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Mechanical Treatment of Drainage Water for Fish Culture in Fayoum Governorate, Egypt

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ABSTRACT

Egypt, one of the world's biggest producers of cultured tilapia, is facing significant challenges in using drainage water for aquaculture due to the lack in freshwater. The current study was conducted to evaluate the effects of drainage water treatment on the growth and flesh quality of the Nile tilapia (*Oreochromis niloticus*), raised on five distinct fish farms in the El-Fayoum Governorate and irrigated with various drainage water sources. Fish growth characteristics, flesh quality, irrigation resources, drainage canals, and water quality of the investigated fish farms were all investigated. The Dayer El-Berka fish farm had the highest values of pH, total hardness, total alkalinity, salinity, and total ammonia, demonstrating the negative effects of the untreated drainage water on aquaculture water quality. All farms, with the exception of Dayer El-Berka and El-Bats fish farm (earthen pond), which showed a high lead content, had copper concentrations below detection limits. Wadi Al-Raian fish farm was recorded with higher cadmium concentrations. The El-Bats fish farm (concrete pond), which is watered with El-Bats drain's treated drainage water, showed the lowest levels of heavy metals. The maximum growth performance was found in the Nile tilapia raised on Wadi Al-Raian and Al-Wadi fish farms, whereas the lowest growth performance was found in Dayer El-Berka fish farms, according to productivity metrics. The current study's findings indicate that fish raised on farms that use treated drainage water for irrigation have great growth rates, superior meat quality, and safe flesh for human consumption.

INTRODUCTION

A vital and quickly expanding part of global economic stability and food security is aquaculture. Over 90% of aquaculture worldwide takes place in low- and middle-income nations, where it makes significant contributions to economic growth either directly through human consumption or indirectly through other means **(Carrera-Quintana *et al*., 2022)**. Due to consumer demands and the depletion of wild capture fisheries, aquaculture is expected to become the primary source of fish by 2030, contributing to global food security with an annual production of over 70 million tons of fish and aquatic products **(FAO, 2016; Fazio, 2019; Yogev *et al*., 2020)**.

For over 3.2 billion people worldwide, fish accounts for 20% of their average animal protein intake **(FAO, 2016)**. **Lafferty *et al*. (2015)** further obstructed the significance of fish by pointing out that the average human consumes around their body weight in seafood annually (fishes in this sense refer to edible aquatic animals and seafood). Fisheries by themselves, however, are unable to meet the rising demand for seafood. Capture fishing has been operating at or close to the boundaries of what is reasonable for aquatic ecosystems for a number of years **(Beveridge *et al*., 2013)**. Aquaculture has expanded as a result of new technology and innovations, but these wild capture fisheries have stagnated **(Anderson *et al*., 2017)**.

There are still various obstacles standing in the way of aquaculture production's intensification: the lack of suitable sites; habitat destruction; worries about adverse environmental effects; conflicts between uses; climate change; bacterial contamination; infectious disease outbreaks that negatively affect farmed (and possibly wild) populations' health and welfare in addition to heavy metal toxicity **(Jennings *et al*., 2016; Handisyde *et al*., 2017; Ahmed *et al*., 2019; Emenike *et al*., 2021)**.

Aquaculture can effectively recycle and repurpose water that would otherwise go to waste by using drainage water **(Tom *et al*., 2021)**. According to **Ibrahim *et al*. (2023)**, drainage water is water that has been utilized for various industrial or agricultural purposes and contains nutrients that may be advantageous for aquaculture systems. This water may originate from industrial wastewater, livestock sewage, or irrigation runoff **(Soliman, 2020; Marmen *et al*., 2021; Rodgers *et al*., 2022)**. Aquaculture may benefit the environment and the economy by using drainage water. Aquaculture producers can lessen their dependency on freshwater sources—which are getting harder to find in many areas—by employing drainage water. Furthermore, aquatic plants can get their fertilization from the nutrients in drainage water, which eliminates the need for synthetic fertilizers. This can encourage more environmentally friendly methods and lessen the negative effects of aquaculture on the ecosystem **(Asgary & Kaviani, 2018)**.

