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Improvement of the Aquatic Environment for the Nile Tilapia (*Oreochromis niloticus*) via a New Developed Automatic Feeding System

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ABSTRACT

This study aimed to improve the production environment for the Nile tilapia (*Oreochromis niloticus*) through developing a new automatic feeding system (AFS), focusing on optimizing water physicochemical parameters, fish growth rates, and the economic viability of the Nile tilapia farming. The experiment was conducted using six fiberglass tanks, each with a capacity of 0.25m³. Three of these tanks were equipped with a new AFS, while the other three utilized a conventional AFS. A total of 150 fingerlings, each with an initial weight of 13.50g, were randomly distributed at a density of 25 fish per tank. Throughout the duration of the experiment, water quality parameters were systematically measured and recorded. The fish were fed with a sinking commercial diet containing 30% crude protein, administered at a rate of 5% of their body weight. The obtained results revealed statistically significant differences (P<0.05) between the two AFSs, with the newly developed AFS exhibiting an improved water quality, enhanced growth rates, and a greater economic viability.

INTRODUCTION

Nutrition is crucial for the growth and production of fish, and a significant challenge in advancing aquaculture is the design of effective feeding systems. The processing of feed to align with the nutritional needs of fish is vital for optimizing production benefits. According to **El-Sayed (1999)**, the costs associated with nutrition account for over 60% of total production expenses. It is commonly observed that cultivators manually distribute feed, a practice that can lead to two primary issues. The first issue is the escalation of feed costs due to overfeeding, while the second issue arises from the potential for leftover feed that remains uneaten, which can contaminate pond water and disrupt its pH balance. Furthermore, inadequate nutrition resulting from improper feeding practices can hinder fish development, as noted by **Zuriati *et al.* (2021)**. To address these challenges, various direct and indirect strategies have been implemented. Direct methods include the use of self-feeders that allow for more precise control over feeding amounts, while indirect approaches often involve automated devices designed to deliver feed to fish in a more regulated manner.

Nutrition engineering serves as a pivotal approach to optimize fish feeding practices, ensuring high feeding efficiency while simultaneously maintaining water quality by managing the residues from uneaten feed, as noted by **Ogunlela and Adebayo (2016)** and **Uddin *et al.* (2016)**. They further emphasized that advancements in technology could significantly enhance the efficiency and profitability of aquaculture practices, while also minimizing labor demands, which in turn lowers the overall costs associated with fish production.

In light of the aforementioned context, this research aimed to develop an automatic fish feeder that ensures effective management of fish feedings, ultimately improving both feed utilization and the overall health of the fish population. An automatic fish feeder serves as a prime example of this innovation, operating as a device that dispenses feed to fish at scheduled intervals. This system effectively regulates feeding activities through a combination of mechanical and electrical systems, thereby replacing the conventional approach of manual feeding. Consequently, the main aim of this study was to enhance water quality in fish breeding ponds during various breeding periods, while also taking into water quantities utilized for cultivation purposes. By achieving this, it is expected that more favorable economic outcomes can be realized, thereby promoting sustainable practices within the realm of fish production.

MATERIALS AND METHODS

This experiment was conducted in the Central Laboratory of Aquaculture Research in Abbassa, Abou-Hammad town, Sharkia Governorate, Egypt.

Experimental fish and rearing conditions

A total of 150 Nile tilapia (*Oreochromis niloticus*) fingerlings, each with an average initial weight of 13.4g ± 1.75, were utilized in this study. The fingerlings were distributed to six circular fiberglass tanks of 80cm of diameter and 60cm of depth, providing a net water volume of 0.2m^3. The fish were randomly assigned to the tanks at a density of 25 fish per tank. Continuous aeration was maintained in each tank through the use of a 2 hp blower and air stone diffusers. The fish were fed a basal diet containing 30% crude protein, administered at a feeding rate of 5% of their biomass. The duration of the trial was set at 120 days.

Description of the treatment's procedure

The present study was investigated to include two distinct feeding treatments. The first treatment (TAF) involved the use of a traditional automatic feeder for fish feeding, as illustrated in Fig. (1). The second treatment (DAF) utilized a developed automatic feeder, which featured a movable structural feeding trough that was covered with fabric, as depicted in Fig. (2). Each treatment was replicated three times.

