Environmental Science

AIMS Environmental Science, 10(6): 743–763.
DOI: 10.3934/environsci.2023041
Received: 13 September 2023
Revised: 29 October 2023
Accepted: 07 November 2023
Published: 16 November 2023

http://www.aimspress.com/journal/environmental

Research article

Reuse of wastewaters from slaughterhouse and palm oil mill: Influence on the growth performance of catfish (*Clarias gariepinus*)

Cornelius Tsamo[1,2,*], Tita Mangi Germaine[1] and Adjia Henriette Zangue[3]

[1] Department of Agricultural and Environmental Engineering, College of Technology, University of Bamenda, Bambili, Cameroon
[2] Department of Chemistry, Higher Teachers'Training College, University of Maroua, Cameroon
[3] Department of Applied Chemistry, National School of Agro-industrial Sciences Ngaoundere, P.O. Box 455 Ngaoundere, Cameroon

***Corresponding author:** Email: tcornelius73@yahoo.com; Tel: +237676485577.

Abstract: Integrating fish farming with wastewater recycling can improve fish farming programs, ensuring environmental sustainability while improving cost of fish farming. This study examines the influence of wastewaters from slaughterhouses and palm oil mils on the growth performance of catfish. Artificial ponds created with transparent buckets, where the fingerlings were grown for six weeks, contained each wastewater type comprising 30%, 40% and 50% wastewater, the rest being tap water. Tap water was used as the control. Live body weight, weight gain, live length and gain in length of fish were used to monitor fish growth performance on a weekly basis. Pond temperature and pH were also monitored weekly. The physicochemical parameters of the water in the ponds were above the standards required for fishponds. There was no significant difference between the growth performance parameters in the control and other treatments during the entire period of study. There was also a strong correlation ($r \approx 1$) between the growth performance and the duration of study for all the treatments, indicating the fish could survive in the ponds for as long as necessary. Highest live weight of 14 g in T3R1, 13.33 g for control, 12 g for T2R1 and T4R1 were obtained. Highest live length values of 13.70, 13.50, 13.30, 13.20, 13.10 cm were obtained for T3R2, T3R3, T2R2, control and T2R3 respectively. Temperature in the adapted ponds ranged from 24–28 °C, and pH raged from 6–8. A low mortality rate of 4.16% (4 deaths) was obtained in the case of T3R3 only for the first week, but there no other mortality in other treatments throughout the period of the study. Results obtained show that wastewaters from slaughterhouses and palm oil mills can effectively be used to grow fish, reducing cost of fish farming and ensuring environmental sustainability from dumping of the wastewaters.

Keywords: catfish; temperature; pH; slaughterhouse wastewater; palm oil mill wastewater

1. Introduction

Water is undoubtedly the most precious resource on earth since it is used for almost all human activities. This implies a significant amount is generated as wastewater. It is estimated that about 380 billion m^3 of municipal wastewater alone is generated worldwide annually [1]. This amount is expected to increase by 24% in 2030 and 51% in 2050 due to continuous growth in population, improvement in water supply, living standards and economic growth. This will increase water scarcity since most developing countries lack the resources and technology to properly treat the wastewater. Reports show that 60% of the world population will suffer from water scarcity by the year 2025 [2]. Alternatively, the wastewater can be recycled or reused to reduce or eliminate environmental pollution resulting from disposal of untreated wastewater.

Amongst the activities generating much wastewater are the slaughterhouse and palm oil mills. The meat processing industry consumes 29% of the total freshwater used by the agricultural sector worldwide [3–5]. This trend will increase because in the past decade, worldwide production of beef, pork and poultry meat doubled and is estimated to grow linearly until 2050 [3]. It is also estimated that 5 to 7.5 tons of effluents are produced from 1 ton of crude palm oil (CPO) in the palm oil mills [6,7]. This effluent is a colloidal suspension containing 95–96% water, 0.6–0.7% oil and 4–5% total solids including 2–4% suspended solids [6,8,9]. Meanwhile slaughterhouse effluent is rich in organic content mainly from paunch, feces, urine, blood, lint, fat and lard, carcasses, undigested food, microbial pathogens, pharmaceuticals, disinfectants, loose meat, suspended material, facility cleanings, oil and grease, carbohydrates, proteins and lignin [9]. Numbers “2” and “6” of the 17 Sustainable Development Goals (SDGs) outlined by the United Nations (UN) are “Zero Hunger” and “Clean Water and Sanitation,” respectively [9]. These two goals are directly related to the meat industry as a result of growth and commercialization. This leads to a significant increase in the usage of water for slaughtering and cleaning of slaughtering activities in slaughterhouses and meat-processing plants. As reported by Jones et al. [10], wastewater is today considered as a potential and cost-effective source of freshwater, more especially in the domain of agriculture. Unfortunately, very scanty research has been reported on wastewater as resource [10]. This is very necessary as the global quality of water resources has been greatly altered negatively in the last 50 years [11].