However, there are a number of hazards associated with using drainage water in aquaculture, therefore it must be carefully examined. Contamination of drainage water by contaminants such wastewater, fertilizers, pesticides, and solid waste is one of the main risks. The health and welfare of aquatic animals may suffer when these pollutants are introduced into aquaculture systems **(Quyet, 2021)**. Moreover, untreated wastewater and municipal garbage are frequently found in drainage water, which might introduce bacteria and diseases that are hazardous to the aquaculture environment. This puts the growth and survival of the aquatic species at risk by allowing illnesses and infections to spread among them. The influence on water quality is another danger connected to the use of drainage water in aquaculture **(Awaad *et al*., 2020)**. Drainage water must be properly treated and its quality closely monitored before being used in aquaculture systems **(Lindholm-Lehto, 2023)**.

Aquaculture using fish can suffer greatly from water pollution. High concentrations of pollutants, including pesticides, heavy metals, and organic pollutants can be found in polluted water. These toxins can impair fish development and health, which in turn affect the quality of fish raised in aquaculture systems. Water pollution can have both direct and indirect effects on fish aquaculture, including slower development rates, higher stress levels, and a greater vulnerability to illness and death **(Manalo & Hemavathy 2023)**. Because aquaculture benefits both humans and the environment, treatment of aquaculture for the mitigation of heavy metals and other contaminants has gained popularity in recent years **(Emenike *et al.*, 2021; Kong *et al.*, 2023; Mosleh *et al.*, 2023)**. Therefore, the current study's goal was to investigate how mechanical drainage water treatment affects the growth indices and flesh quality of fish raised on *Oreochromis niloticus* cultures.

MATERIALS AND METHODS

The present field study examined the water quality of five fish farms in El-Fayoum Governorate, focusing on irrigation source, the main drains and the cultured Nile tilapia (*Oreochromis niloticus*). The studied farms are located near Wadi El-Raian first Lake, El-Wadi drain, El-Bats drain, and Dayer El-Berka drain that receive agricultural drainage water by law. The Nile tilapia fries were cultured in the studied fish farms, with a number of fries varying between 10000 for earthen pond (per fadan) and 15000 per pond in the concrete treated water fish farm (200m^3 with 15m diameter). Two of the five farms were subjected to water treatment mechanically, Wadi El-Raian that receive drainage water through Wadi El-Raian tunnel (9.24km, treat and precipitate pollutants) and El-Bats concrete pond receiving artificial mechanical water treatment through sandy filters. Water and fish samples were collected every 15 days for six months to follow up growth rate of cultured fish. Application of ethical consideration was approved by Fayoum university Institutional Animal Care and Use committee (FU-IACUC).

Water sampling and physiochemical analysis

Water samples were collected from the five fish farms and their irrigation drains at least five localities in each of the studied sites between 10.00 and 12.00 a.m., approximately 30cm below the surface water. The samples were mixed together in a plastic container, then placed in clean polyethylene bottles (washed with detergent, then with deionized water, 2 M nitric acid), then deionized water again, and finally surface water. Samples were filtered in the field and acidified with 10% HNO_3 for preservation, placed in an ice bath and brought to the laboratory for physicochemical analyses.

For on-site sampling, pH was measured using a pocket-pH meter, salinity was measured using a salinity-conductivity meter, total hardness and total alkalinity were measured by titration method according to the American Public Health Association standard methods, ammonia, nitrite, and nitrate were measured according to the American Public Health Association standard methods, and heavy metal concentrations in water (Copper, lead, and cadmium) were determined by an atomic absorption spectrophotometer (model, Milton Roy 21D).

The cultured *Oreochromis niloticus* fish were collected from five fish farm sites every two weeks to assess the impact of drainage water treatment on productivity of fish farms. The growth indices were determined, including weight gain, daily weight gain, specific growth rate (SGR), initial biomass (IBM), final biomass (FBM), feed conversion ratio (FCR), and survival rate (SR). Weight gain was calculated as the difference between the final main body weight (W_f) and the initial main body weight (W_i). Specific growth rate (SGR) was determined as the percentage of body weight gain per day using the equation postulated by **Allen and Wooton (1982)**. Initial biomass was calculated using the equation W_i x (IF/fadan), while final biomass was calculated using the equation W_f x (FF/fadan).

Diets and fish carcass were analyzed according to **AOAC (2010)** methods: Samples were dried in a drying oven at 70°C for 24 hours, then at 105°C to a constant weight. Ash content was determined by ashing dried carcass at 550°C in muffle furnace for three hours. Crude protein was determined by micro-Kjeldhal method, %N × 6.25 (using Kjeltech autoanalyzer, Model 1030, Tecator, Höganäs, Sweden). However, for lipid content, ether extract, soxhlet apparatus with petroleum ether (60 –80°C) were used for 16h extraction.