DAF was equipped with a feeding trough consisting of a galvanized iron structure consisting of rectangular prism covered on all sides other than the surface with a water-permeable cloth by dimensions 30 × 30 × 30cm. This trough is connected to the device by means of four ropes connected to its four corners by means of hooks, where these ropes are connected to the device through two horizontal columns linked to the device and they are connected to a motor, where it moves them in a circular motion in the same direction to raise the feeding trough from the water after the end of the feeding process, and a reverse movement to descend when the feeding process is carried out (Fig. 3).

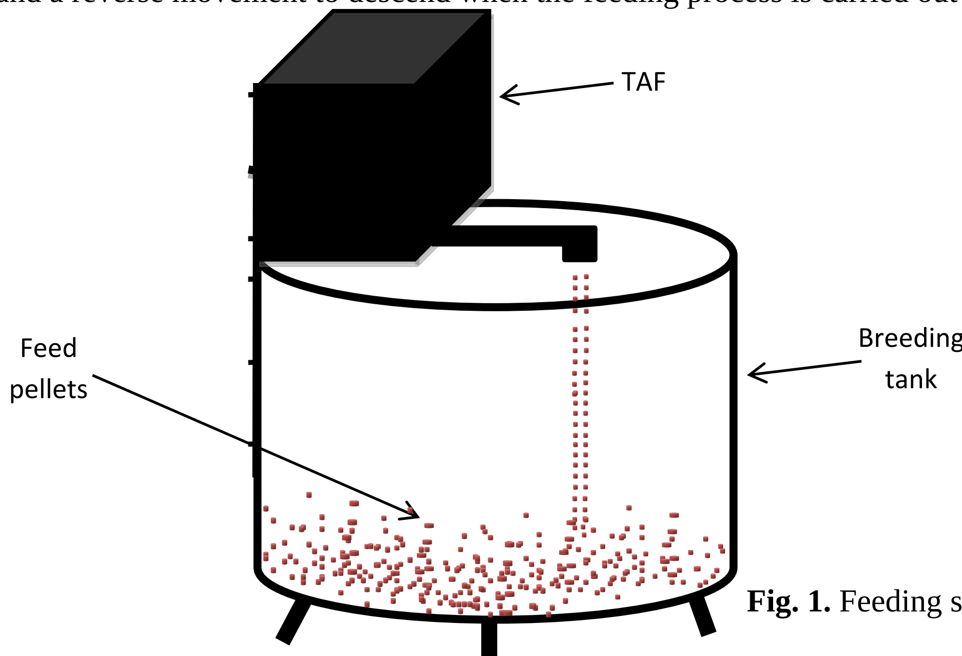

Fig. 1. Feeding system by TAF

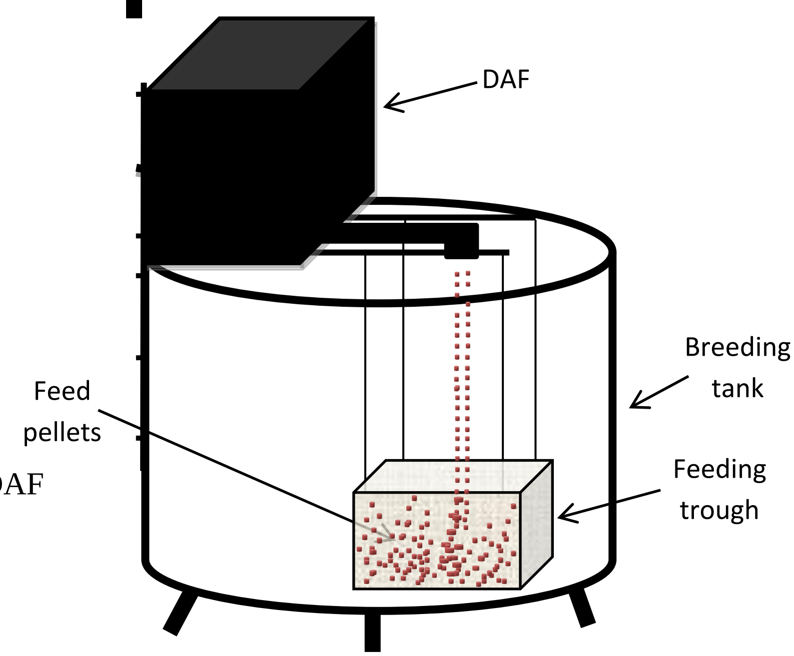

Fig. 2. Feeding system by DAF

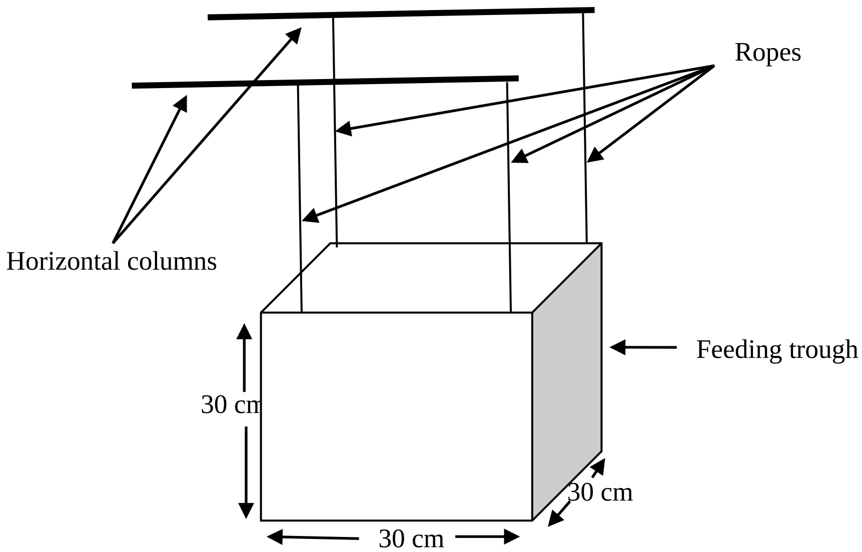

Fig. 3. Feeding trough

Water physiochemical indicators

Water temperature and dissolved oxygen were daily measured using an oxygen and temperature meter (model DOH_SD1), which has a measurement range of 0.00 to 20.00mg/ l for dissolved oxygen. This meter was also used to measure water temperature. pH was measured daily with a pH meter (model AD110), which features compact automatic calibration, functionality indicators, low battery indication, and temperature measurement with compensation.

Total phosphorus (TP), total ammonia nitrogen (TAN), nitrite (NO2), and nitrate (NO3) were measured using chemical methods according to **Scheiner (1974)** and **APHA (1985)**.

Calculations

The following calculations were conducted according to **Salem (2016)**:

Body weight gain (BWG) = final weight (g) – initial weight (g).

Feed conversion ratio (FCR) = feed intake (g) / weight gain (g).

According to **Jauncey and Rouse (1982)**, relative growth rate was conducted:

RGR = BWG × 100 / initial weight.

Specific growth rate (SGR %) = ((ln W_2 – ln W_1) / period in days) 100.

Fish production cost

This cost includes the cost of each tank, fingerlings, fish feed and each automatic feeder which it can divide to the following:

Fixed cost

Deprecation cost was calculated by the following equation **(Sheply & Schantzl, 1984)**:

Deprecation cost = (Initial price – Salvage value) / Useful life in hours.

Salvage value has been assumed as 0.1 of the initial prices.

Interest on investment cost = (Unit price + Salvage value * 0.18) / (2 * yearly operation hours).

Variable costs

Fish Price, Diet Cost, and Labor Cost: The labor cost was estimated at 500 EGP per month for simple tasks such as draining feed residues and monitoring the tanks in the fourth treatment.

Electricity Costs: These were calculated based on the Egyptian Ministry of Electricity's rate of approximately 0.48 EGP per kWh.

Repair and Maintenance Costs: These were considered at a rate of 90% depreciation **(Salem, 2016)**.

Miscellaneous cost

According to **Salem (2016)**, miscellaneous cost = (V + F) * 0.05. Where, V = variable costs, F = fixed costs and 0.05 = coefficient of miscellaneous costs as a percentage of variable and fixed cost.

Net profit was calculated using the equation of **Younis *et al.* (1991)**:

P = (Yt * d) – Ct

Where, p = net profit EGP/m^3, Yt = total yield (number of fish / m^3), d = yield price (50 LE / 1000 g) and Ct = total production costs (EGP / m^3).

Statistical analysis

The comparatives of means were conducted using independent sample t- test, using SPSS software version 23.

RESULTS AND DISSCUTION

Water quality

Table (1) indicates the levels of dissolved oxygen (DO), temperature, and pH after the 1st and 2nd months of the experimental duration. The results showed no significant effects ($P > 0.05$) between the two groups. However, total phosphorus (TP), total ammonia nitrogen (TAN), nitrate (NO3), and nitrite (NO2) were significantly higher ($P < 0.05$) in the TAF group compared to the DAF group. After 90 days, the water quality indices followed the same trend as those in the 1st and 2nd months, except for pH, which significantly increased in the TAF group compared to the DAF group. All water parameters after 1st and 2nd month were within the acceptable limits for health and growth of fishes, according to **Boyd (1990)**, **Abd EL-Aal (2006)** and **Shaker and Mahmoud (2007)**.