The United Nations Sustainable Development Goal 6 (UN SDG6) highlighted the necessity of recycling wastewater to guarantee water availability for individuals [12]. So, by integrating fish farming with slaughterhouse and palm oil mills wastewater reuse, fish farming programs can have a direct impact on achieving SDGs by improving environmental sustainability and equally improving fish rich in protein at reduced cost to the population. In some countries fish constitutes up to 70% of the animal protein consumed; in Africa over 200 million people eat fish regularly but it accounts only for about 20% of animal protein in their diets [13]. Generally, Africa consumes the least protein daily per capita, approximately 13.61 kg per year [14]. However, the reuse of wastewater for production of food for humans poses obvious questions about the risk to human health. Most of the water used in the slaughterhouse and oil palm mills is assumed to come from domestic water or underground water which is less likely to contain harmful toxins associated with industrial wastes and direct use of surface waters [15]. According to WHO [16], risks to the consumers of fish fed with wastewater may be due to accumulation of pathogenic bacteria on the skin of fish, in their gills and in the intestines. Other studies have also reported that only *Clonorchis* and its closely related *Opisthorchis* are transmitted through fish grown in waste-fertilized or wastewater ponds [12]. However, due to the short grow out period for fish–four to six months–the accumulation of potentially harmful substances is not a major concern.

Several studies have reported the use of different media for fish growth. Ssekyanzi et al. [17] reported that the main water sources of water for fish farming in Rwenzori region of Uganda are streams/rivers (29%), swamps (35%) and groundwater/wells (26%). Awoke et al. [18] grew catfish fish using rainwater, bore hole water and well water. Yosmaniar et al. [19] investigated the optimal growth and survival performances of catfish rearing with the application of nitrifying and denitrifying bacteria. Krishnakumar et al. [20] investigated the influence of water hardness on growth and reproduction of two aquarium fishes. Ghozlan et al. [21] reported the effect of fresh water, agricultural drainage water and well water on the survival rate, growth performance, feed utilization, fish yield, economic evaluation and production of Nile tilapia while Elnady et al. [22] investigated the effect of water temperature and salinity on rearing of Nile tilapia. Jemal and Van Hulle [23] reported that the main areas of reuse for globally reclaimed water are for irrigation in agricultural sector, landscape irrigation, urban park irrigation, fish farm, industrial process cooling, firefighting, toilet flushing and aquifers recharge. But in case of fish farming, the rare study in literature integrating wastewater effluent for fish farming was reported by Girard, [24] where wastewater from municipal effluents was used. The reported literature shows that studies involving the use of different effluents are scarce and are almost nonexistent for slaughterhouse and palm oil mill effluents. This work is therefore aimed at evaluating the influence of wastewaters from slaughterhouse and palm oil mill on the growth performance of catfish. Artificial ponds with each wastewater type and mixture of the two wastewaters having three treatments (30%, 40% and 50% of wastewater type) were created with transparent buckets where the fingerlings were grown for 6 weeks. Live body weight, weight gain, live length and gain in length of fish were used to monitor fish growth performance on weekly basis. The ponds temperature and pH were equally monitored.

2. Materials and methods

2.1. Preparation of test samples

Wastewater was collected from the mile four Nkwen slaughterhouse and Bambui local palm oil mill twice a week. Water sampling was performed using polyethylene bottles washed with distilled water, followed by 10% HNO3 and distilled water again 24 h before sampling to allow it to dry properly. In the field, polyethylene bottles were washed with sample wastewater or tap water prior to collection. The sample wastewaters and tap water were treated with humivet, which was meant to prevent the fish from infection and to detoxify the water from bacterial and other microflora contamination.

One hundred fingerlings of African catfish, *Clarias gariepinus* (average weight of 3.4±0.1g), were obtained from a local fish farm in the Mankon Northwest Region of Cameroon. The fingerlings were transported in aerated plastic buckets and left to acclimatize to the experimental conditions for two weeks. The fingerlings were raised in plastic buckets (10 liters) (Figure 1) containing 5 L of tap water under a natural photoperiod of approximately 12/12 h light/dark cycle and were fed a commercial catfish feed (Belgocam) of 2.0 mm in size. After two weeks, they were ready for use in the experiment.

Figure 1. Transparent plastic buckets used as artificial fishpond.