Statistical analyses

The results were statistically analyzed using the analysis of variance (F-test) followed by Duncan's multiple range test to determine differences in means for each studied parameter using the statistical analysis systems, version 6.2 **(SAS, 2000)**.

RESULTS AND DISCUSSION

Five fish farms in the El-Fayoum Governorate that are irrigated using various drain systems are the subject of the study. While the fifth farm was irrigated by the Wadi El-Raian initial lake, the other four farms used agricultural drainage ditches. Water from two farms is mechanically treated. The study addressed how *Oreochromis niloticus*, a common species of cultivated fish, is affected by the quality of the water. It also investigated the productivity of fish farms and the quality of the flesh of *Oreochromis niloticus*.

Water quality

The study investigated five fish farms that use various drains for irrigation in the El-Fayoum Governorate. While the fifth farm used Wadi El-Raian First Lake for irrigation, the other four farms used agricultural drainage ditches. Two farms have their water treated mechanically. The quality of *Oreochromis niloticus*, a common species of cultivated fish, was examined considering the effects of water quality. It also looks at fish farm productivity and the quality of the flesh produced by *Oreochromis niloticus*.

Table (1) shows the quality indices and irrigation resources of the water collected from the several fish farms under study (Wadi Al-Raian, Al-Wadi, El-Bats (Concrete pond), El-Bats (Earthen pond), and Dayer El-Berka). The results of the analysis of variance (F-test) indicated that there were significant differences between the irrigated fish farms and the various drains under study in terms of pH, total hardness, salinity, ammonia, nitrite, nitrate, and phosphorus (F- values = 6.8, 109.9,107.3, 340.1, 14.5, 77.2, 8.1, and 26.4 respectively).

While the maximum mean pH value of Dayer El-Berka Fish Farm was 8.5± 0.08, pH values for the investigated fish farms were consistently on the alkaline side and ranged between 8.1 and 8.5, which is suitable for fish farming (6.0 – 9.0 fish farm standard according to **Meade (2012)**). The fish farms' water sources from drainage canals had lower pH levels than the fish farms themselves. The water of the Dayer El-Berka fish farm had excessive levels of salt, total alkalinity, total hardness, and pH, according to the current statistics.

Significant volumes of carbon dioxide are released into the water as a result of fish farm operations, which use artificial diets in fish ponds. The artificial feed has two main functions: it feeds fish and enriches the environment with nutrients, making natural food sources more accessible. But over 80% of the artificial feed ends up as wasted feed and excrement instead of being digested. The respiratory mechanism gets rid of most of the extra organic materials **(Osman *et al*., 2010)**.

Padmavathi and Prasad (2017) found that high pH levels in pond water are connected with algal blooms. In contrast to fish ponds, the drains channel did not get nutritional supplies, which decreased the metabolic CO_2 production in these canals. Additionally, the results collected indicated that Dayer El-Berka fish farm had higher total ammonia (NH_3) than the other fish farms. This difference could be attributed to the decomposition or the large amount of organic waste in the Dayer El-Berka drain. The production of ammonia is dependent on the pH and temperature of the water; at high pH and temperatures, significant levels of free hazardous ammonia are generated **(Soltan *et al*., 2016)**.

Out of all the primary inorganic nitrogen compounds, nitrate is the least hazardous. It is produced as the final byproduct of nitrification, and its concentrations are typically greater than those of nitrite and ammonia **(Nzeagwu *et al*., 2017)**. On the other hand, according to **Chang *et al*. (2019)**, nitrite is an intermediate result of aerobic nitrification. The NO3 and NO2 levels in the farms under investigation varied greatly from one another in the current study. In comparison with other farms, El-Bats Fish Farm's nitrate and nitrate levels in the concrete pond were incredibly high. Higher fish densities may be the cause of this since uneaten feed can produce significant amounts of ammonia-nitrogen, and the breakdown of solid fish wastes produces a higher amount of $NH_4{}^{+}$ -N as a byproduct of metabolism **(Peterman, 2011; Ude *et al.*, 2018)**. Given that NO_3-N is the most stable form of inorganic nitrogen in natural water, its concentrations are typically higher in many stations than those of $NH_4{}^{+}$ -N and NO_2-N **(Emara *et al.*, 2016; Sipaúba-Tavares *et al*., 2017; Nzeagwu *et al*., 2017)**.

Table 1. Quality of water collected from some selected fish farms irrigated with the main drains in El-Fayoum Governorate, Egypt

Studied sites of collection	pH	Total hardness as $CaCO_3$ mg/l	Total alkalinity as $CaCO_3$ mg/l	Salinity g/l	NH_3 mg/l	NO_2 mg/l	NO_3 mg/l	PO_4 mg/l	Cu^{+2} P.l. = 2 mg/l	Pb^{+2} P.l. = 0.01 mg/l	Cd^{+2} P.l. = 0.003 mg/l
Wadi Al-Raian drain	8.05± 0.04D	410± 3.1E	196± 1.6F/G	0.66± 0.01G	1.9± 0.04B	0.42± 0.003D/E	3.2± 0.08B/C	0.71± 0.009B/ C/D	2.2± 0.3B	0.30±0.008A/B/ C/D	0.005± 0.0003D
Wadi Al-Raian lake after treat. 1	8.3± 0.13 A/B/C/D	467.6± 17.7 F/G	195.3± 1.5 D/E	1.5± 0.001D/ E/F	0.14± 0.01B	0.06± 0.001E/F	3.3± 0.08B/C	0.11± 0.03 D	0.0003± 0.00007D	0.267± 0.0007A/B/C/D	0.011± 0.002D
Wadi Al-Raian fish farm (irrigated with Wadi EL-Raian first lake)	8.1± 0.08 C/D	570.6± 40.7 C/D	235± 5.7 D/E	1.9± 0.08C	0.19± 0.01B	N.D	4.3± 0.63 B	0.24± 0.10C/D	N.D	0.21± 0.039 D/E	0.043± 0.01C
El- Wadi drain	7.7 ± 0.06 E/F	540.3 ± 11.4 C/D	283.6 5.003± C	1.32 ± 0.07 D/E/F	1.3 ± 0.04 B	1.7 ± 0.18 C	7.3 ± 0.08 A	0.93 ± 0.03 B/C	0.93 ± 0.056 C	0.237 ± 0.029 A/B/C/D	0.12 ± 0.004 A
Al- Wadi fish farm (irrigated with EL-Wadi drain)	8.2± 0.10 B/C/D	502± 40.9 C/D/E	215± 9.6 E/F	1.5± 0.08C/D	0.21± 0.01B	0.52± 0.004D	2.2± 0.20 C/D	0.28± 0.11C/D	N.D	0.213± 0.04 C/D/E	0.006± 0.0003D
El-Bats drain	7.6± 0.02 F	598.6± 26.5 C	247.38.2± D	1.2± 0.03E/F	1.7± 0.13B	2.2± 0.32 B	4.5± 0.29 B	1.3± 0.10B	3.27± 0.28 A	0.33± 0.019 A/B	0.066± 0.018B
El-Bats filter	8.4± 0.23 A/B/C	610± 3.1 C	206.6± 14.2 F	1.1± 0.01F	1.2± 0.32B	3.6± 0.005 A	3.04± 0.56 B/C/D	1.08± 0.07B	N.D	0.213± 0.007 C/D/E	0.006± 0.0003D
El-Bats fish farm (Concrete pond) (Mechanical treatment of EL-Bats drain)	8.4 ± 0.12 A/B/C	589.6 ± 28.6 C/D	233.6 1.7± D/E	1.5 ± 0.18 D/E	0.85 ± 0.33 B	1.6 ± 0.005 C	7.04 ± 2.07 A	0.87 ± 0.09 B/C	N.D	0.127 ± 0.05 E	0.01 ± 0.0005 D
El- Bats fish farm (Earthen pond) (irrigated with EL-Bats drain)	8.5± 0.12 A/B	544.6±53.2 C/D	174.3± 11.4 G	1.5± 0.06C/D	0.27± 0.007B	N.D	1.1± 0.10D	0.28± 0.11C/D	N.D	0.32± 0.009 A/B/C	0.007± 0.0004D
Dayer El-Berka drain	8.01± 0.06D/E	982.7±81.4B	427.7± 11.3B	3.5± 0.39B	18.8± 4.7A	0.06± 0.002E/F	6.7± 0.52A	5.2± 0.9A	0.986± 0.007C	0.34± 0.02A	0.006± 0.0004D
Dayer El-Berka fish farm (irrigated with Dayer El-Berka drain)	8.5± 0.08A	2263.8±114.3A	450.6± 14.2A	10.2± 0.15A	1.1± 0.10B	0.09± 0.0001E/F	3.03± 0.24B/C/D	0.08± 0.001D	0.003± 0.0007D	0.227± 0.05 A/B/C/D	0.02± 0.003D
F-values	**6.8*****	**109.9*****	**107.3*****	**340.1*****	**14.5*****	**77.2*****	**8.1*****	**26.4*****	**88.83****	**3.86****	**21.26****

Data are represented as means of six samples ± Sterr.
N.D. = Not detectable.
P.l. = Permissible level in water according to **WHO (2021)**.
Means with the same letter for each parameter are not significantly different, otherwise they do.
** Highly Significant difference (P< 0.01).

Nitrate is comparatively harmless to fish and does not pose a health risk until it is present in extremely high concentrations (over 90mg/ l) according to **Stone and Thomforde (2004)**. **Santhosh and Singh (2007)** reported that fish culture water has a good range of 0.1 - 4.0mg/ l. It is important to note that there is a clear negative significant association between N-forms and salinity, with N-forms being lower in water with higher salinity. Similar observations were reported in the studies of **Bach and Shin (2011)** and **Shaaban *et al*. (2022)**. Fish's metabolic rate is impacted by the increasing salinity, which lowers the ammonia generated by metabolic processes **(Kır & Öz, 2015)**.

A limiting nutrient required for the growth of all plants, including algae and aquatic plants, is phosphate. Nonetheless, excessive quantities cause algal blooms, particularly in rivers and lakes **(Nzeagwu *et al*., 2017)**. El-Bats Fish Farm (concrete pond) displayed the highest values of dissolved inorganic phosphorus (DIP) (0.87mg/ l) in comparison with other fish farms, similar to dissolved inorganic nitrogen (DIN). This might be because the El-Bats fish farm's concrete pond has the highest fish density, and phosphorus is one of the primary nutrients found in aquaculture wastes **(El Zokm *et al*., 2018)**. Furthermore, fish meal often has phosphorus levels up to 17µM. Accordingly, fish population and phosphorus levels in the pond are related **(Osman *et al*., 2010)**. The current study's findings fell between the 0.01 and 3mg/ l permissible range for aquaculture among the fish farms under investigation, as previously recorded by **Bhatnagar and Devi (2013)**.

Given their toxicity and danger to plant and animal life, heavy metals pose a major threat to the aquatic environment and disrupt the delicate balance of the ecosystem **(Bhattacharya *et al*., 2008)**. According to the current study, there was a relative fluctuation in the values of the three heavy metals (copper, lead, and cadmium) among the several fish farms that were irrigated with treated drainage water from the main drains in El-Fayoum Governorate. For all the investigated fish farms, Pb was more abundant than Cd and Cu in terms of concentration levels. With the exception of the Dayer El-Berka Fish Farm (0.003mg/ l), all the investigated fish farms had copper concentration values below the detected limit. El-Bats Fish Farm (earthen pond) had the highest lead content (mean of 0.32mg/ l) of any of the farms that used El-Bats drain for direct irrigation without any pre-treatment (mean of 0.33mg/ l). The lowest value was found in El-Bats Fish Farm (concrete pond), which used El-Bats drain's treated drainage water (mean of 0.127mg/ l). However, the Wadi Al-Raian Fish Farm had greater cadmium contents. Comparatively, the water in fish farms contained almost all of the metals under study at lower concentrations than the corresponding values in feeding drains. Furthermore, **Abd El-Atti *et al.* (2018)** and **Taha *et al*. (2021)**, hypothesized the presence of heavy metals in drainage water; and this finding agrees with the current study.

One important factor that can be used to determine the success of aquaculture biota development is the production performance **(Hartnoll, 2012)**. Growth metrics are crucial markers of the fish's overall health **(Harianto *et al*., 2021)**. In general, changes in an organism's metabolic processes are reflected in its growth **(Abdel-Tawwab *et al*., 2016)**. The purpose of the study was to determine how different water sources affect the Nile tilapia's growth. The fish farms of Wadi Al-Raian and Al-Wadi have the best growth performance, according to the results, whereas Dayer El-Berka and El-Bats (Earthen Pond) have the worst growth performance (Table 2). These results might have something to do with the water quality used to irrigate the fish farms under study.

It is often recognized that one of the external elements that significantly influences the growth of aquatic species is the water sources utilized for fish farming and its quality parameters **(Altan, 2020)**. The distribution and activity of aquatic creatures are significantly influenced by the physical, chemical, and biological characteristics of the water **(Chaudhuri *et al*., 2012)**. Aquaculture water quality affects disease burden, growth, feeding, and survival **(Chainark & Boyd, 2010)**. **Rakocy (1990)** reported that the problem is caused by low water quality. Fish may not be able to consume enough due to stress caused by high ammonia, nitrite toxicity, low dissolved oxygen, high carbon dioxide, or other issues with water quality. Furthermore, the pH and ammonia levels of the water are essential for the culture of tilapia. When the pH of the water changes from the appropriate range for the species, it might have an impact on fish performance and survival. Fish exhibit behavioral and physiological changes when subjected to difficult pH circumstances **(Abd El-Hack *et al*., 2022)**.

Fish are poisoned by unionized ammonia, which is present in higher concentrations at higher pH values **(Stone & Thomforde, 2004)**. According to **El-Sherif and El-Feky (2008)**, ammonia is poisonous to tilapia at concentrations of 7.1mg/ L, whereas it has the reverse effect at as little as 0.1mg/ L. Fish cannot expel ammonia at toxic levels, hence it builds up in the blood and tissues and changes the way enzymes work.

Growth rates are slower, feed conversion is less, and disease resistance is lower **(Gandhi, 2012)**. Marine life is more vulnerable to ammonia at higher pH levels and temperatures. A higher pH corresponds to a higher concentration of unionized ammonia. For every unit increase in pH, the NH_3 to NH_4 ratio rises by 10, and for every 10 units increase in temperature, it rises by 2 **(Levit, 2010)**. The findings exhibit a favorable link with the pH and ammonia levels of the water at Wadi Al-Raian and Al-Wadi fish farms. Furthermore, Dayer El-Berka Fish Farm and El-Bats Fish Farm (Earthen Pond) reported the highest values for water pH and ammonia, which had an impact on their growth and output.

High-density tilapia cultures have shown promise, but because individual studies do not address issues originating from multiple interaction factors, it has been challenging to compare the results with research on low-storage tilapia **(Ali *et al*., 2006)**. There appears to be little information regarding the relationships between water quality parameters, such as dissolved oxygen, pH, and ammonia excretion, and the performance of growth, stock density, and size variation, despite the fact that numerous studies have examined the growth, survival, and production of various tilapia species under various stocking densities **(Ali *et al*., 2006)**. El-Bats Fish Farm (concrete pond) had the best growth performance in this experiment, which was explained by the high stocking density. **Pinto *et al*. (2011)** analyzed Thailand's productivity and red tilapia subjected to varied stock densities (200, 250, and 300 fish/m^3) and examined the feasibility of the cages ($1m^3$) put on farm ponds. They observed that the stocking density examined in the trials had no effect on tilapia growth (P>0.05).

Table 2. Productivity parameters of *Oreochromis niloticus* on the different studied fish farms irrigated with treated drainage water of the main drains at El-Fayoum Governorate, Egypt

Studied fish farms	Initial MBW (gm)	Initial biomass (kg)	Initial no of fry	Feed intake (kg)	Final MBW (gm)	Final biomass (kg)	Survival rate (%)	Final no of fry	FCR	SGR (%/day)	Daily weight gain(gm)	Weight gain(gm)
Wadi Al-Raian fish farm(irrigated with Wadi EL-Raian first lake)	0.94 ± 0.029	9.4 ± 0.29B	10000	3850.03± 243.2B	290 ± 5.7A	2745.6 ± 68.01B	94.6 ± 0.88A	9466 ± 88.1B	1.4 ± 0.05A	3.14 ± 0.008A	1.6 ± 0.03A	289.05 ± 5.7A
Al- Wadi fish farm (irrigated with EL-Wadi drain)	0.95 ± 0.026	9.5± 0.26 B	10000	3462.7 ± 39.5 C	266.6 ± 8.8B	2480 ± 82.01C	93± 0.0001A	9300± 0.0001B/C	1.4± 0.05 A	3.1± 0.02 B	1.47± 0.04B	265.7± 8.8B
EL-Bats fish farm (Concrete pond) (irrigated with EL-Bats drain after mechanical treatment)	0.95 ± 0.02	14.2 ± 0.31A	15000/200 m^3	6486.3 ± 43.6A	293.3 ± 8.8A	4145 ± 114.1A	94 ± 0.57A	14133 ± 88.1A	1.5 ± 0.03A	3.15 ± 0.01A	1.62 ± 0.04A	292.3 ± 8.8A
El- Bats fish farm (Earthen pond) (irrigated with EL-Bats drain)	0.94 ± 0.017	9.4 ± 0.17B	10000	3593.4 ± 107.9B/C	248.3 ± 6B	2298 ± 74.8C	92.3 ± 0.88A	9250 ± 76.3C	1.5 ± 0.06A	3.05 ± 0.01C	1.36 ± 0.03B	247.3 ± 6B
Dayer El-Berka fish farm(irrigated with Dayer El-Berka drain)	0.95 ± 0.024	9.5 ± 0.24B	10000	3480.6 ± 32.2C	250 ± 5.7B	2325.6 ± 68.1C	93 ± 0.57A	9300 ± 57.7B/C	1.5 ± 0.05A	3.05 ± 0.006C	1.37 ± 0.03B	249.04 ± 5.7B
F-values	0.03*	66.27**		112.4**	8.8**	86.3**	1.9*	934.9**	2.2*	12.4**	9.2**	8.8**

Data are represented as means of twenty-four samples ± Sterr.
Means with the same letter for each parameter are not significantly different, otherwise they do.
* Significant difference (*P*< 0.05) ** Highly Significant difference (*P*< 0.01).

Data representing the changes in muscle chemical composition of the studied fish species; *Oreochromis niloticus* collected from the different studied fish farms irrigated with treated drainage water of the main drains in El-Fayoum Governorate, Egypt are shown in Fig. (1). Fish chemical composition is a significant area of study since it affects the fish's physical attributes and preservation quality **(Huss, 1988)**. To make sure that fish meat satisfies the requirements for food standards and commercial specifications, its protein, lipid, water, and mineral content must be determined **(Jim *et al.*, 2017)**. The current study demonstrates an effort to look into the impact of various treated agricultural drainage water sources on the Nile tilapia (*Oreochromis niloticus*) flesh quality. The primary conclusion drawn from these data was that the highest quality meat (highest crude protein and lowest ether extract and ash) was found in the Nile tilapia (*Oreochromis niloticus*) raised in Wadi Al-Raian Fish Farm and El-Bats Fish Farm (Concrete pond). Conversely, the fish farms in Dayer El-Berka and Al-Wadi had the lowest crude protein, maximum ether extract and ash content, as well as the lowest flesh quality.

A variety of factors impact the quality of fish meat, which is a significant and abundant source of white protein. Fish reproduction is also impacted by water quality, which is thought to be the primary determinant of fish quality **(Jim *et al.*, 2017; Channa *et al*., 2024)**. Fish are particularly susceptible to pollution in aquatic environments since they feed and reside there, making it impossible for them to escape toxins **(Huang *et al*., 2022)**. Since they can bioaccumulate, heavy metals have the highest potential to cause harm to fish among the several pollutants found in fish feed and water **(Zaghloul *et al*., 2022)**.

Fish populations are impacted by declining water quality in irrigated fish farms, which can hinder fish growth, reduce their chances of reproducing, and perhaps endanger fish lives **(El-Sherif & Abd El-Ghafour, 2016; Elwasify, *et al*., 2021)**. The high quantities of copper, lead, and cadmium in the lake may be caused by the industrial and agricultural drainage water that feeds it, as reported by **Abdel-Khalek *et al*. (2018)**. This water is rich in chemicals and fertilizers.

The results are consistent with the study's findings regarding the concentration of heavy metals in water, which showed that the Dayer El-Berka Fish Farm's water had the greatest concentration of heavy metals (copper, lead, and cadmium). Furthermore, the results supported those of **Elghobashy *et al*. (2001)** and **Zaghloul *et al*. (2001)**, who found that the African catfish (*Clarias gariepinus*) and the Nile tilapia (*Oreochromis niloticus*) subjected to high concentrations of heavy metals recorded a decrease in muscle total protein and total lipids. The overall protein and lipid content of fish muscles may be declining because of heavy metals that fish gills are exposed to deteriorated water. This is probably because the several fish farms under consideration are fed by agricultural drainage water. According to earlier studies by **Reader *et al*. (1989)**, metals damage the gill structure and reduce the amount of oxygen that is taken in.