During the 3rd month, high levels of total ammonia nitrogen (TAN) and nitrite (NO_2) were observed, reaching means of 9.92 and 0.364mg/ l, respectively. This resulted in a mortality rate of 90% of the stocking density in the TAF group compared to the DAF group. Consequently, the TAF group was discontinued, while the DAF group continued for an additional month.

The results showed that the DAF group had low levels of nitrite (NO_2) at the end of the experiment. This may be due to simple chemical reactions **(Wheaton, 2017)** as follow:

$$NH_4^+ + OH^- + 1.5O_2 \longrightarrow H^+ + NO_2^- + 2H_2O + 59.4\ Kcal$$

$$NO_2^- + 0.5O_2 \longrightarrow NO_3^- + 18.0\ Kcal$$

$$2NO_3^- + 2H^+ + 21\ Kcal \longleftrightarrow N_2O + 2O_2 + H_2O$$

Table 1. Water quality measurements during the experimental period

Items	DO, mg/l	T, ºC	pH	TP, mg/l	TAN, mg/l	NO3, mg/l	NO2, mg/l
30 day after starting trial							
TAF	5.707	26.417	7.867	1.200a	5.130a	37.264b	0.183a
DAF	5.873	26.487	7.877	0.755b	4.320b	37.404a	0.105b
Sig.	0.057	0.272	0.823	<0.001	<0.001	<0.001	<0.001
60 day after starting trial							
TAF	5.687	24.943	7.943	1.824a	7.710a	30.258a	0.145
DAF	5.787	24.96	7.92	0.812b	5.510b	28.349b	0.132
Sig.	0.474	0.78	0.599	<0.001	<0.001	<0.001	0.012
90 day after starting trial							
TAF	5.68	24.507	8.400a	2.245a	9.920a	25.376a	0.364a
DAF	5.63	24.53	8.000b	0.954b	6.740b	24.885b	0.197b
Sig.	0.836	0.875	<0.001	<0.001	<0.001	<0.001	<0.001

Fish growth measurements

The results of growth rate and feed conversion ratio were presented in Table (2). There were significant differences between two groups in FW, WG, FCR, RGR, and SGR. The best growth and FCR was found with DAF.

The results are in line with those of **Amend *et al.* (1982)**, **Colt (2006)** and **Colt *et al.* (2009)**, who found that fish are usually grown at high densities to achieve large profits, but with these high densities, water quality deteriorates and concentrations of ammonia, nitrate and nitrite rise. Moreover, **Brooks and Conkle (2019)** affirmed that water quality deteriorates due to the accumulation of uneaten food and the generation of toxic nitrogen species.

Table 2. Growth performance of the Nile tilapia automatic-fed for 90 days

Items	Treatments		Sig.
	TAF	DAF	
FW, g	120.00^{b}	132.00^{a}	<0.001
WG, g	106.60^{b}	118.60^{a}	<0.001
FCR,	1.554^{a}	1.511^{b}	<0.001
RGR, %	795.520^{b}	885.077^{a}	<0.001
SGR, %/ days	2.357^{b}	2.543^{a}	<0.05

Economic efficiency

The eonomic study is shown in Table (3).

Table 3. Economic efficiency per fish of the Nile tilapia automatic-fed for 90 and 120 days

Items	Production cost, EGP	Profit, EGP
TAF, 90 days	6.95	3.85
DAF, 90 days	7.23	4.65
DAF, 120 days	10.75	7.25

It was clearly indicated from the results that the development attempt raised the quality of the culture water, which was directly reflected on the vitality of the fish and their weight gain without consuming any amounts of water.

The high percentage of nitrates in the treatments is considered an essential factor for the length of the production period until this period, as this explains the conversion of a large percentage of nitrite and ammonia into nitrates, which maintained the water quality for this long period without harming the fish.

CONCLUSION

The obtained results indicated that the most effective treatment involved the utilization of the newly developed automatic feeder, which significantly enhanced the quality of the rearing water, accelerated fish growth rates, and improved economic efficiency. The optimal fish weight recorded was 225g, suggesting that there remains potential for further advancements in this area. Although the implementation of the feeder has contributed to the preservation of water quality, it has not achieved its fullest potential, as some fish waste remains unaddressed. Consequently, it is advisable to pursue ongoing research in this field to maximize water quality over extended cultivation periods, ultimately aiming to achieve the largest possible fish size and profitability.

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