2.2. Experimental design

A total of 96 fingerlings of African catfish, *Clarias gariepinus* (average weight of 3.4±0.1) were randomly assigned to four experimental treatments (Figure 2). The treatments consisted of wastewater from the slaughterhouse, palm oil mill, a mixture of slaughterhouse and palm oil mill and, serving as the control, tap water. These are denoted as T2, T3, T4 and T1, respectively. T1 is tap water, T2 is slaughterhouse wastewater, T3 is palm oil mill wastewater and T4 is a mixture of palm oil mill and slaughterhouse wastewaters. T2, T3 and T4 had sub-sample mixtures each containing different amounts of each wastewater type described as follows: T1:100% tap water (0% wastewater); T2R1 (30% slaughterhouse wastewater); T2R2 (40% slaughterhouse wastewater); T2R3 (50% slaughterhouse wastewater); T3R1(30% palm oil mill wastewater); T3R2(40% palm oil mill wastewater); T3R3 (50% palm oil mill wastewater); T4R1 (15%/15% palm oil mill/slaughterhouse wastewater mixture); T4R2 (20%/20% palm oil mill-slaughterhouse wastewater mixture); T4R3 (25%/25% palm oil mill/slaughterhouse wastewater mixture). Fish were raised in plastic buckets (10 L) with a total volume of 5 L of water (Figure 1). Each of the T2, T3 and T4 treatments contained 24 fish with 8 fish per sub treatment (Figure 2).

The cleaning of fish buckets was carried out every two days by siphoning out residual feed and fecal matter, while the water in the buckets was changed three times weekly.

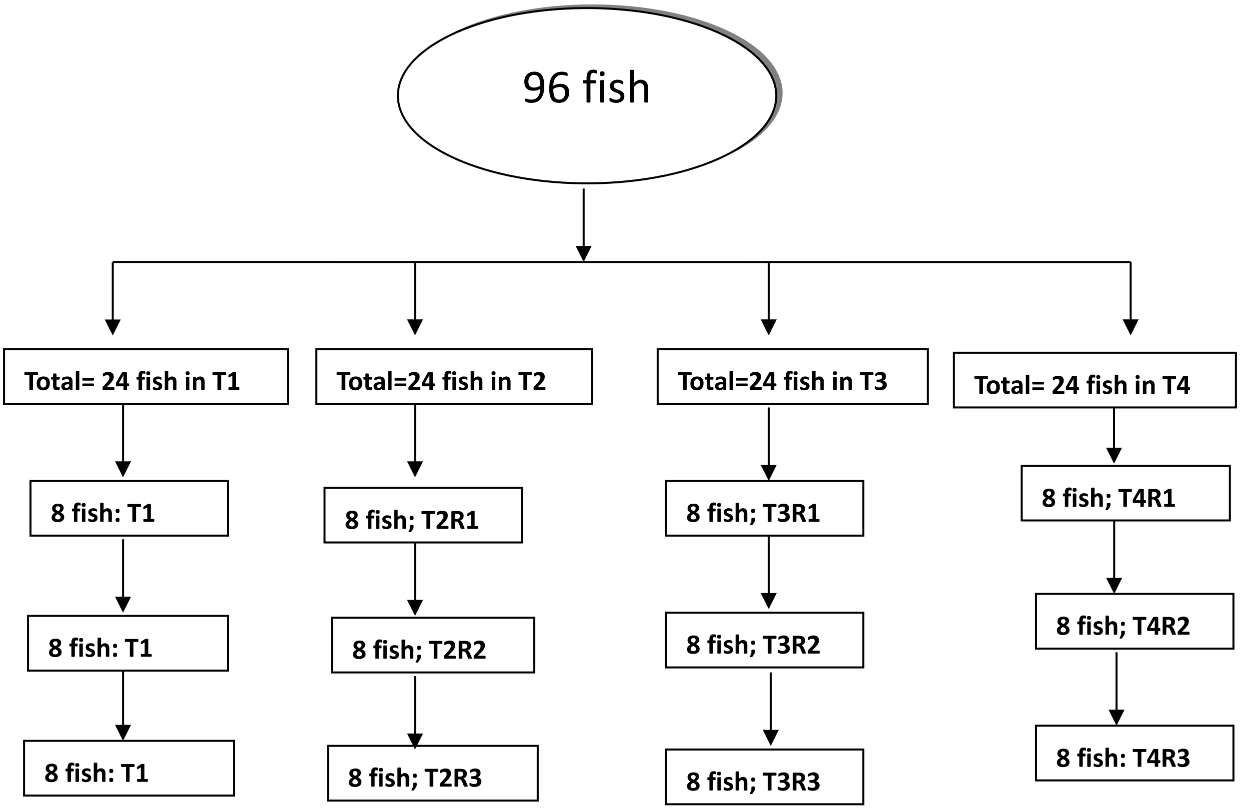

Figure 2. Experimental layout.

2.3. Determination of fish growth parameters

2.3.1. Mortality rate (MR)

Here the number of dead fish or mortality rate (MR) found in each treatment was determined using the following equation.

$$R(\%) = \frac{number\ of dead\ fish\ in\ the\ period\ of evaluatin}{number\ of\ fish\ at\ the\ beging\ of\ the\ experiment} \times 100 \quad (1)$$

2.3.2. