish. Organic manure causes the propagation of bacteria in large quantities. Bacteria decompose organic materials, mineralizing them into nutritional inorganic materials, which can be utilized by phytoplankton (Payer, 2001).

Fish – cum – duck integration could result in good economic efficiency of fish production. Jian (1985) raised ducks in common carp fish ponds and found that 0.9 – 1.7 Kg of fish could be increased by raising one duck. Moreover, Salama and Hassan (1995) found that differences in water quality (DO, pH, NO_3, NO_2, and P) were insignificantly affected by various fertilizers (chicken droppings and cow manure). They added that poultry manure increased the fish yield and growth rate than the control (without manures). However, Magouz *et al.* (1999) used duck manure as initial fertilizer for fish ponds, since organic and inorganic fertilization is one of the most important facilities that can increase the natural food for fish and improve fish production.

Soliman *et al.* (2000) mentioned that raising ducks on fish ponds (fish-duck culture) on a commercial scale is a new practice in Egypt. They added that there were no differences in temperature or pH in any of the ponds but dissolved oxygen levels were lower in integrated ponds concomitant with increasing levels of ammonia, phosphate and nitrate. Water in integrated ponds was richer in natural productivity (phytoplankton and zooplankton) either in species or density when compared with those variables in non-integrated ponds. El-Nady *et al.* (2001) indicated a super abundance of algae in all fertilizer treatments over that of the ration and control treatments in all seasons. The control treatment had the lowest algae turbidity compared to that of the ration treatments. The increasing the fertilizers the increasing values of ponds' water nitrate and total ammonia.

Table 4: Means of phytoplankton per liter of water as affected by the tested rearing systems of mono sex Nile tilapia (*Oreochromis niloticus*).

Pond No.	Total	Diatoms	Euglina	Green	Blue Green
1	1179999^{a}	122222^{a}	291111^{a}	471111^{a}	295555^{a}
2	1867776^{a}	000000.0^{b}	460000^{a}	790555^{a}	617222^{a}
3	1651108^{a}	105000^{ab}	347221^{a}	789999^{a}	408888^{a}
4	1192776^{a}	31111^{ab}	351667^{a}	589999^{a}	224444^{a}
5	1888498^{a}	133889^{a}	222777^{a}	841833^{a}	689999^{a}
6	1057109^{a}	57778^{ab}	173222^{a}	458888^{a}	367221^{a}
7	1679998^{a}	58888^{ab}	160555^{a}	867777^{a}	592777^{a}
8	1526109^{a}	28889^{ab}	333888^{a}	667777^{a}	495555^{a}

a–b: Means in the same column superscripted by different letters significantly ($P \leq 0.05$) differ.

Also, Hafez *et al.* (2002) found that poultry litter for 60 days followed by artificial feeding led to lower dissolved oxygen and pH value and higher alkalinity and phosphorus; yet, it was responsible for higher chlorophyll (a) and zooplankton as well as higher daily gain of tilapia than the control (artificial feeding only). Moreover, Abdel-Tawab and Sweilum (2004) found that rearing Nile tilapia in earthen ponds with high level of organic fertilizer (3 m^3 poultry and cattle manure) gave the highest water temperature, pH and salinity comparing with the low level of organic fertilizer (1.5 m^3) or no organic fertilizer addition. However, Lu *et al.* (2004) reported that euglena is one of freshwater algae which is acceptable as a diet for larval Nile tilapia.

On the other hand, Abd Elaziz and Ehab (2003) found that using poultry droppings as a feed for cultured tilapia led to increases in water concentrations of NH_3 and NH_4 and a decrease of DO level. Additionally, Ampofo and Clerk (2003) mentioned that the use of animal wastes to fertilize pond farms as practiced in many countries is considered superior to inorganic fertilizers in producing and maintaining desirable species of planktonic and benthic organisms and to enhance fish production.

Table 5: Means of zooplankton per liter of water as affected by the tested rearing systems of mono sex Nile tilapia (*Oreochromis niloticus*).