The net result of these impacts is a marked decline in metabolic rate. Furthermore, when the body's muscle total protein and total lipids are decreased, tissue hydration takes place. Muscle protein, lipid, and water levels are inversely correlated according to research by **Weatherley *et al.* (1987)**. The use of body fat and/or protein as an energy source to fulfill rising physiological demands directly resulted in a decrease in body fat and protein under inappropriate conditions, as demonstrated by **El-Sayed *et al.* (1996)**.

Furthermore, **Vutukuru (2005)** noted that the consumption of protein as a substitute source of energy in response to water pollution may have contributed to the decrease in protein concentration. However, a decrease in the amount of lipids in muscle may be the result of toxin activation, which inhibits the action of the enzymes that transform lipids, disrupting lipid metabolism in the process **(Saeed & Shaker, 2008; Tulgar & Berik, 2012)**.

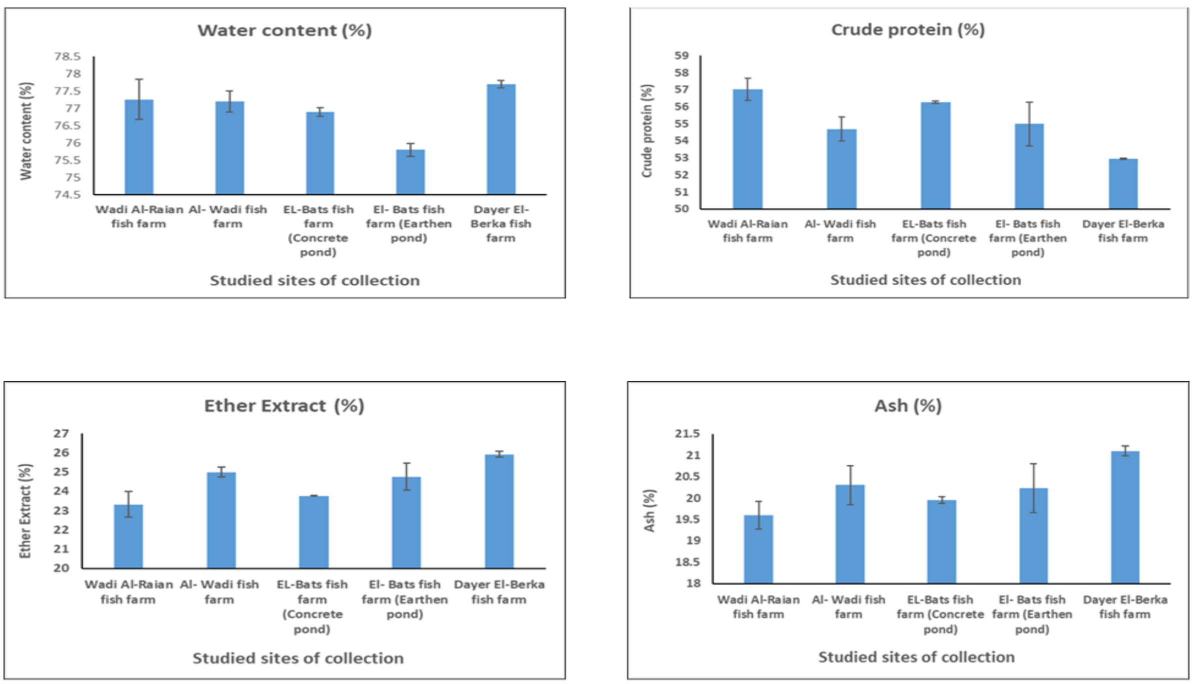

Fig. 1. Meat quality of *Oreochromis niloticus* collected from the different studied fish farms irrigated with treated drainage water of the main drains at El-Fayoum Governorate, Egypt

CONCLUSION

It can be concluded that fish raised on farms irrigated with high-quality water resources exhibit an exceptional growth performance, superior meat quality, and safe flesh for human consumption. Conversely, using untreated drainage water for fish farm irrigation may stunt fish growth and diminish meat quality. High-density tilapia cultures have demonstrated that while gross productivity increases with higher stocking densities, the net yield per individual tends to decrease.

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