Pond No.	Total	Nauplii	Ostracods	Rotifers	Clado-cerans	Cope-pods	Larvae
1	6139.0^{a}	58.3^{bc}	65.7^{a}	5910^{b}	90.33^{bcd}	2.33^{b}	12.33^{ab}
2	5960.3^{b}	42.3^{c}	22.7^{a}	5777^{b}	110.33^{abc}	6.00^{b}	1.67^{b}
3	5816.0^{b}	27.6^{c}	17.3^{a}	5723^{b}	33.67^{cd}	2.67^{b}	12.00^{ab}
4	9434.0^{a}	64.3^{bc}	23.7^{a}	9247^{a}	83.33^{bcd}	10.67^{b}	5.33^{ab}
5	6246.0^{b}	123.0^{b}	17.3^{a}	5945^{a}	138.0^{ab}	18.33^{b}	4.00^{ab}
6	5507.3^{b}	83.0^{bc}	48.7^{a}	5171^{b}	176.33^{a}	14.00^{b}	14.67^{a}
7	1579.3^{c}	81.0^{bc}	0.33^{a}	1469^{c}	12.67^{d}	16.33^{b}	0.33^{b}
8	1997.0^{c}	258.7^{a}	6.67^{a}	1630^{c}	49.99^{cd}	52.00^{a}	0.67^{b}

a–d: Means in the same column superscripted by different letters significantly ($P \leq 0.05$) differ.

Pershbacher and Southworth (2004) mentioned that organic fertilizer produced lower phytoplankton and pH levels than inorganic and inorganic with sodium bicarbonate fertilizers. Sophin (2007) cited that manure is decomposed to supply phytoplankton, bacteria and fungi (which would be fed by zooplankton) with their nutrient requirements of different elements, as a pathway for manure to increase fish production. He added that shortly after the development of the first phytoplankton, the zooplankton will start to multiply. Protozoa, small unicellular animal organisms, will be the first zooplankton to reach a peak. The protozoa are then followed by other, bigger zooplankton: rotifers, micro- and macro-cladocera and finally copepods. By the addition of regular, small amounts of fertilizer the food cycle can be kept in better balance, providing a continuous food supply to all steps in the food chain and so reducing large fluctuations of water quality.

2- Fish Production:

2.1- Fish performance:

The initial live body weight and total length as well as condition factor of the fish did not differ significantly ($P \geq 0.05$) among various experimental ponds (Table 6). Yet, there were significant ($P \leq 0.05$) effects of the treatments on final body weight, body weight gain, and final total body length of the experimental fish. Where pond No. 3 reflected significantly the heaviest final body weight, body weight gain and longest total body length. Ponds No. 1 and 4 did not differ significantly with pond No. 3 concerning the superiority of their fish final body weight and body weight gain. This means that the best treatment concerning fish performance was 4 fish/m^2 at daily feeding rate of 5% for 2 months followed by 4% and 3% for the 3rd and 4th month, respectively combined with 40 ducks/pond (pond No. 3). Pond No. 3 was similar to pond No. 1 (80 ducks/pond) and pond No. 4 (40 ducks/pond) at daily feeding rates in both ponds as 4, 5 and 2% during 1st two months and 3rd and 4th month, respectively (Table 1).

However, the worst treatments were those of pond No. 8 and pond No. 7. They gave the lowest values ($P \leq 0.05$) for final body weight, body weight gain and final total length of their fish. This means that artificial feeding alone (even at high daily feeding rate, being 5, 4 and 3% of the biomass during the 1st 2, 3rd, and 4th month, respectively) were not sufficient as feeding plus duck integration, even at the lowest stocking density of 20 ducks/pond in ponds No. 5 and 6.

Table 6: Nile tilapia performance* as affected by the experimental treatments in the earthen ponds throughout the 120-day experimental period (Means ± standard errors).

Pond No.	W_o	W_F	Gain	L_o	L_F	K-factor
1	$5.95^{a} \pm 0.031$	$124.70^{ab} \pm 10.066$	$118.75^{ab} \pm 10.069$	$6.97^{a} \pm 0.028$	$17.70^{b} \pm 0.420$	$1.78^{a} \pm 0.310$
2	$5.92^{a} \pm 0.031$	$109.00^{bc} \pm 8.408$	$103.08^{bc} \pm 8.401$	$6.95^{a} \pm 0.031$	$18.00^{b} \pm 0.420$	$2.11^{a} \pm 0.170$
3	$5.93^{a} \pm 0.34$	$148.60^{a} \pm 15.094$	$142.67^{a} \pm 15.091$	$6.94^{a} \pm 0.034$	$20.20^{a} \pm 0.610$	$1.24^{a} \pm 0.202$
4	$5.87^{a} \pm 0.041$	$120.70^{ab} \pm 11.693$	$114.83^{ab} \pm 11.670$	$6.97^{a} \pm 0.028$	$18.90^{ab} \pm 0.455$	$2.08^{a} \pm 0.167$
5	$5.94^{a} \pm 0.031$	$97.00^{bc} \pm 9.164$	$91.06^{bc} \pm 9.177$	$6.95^{a} \pm 0.031$	$17.50^{b} \pm 0.500$	$2.14^{a} \pm 0.231$
6	$5.91^{a} \pm 0.34$	$105.40^{bc} \pm 7.943$	$99.49^{bc} \pm 7.949$	$6.93^{a} \pm 0.031$	$17.90^{b} \pm 0.376$	$1.82^{a} \pm 0.234$
7	$5.93^{a} \pm 0.34$	$89.00^{cd} \pm 8.895$	$83.07^{cd} \pm 8.882$	$6.93^{a} \pm 0.028$	$16.10^{c} \pm 0.525$	$2.12^{a} \pm 0.338$
8	$5.88^{a} \pm 0.041$	$64.10^{d} \pm 5.575$	$58.22^{d} \pm 5.563$	$6.95^{a} \pm 0.031$	$15.10^{c} \pm 0.525$	$1.98^{a} \pm 0.313$

W_o = Initial weight, g/fish **W_F = Final weight, g/fish**
Gain = ($W_F - W_o$), g/fish **L_o = Initial length, cm/fish**
L_F = Final length, cm/fish **K-factor = Condition factor.**
a–d: Means in the same column superscripted with different letters significantly ($P \leq 0.05$) differ.
*** each value is the mean of 10 fish/pond.**

2.2- Fish growth and feed utilization:

Table 7 shows that there were significant ($P \leq 0.01$) variations among the experimental treatments. Once again, pond No. 3 gave fish with the best ($P \leq 0.05$) average daily gain (ADG) and specific growth rate (SGR) being

594.46 mg and 1.32%/day, respectively. Pond No. 1 was similar (P ≤ 0.05) to pond No. 3 concerning ADG and SGR. The worst treatment was that of pond No. 7, taking the same trend as in fish performance criteria (Table 6). However, the best (false) values of FCR, PER, PPV, and EU for pond No. 8 assuming that its fish consumed the duck manure as a direct feed. Although, the manure was given only during the days where the water turbidity was decreased. Additionally, the primary productivity was not taken in these calculations, since the water was drainage and very rich in natural food. These findings highlight the importance of fish/duck integrated system in increasing fish performance and feed and nutrients utilization by fish in earthen ponds.

Table 7: Means* and standard errors of some parameters of growth and feed and nutrients utilization of mono sex Nile tilapia fish throughout 120-day experimental period as affected by the experimental treatments.

Pond No.	ADG	SGR	FCR	PER	PPV	EU
1	494.81^{ab} ± 41.962	1.25^{ab} ± 0.028	1.67^{d} ± 0.060	2.27^{b} ± 0.354	124.2^{c} ± 14.829	64.97^{b} ± 8.079
2	429.51^{bc} ± 35.012	1.20^{bc} ± 0.028	1.29^{d} ± 0.050	2.94^{b} ± 0.471	161.3^{b} ± 20.297	86.64^{a} ± 11.379
3	594.46^{a} ± 62.886	1.32^{a} ± 0.041	2.67^{b} ± 0.072	1.43^{c} ± 0.632	87.68^{d} ± 28.012	46.21^{c} ± 15.765
4	478.47^{ab} ± 48.636	1.24^{ab} ± 0.034	2.00^{c} ± 0.091	1.91^{c} ± 0.363	109.1^{c} ± 15.797	57.13^{b} ± 8.645
5	379.43^{bc} ± 38.250	1.14^{bc} ± 0.037	2.91^{b} ± 0.148	1.31^{c} ± 0.268	78.15^{d} ± 11.569	41.85^{c} ± 6.632
6	414.55^{bc} ± 33.120	1.18^{bc} ± 0.031	1.58^{d} ± 0.098	2.40^{b} ± 0.617	138.8^{c} ± 13.569	76.60^{a} ± 7.569
7	346.13^{cd} ± 37.015	1.10^{c} ± 0.041	3.45^{a} ± 0.221	1.10^{c} ± 0.541	67.14^{d} ± 10.006	34.03^{d} ± 5.262
8	242.60^{d} ± 23.189	0.98^{d} ± 0.031	1.74^{d} ± 0.316	4.01^{a} ± 0.196	224.8^{a} ± 8.196	131.11^{b} ± 4.854

ADG = Average daily gain, mg/fish. PER = Protein efficiency ratio.
SGR = Specific growth rate, %/day. PPV = Protein productive value, %.
FCR = Feed conversion ratio . EU = Energy utilization, %.
a–d: Means in the same column superscripted with different letters significantly (P ≤ 0.05) differ.

2.3- Fish yield and fish classes:

Table 8 presents data relative to the surface unit (feddan). In this case, the best total fish production was given by the third treatment (pond No. 3) in accordance with previous data of fish performance, growth, and feed and nutrients utilizations (Tables 6 and 7). However, the 7th pond produced more total fish yield than ponds No. 2, 5 and 6, but the worst total production (812 Kg/feddan) was given by the 8th treatment.

The majority of tilapia yield, regardless to the treatments, was of class No. 1 (35.34%), class No. 2 (34.68%) and class No. 3 (20.48%) from the total 8 ponds' yield (100%) 14765.4 Kg/8 feddan during the 4-month experimental period (Table 8). The highest fish production from the best classes was recorded for the 3rd treatment, being 96.63% (25.55% super, 52.64% class No. 1, and 18.33% class No. 2) of the total fish yield, followed by the 4th treatment, being 94.65% (19.27% super, 45.87% class No. 1, and 29.51% class No. 2) of the total fish yield (Table 8).

Sophin (2007) cited that duck manure (production per adult, being 0.05 ton/year) has similar C/N ratio as in chicken manure, being 18. He added that addition of manures to the pond can increase fish production by two main pathways, by direct consumption by the fish and/or by the increase in natural food (phyto-and zooplankton as well as benthos) due to the release of nutrients from the decomposition of the manure. So, the range of manure loading used in fish ponds from meat ducks were 150 – 600 Kg/day/ha, and the conversion ratio of manure to fish is 15 – 25 (Kg fresh duck manure/Kg increase in weight of fish) according to STOAS (1993).

Table 8: Nile tilapia fish production and its classification as affected by the experimental system at the end of four months rearing period in Kg/feddan* (and % of the production).

Pond No.	Super	No. 1	No. 2	No. 3	No. 4	Total
1	- (-)	673.0 (30.82)	961.4 (44.02)	549.4 (25.16)	- (-)	2183.8 (100)
2	- (-)	451.9 (27.42)	641.8 (38.94)	554.4 (33.64)	- (-)	1648.1 (100)
3	651.0 (25.66)	1335.5 (52.64)	465.0 (18.33)	85.6 (3.37)	- (-)	2537.1 (100)
4	446.2 (19.27)	1062.4 (45.87)	683.5 (29.51)	123.9 (5.35)	- (-)	2316.0 (100)
5	- (-)	868.8 (51.78)	746.6 (44.50)	62.4 (3.72)	- (-)	1677.8 (100)
6	- (-)	826.4 (46.32)	758.1 (42.49)	199.6 (11.19)	- (-)	1784.1 (100)
7	- (-)	- (-)	688.7 (38.12)	812.9 (45.00)	304.8 (16.87)	1806.5 (100)
8	- (-)	- (-)	175.6 (21.63)	636.4 (78.37)	- (-)	812.0 (100)
Total	1097.2 (7.43)	5218.0 (35.34)	5120.7 (34.68)	3024.6 (20.48)	304.8 (2.06)	1476.4 (100)

*** one feddan (fed) = 4200 m².**

Animal wastes are recycled in animal feeding (Gabr *et al.*, 1991-a & b and Abdelhamid *et al.*, 2001-b). However, organic fertilizers are usually animal manures or plant wastes and cuttings (green manure). Manure from chickens, goats, sheep, ducks, pigs, rabbits, cattle and horses are excellent fertilizers for fish ponds. Six to eight kilogram of ducks manure are the application rate per 100 m^2 per week, i.e. each 100 m^2 of pond needs 10 – 15 ducks to supply manure (Bocek, non). However, feed costs in the aquaculture are about 30 – 60% or 30 – 85% of the total changeable costs, according to the degree of intensification (Shiau, 2002 and Wet and Linde, 2007, respectively).

It is estimated that 20 ducks produce one ton of manure per year. Although washings from chicken pens used to be applied directly into ponds, the present practice in most areas is to ferment them for 10 to 15 days before application. A major objective of integrated fish culture is to reduce operating costs and maximize the farmer's income. The farm has increased its fish production almost nine times and the production of ducks three to five times in China (FAO, 1981).

Jian (1985) identified the so-called "integrated fish farming" as diversification, overall rural development and comprehensive utilization of fisheries, agriculture, forestry and commerce, with emphasis being placed on fisheries. It is a model farming system for full utilization of local resources, for waste recycling and energy saving, and for maintaining ecological balance and circulation. Besides increasing the supply of fish, meat and eggs, and employment opportunities. It also reduces the cost of fish production through utilization of local farm products as fish feeds and fertilizers and reorganization of farm labor for effective output. Moreover, feed supplementation to manure ponds led to significant increase in fish weight and yield (Abdel-Gawad *et al.*, 2003), the increase was improved too by increasing feeding rate of the supplement (Middendorp, 1995). Tacon (1995) concluded that methodological approaches for undertaking research on the dietary nutrient requirements of farmed fish should ensure that the studies are designed and conducted in such a manner that the ensuing results can be applied under practical farming conditions.

Rakocy and Mc Ginty (1989) cited that although yields of mouth-brooding tilapia are not as high those obtained with feed, fertilizers and animal manures can be used to reduce the quantity and expense of supplemental feeds. An increase in natural food has a much greater effect on tilapia production at densities less than 4.000/acre. Manuring may have application in the production of tilapia as a source of fish meal for animal feeds. The quality of manure as fertilizer depends on several factors. Pig, chicken and duck manures increase fish production more than cow and sheep manure. Animal fed high quality feeds (grains) produce manure that is better as a fertilizer than those fed diets high in crude fiber.

Abdel-Halim *et al.* (1998) reported superiority of tilapia growth in complete feed ponds. However, they registered maximum net return from chemical fertilizers plus duck droppings treatment. They recommended the latter system for extensive local fish farming. Also, Abdel-Hakim *et al.* (1999) reported that duck manure with supplementary feed produced the heavier and longer fish bodies of Nile tilapia as well as higher total fish production than in ponds treated only with duck manure. Yet. The last group (duck manure) had higher net return than duck manure plus supplementary feed.

Yet, Abdel-Halim *et al.* (1998) reported higher net production of polycultured fish species (Nile tilapia, common carp and silver carp) on complete feed ponds (1515 Kg/ha) followed by those on chemical fertilizer plus cattle feed (1067.5 Kg/ha), then those on chemical fertilizer plus duck droppings (979 Kg/ha), and lastly those on chemical fertilizer alone (845.6 Kg/ha). Whereas the net return and % return on average investment were the best (1760 L.E. and 82.4%) for the ponds treated with chemical fertilizer plus duck droppings. So, they recommended this treatment for extensive local fish farming. In a 120-day study on integrated fish-duck production system in earthen ponds (2000 m^2 each, stocked with 4000 fish/pond), Abdel-Hakim *et al.* (2000-a) found that total fish (Nile tilapia) production at the end of this study for duck manure (DM) and DM + artificial feed (DM + F) treatments were 1273.3 and 1485.3 Kg, respectively. The DM + F treatment increased significantly the final fish weight, average daily gain and survival rate.

Nagdi *et al.* (1998) compared chicken litter for 60 days replaced by complete feed (25% protein) then after, complete feed only (25% protein at 3% of fish biomass), and chemical fertilizer only (urea/super phosphate) for Nile tilapia (20000 juveniles/hectare) in earthen ponds. They obtained high production (19.81 Kg/ha/day) in the chicken litter ponds against 11.62 and 8.94 Kg/ha/day for ponds fed exclusivity with complete feed and those fertilized with chemical fertilizers, respectively

Duck manure of 125 ducks per pond (2000 m^2) plus 3% of fish biomass as daily feeding rate (25% crude protein) was the best treatment in an experiment for integrated poly culture of fish (4000 fish/pond) with farm animal (Abdel Hakim *et al.*, 1999) concerning body weight and fish production comparing with the other treatments (5 Kg buffalo manure/pond/day + 3% daily feeding rate on 17% protein diet, or duck manure or buffalo manure only at the same rates). Yet, the SGR and net return were lower for this treatment for all reared fish species (*O. nilaticus, O. aureus*, and *Cyprinus carpio*).

Fish species reared in integrated ponds exhibited better body weight, food conversion and protein efficiency ratios compared with those of fish species in the non-integrated ponds. Fish yield produced from the integrated ponds was significantly higher than that obtained from non-integrated ones (Soliman *et al.*, 2000).

Payer (2001) mentioned that ducks and goose are bred with fish since thousands of years in subtropics such as Egypt in its Nile and Nile Delta as an old tradition. He added that there are 9 million ducks in Egypt at 1999. Concerning integrated agriculture – aquaculture technology (duck – fish culture), the same author cited that benefits of ducks include high fish production, producing valuable eggs and meat, loosen the pond bottom releasing nutrients which increase pond productivity without labor for spreading manure, and get 50 – 75% of their feed from the pond in the form of aquatic weeds or insects and mollusks. Each feddan requires 84 – 126 ducks.

Nile tilapia yields in organic fertilization plus formulated feed treatments were significantly greater than the yield from chemical fertilization ponds. A larger percentage of harvested tilapia in the organic fertilization plus feed treatments was classified in the first and second class size categories compared with the traditional Egyptian system (Green *et al.*, 2002).

The highest daily gain of tilapia was in the treatment of poultry litter (400 Kg/fed/week) comparing with the other treatments [200 Kg poultry litter/fed/week with or without 1.5% daily feeding rate, cow manure (400 Kg/fed) or inorganic fertilizers] (Hafez *et al.*, 2002). Also, Hafez *et al.* (2003) revealed that performance results in terms of live body weight, body weight gain, specific growth rate and condition factor clearly showed that the commercial diets (pellets or mash) exhibited superior performance of Nile tilapia rather those either treated with manure (cow or chicken) or agriculture by-products (bagasse) compost as fertilizers for the earthen ponds.

2.3- Fish composition:

The lowest ($P \leq 0.05$) crude protein (CP) content was associated with significantly high ether extract (EE) content in the fish of pond NO. 8. Yet, the fish of pond No. 3 contained the highest ($P \leq 0.05$) dry matter (DM). However, there was no specific trend for the variations among the experimental treatments in the chemical composition of the whole fish body of the experiment (Table 9).

Table 9: Chemical analysis of the whale fish at the start and at the end of the experiment as affected by the treatments (means ± standard errors).

Pond No.	DM %	On DM basis (%)			
		CP	EE	Ash	EC Energy content (Kcal/100 g)
At the start	75.865^{cd} ± 0.054	58.090^{abc} ± 0.872	16.575^{d} ± 0.485	25.335^{a} ± 0.385	484.095^{f} ± 0.325
1	75.855^{cd} ± 0.044	55.080^{bc} ± 1.122	18.855^{bc} ± 0.596	26.065^{a} ± 0.526	488.640^{f} ± 0.701
2	76.280^{b} ± 0.170	56.085^{abc} ± 1.208	20.350^{ab} ± 0.240	23.565^{ab} ± 0.967	508.420^{cde} ± 4.543
3	76.810^{a} ± 0.059	57.530^{abc} ± 0.792	21.500^{a} ± 0.069	20.970^{bc} ± 0.852	527.430^{cde} ± 5.134
4	75.650^{d} ± 0.049	56.985^{abc} ± 0.00	19.745^{abc} ± 0.185	23.270^{ab} ± 0.571	507.790^{cde} ± 3.931
5	75.670^{d} ± 0.000	58.195^{abc} ± 0.375	21.360^{a} ± 0.541	20.445^{c} ± 0.165	529.860^{ab} ± 2.988
6	76.225^{b} ± 0.124	58.685^{a} ± 1.328	21.350^{a} ± 0.604	19.965^{c} ± 0.014	532.525^{a} ± 4.909
7	76.085^{bc} ± 0.085	58.385^{a} ± 0.325	18.095^{cd} ± 0.285	23.520^{ab} ± 0.039	500.110^{def} ± 0.862
8	76.790^{a} ± 0.180	55.005^{c} ± 1.007	21.315^{a} ± 0.218	23.680^{ab} ± 1.935	511.440^{bcd} ± 14.442

a–f: Means in the same column superscripted by different letters significantly ($P \leq 0.05$) differ.

However, Abdel-Hakim *et al.* (2000-b) came to the conclusion that increasing poultry manure (150, 300 and 450 Kg/fed/week) of silver carp ponds at a lower stocking density (3200 fish (75.36 g)/fed) resulted in significant increase in growth parameters, flesh weight and crude protein content of the whole fish body but decreased its fat content. Negative relationship between CP and EE was reported frequently in tilapia fish

(Abdelhamid *et al.*, 1998, 1999, 2002, 2004-a & b, 2005-a & b) and other fish species (Abdelhamid *et al.*, 2001-a).

Ayyat *et al.* (2000) reported that increasing dietary protein level from 20.6 and 25.7 to 31.5% increased fish body protein and reducing fish body fat. Also, body composition of fish species was affected by the type of farming. Carcass crude protein of grey mullet, silver carp and tilapia was improved in the integrated system (Soliman *et al.*, 2000).

2.5- Fish profitability:

Table 10 illustrates data of the experimental ponds concerning production costs inclusion fry cost, feed cost, and labor and other costs. Total inputs took the descending order from pond No. 7, pond No. 3, pond No. 5, pond No. 6, pond No. 1, pond No. 4, pond No. 2 to pond No. 8, being 5367.1, 3642.2, 3614.0, 2962.9, 2829.0, 2654.1, 1690.3 to 508.5 LE., respectively. Yet, the total fish production price took the descending order from pond No. 1, pond No.3, pond No.7, pond No.4, pond No. 6, pond No. 5, pond No. 2 to pond No. 8, being 4594, 4512, 4200, 4058, 4046, 3704, 3198 to 1970 LE, respectively. This means that the best return was from pond No. 1 [for its highest productivity from the high class (quality) fish], being 1765.0 LE, followed by pond No. 2, 1507.7 LE (for its lowest feed costs). Whereas pond No. 7 was the worst one, since it realized loss of 1167.1 LE, because it was depending only on artificial feed (without duck); so, it consumes the highest feed quantity with the highest feed cost (even the high fish price did not compensate the high feed cost). Yet, pond No. 8 (with manure only without artificial feed) reflected reasonable return, being 1461.5 LE more better than ponds No. 7, 5, 3, 6 and 4, being -1167.1, 90.0, 869.8, 1083.1 and 1403.9 LE, respectively. However, all the experimental ponds realized 7013.9 LE as a total (allover) return, regardless to the loss of pond No. 7, i.e. regardless of the ponds No. or experimental treatments.

Table 10: Inputs and outputs* of the experimental fish ponds throughout the 4-month rearing period in LE/pond.

Pond No.	Feed consumed, Kg	Feed price	Fry cost	Labor and other costs	Total inputs	Fish production price	Return
1	1270	2349.5	367.0	112.5	2829.0	4594	1765.0
2	672	1243.2	334.6	112.5	1690.3	3198	1507.7
3	1748.5	3234.7	295.0	112.5	3642.2	4512	869.8
4	1220	2257.0	284.6	112.5	2654.1	4058	1403.9
5	1692	3130.2	371.3	112.5	3614.0	3704	90.0
6	1330	2460.5	398.9	112.5	2962.9	4046	1083.1
7	2599	4868.2	446.4	112.5	5367.1	4200	-1167.1
8	--	--	396.0	112.5	508.5**	1970	1461.5
Total	10531.5	20536.4	2893.7	900.0	24330.3	30282	7013.9

***Price of one ton diet was 1850 LE, price of one Kg tilapia fish class super, No. 1, No. 2, No. 3 and No. 4 was 7.2, 6.25, 6, 5 and 5 LE, respectively, and price of 1000 fry was 60 LE.**
****Without duck manure price.**

Average body weight of tilapia class super, No. 1, No. 2, No. 3 and No. 4 was 179, 147, 111, 79 and 55 g, respectively.

Table 11 presents return of the experimental ponds in relation to the surface unit (feddan). In this case, the 4th treatment realized the best return, being 4971.6 LE/feddan, followed by the 1st, 2nd, and the 8th treatments, being 4848.3, 4542.5 and 3720.2 LE/feddan, respectively. These best treatments in the return may be due to high fish production of the best fish classes (high average weight per fish or low number of fish per Kg), high average daily gain per fish, and/or low feed costs. So, the 8th treatment (no artificial feed cost) although its low fish productivity and quality; yet, it was more profitable than the 7th, 5th, 6th and 3rd treatments, concerning the return in LE per feddan. However, 8 feddans with this experimental design can output 21181.1 LE as allover return from fish selling only after 4-month rearing period.

Table 11: Fish performance and productivity of the experimental earthen ponds of Nile tilapia fish during 4-month rearing period, calculated per feddan.

Pond No.	Total fish production, Kg	Total fish production price, LE	Average weight, g/fish	Average daily gain, g/fish	Return, LE
1	2184	12619	124.1	1.001	4848.3
2	1648	9635	109.0	0.875	4542.5
3	2331	15419	148.6	1.205	2972.5
4	2316	14371	120.7	0.973	4971.6
5	1678	10056	97.0	0.775	244.3
6	1784	10225	105.4	0.845	2737.1
7	1806	9484	89.0	0.708	-2635.4
8	812	5015	64.0	0.500	3720.2
Total	14559	86824	107.2	0.860	21181.1

Economic indicators (net return and net return on investment) ranked the best performance in the order of chicken litter, feed mixture only and chemical fertilizers, respectively (Nagdi *et al.*, 1998). The data on return on sales, return on costs, return on equity, pay-back period and break-even point showed that the integrated system was more profitable than the non-integrated system (Soliman *et al.*, 2000). Organic fertilization plus formulated feed pond management strategies had the highest net returns, average rate of return on capital and the highest margin between average price and break-even prices to cover total variable costs or total costs (Green *et al.*, 2002). Also, Abdel-All *et al.* (2001) working on Nile tilapia for 5 months in earthen ponds. Fish from ponds fertilized by poultry manure 400 Kg/feddan weekly for 60 days followed by artificial feeding (25% protein at 3% daily rate of tilapia biomass) gave higher return than the control (artificial feeding only). Moreover, Hassan *et al.* (2005) found that poultry manure of rice fields was more better than cow manure or minerals fertilization concerning common carp final weight, SGR, survival rate, net production, and net return.

From other studies, it is concluded that rearing Nile tilapia in earthen ponds with low level of organic fertilizer gave the best growth rate and optimum fish production with a high level of profitability (Abdel-Tawab and Sweilum, 2004). Increasing poultry manure (from 75, 150 to 225 Kg/fed./week) in rice fields at stocking rate of 1500 Nile tilapia fingerlings (22.2 g)/fed led to higher total fish yield, individual final fish weight, net fish yield and profitability as well as fish dry matter and protein contents and lower fat and moisture contents (Hassan, 2004). Also, Hassan *et al.* (2006) reported that increasing chicken manure (from 150, 250 to 350 Kg/feddan/week) at stocking density of 6300 *Tilapia aurea* fingerlings (65.8 g) / feddan resulted in higher relative growth rate, daily gain, total gain, yield and carcass quality (dress-out, filet and edible parts) of the earthen pond fish than at higher stocking rate (8400 fish/feddan) or lower manuring rate.

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دراسات على نظام تكامل إنتاج الأسماك/البط :
١ – على جودة المياه وإنتاج الأسماك

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تم إجراء دراسة فى أحواض ترابية على نظام تكامل الأسماك/البط فى ١٢٠ يوما. لم تتأثر معنويا قياسات جودة المياه(درجة الحرارة – الأس السالب لتركيز أيون الهيدروجين – تركيز الأكسجين الذائب – الملوحة – أعداد الهوائم النباتية) بالمعاملات التجريبية، مع ذلك انخفض معنويا كل من أعداد الهوائم الحيوانية وأعداد معظم أنواعها فى مياه الأحواض غير المحمل عليها بط. كانت المعاملة الثالثة (٤٠ بطة/حوض مع معدل تغذية يومى من وزن الأسماك ٥% لشهرين و ٤% لشهر ثالث و ٣% فى الشهر الرابع) هى الأفضل من حيث الوزن والطول النهائيين للأسماك، الزيادة الكلية واليومية فى وزن جسم الأسماك، معدل النمو النوعى، الإنتاج الكلى والإنتاج من الرتب الجيدة للأسماك. وكانت المعاملات بدون تحميل البط (تغذية صناعية أو تسميد بزرق بط فقط) هى الأسوأ من حيث هذه القياسات المختلفة. لذا ينصح بتحميل البط مع التغذية الصناعية للأسماك.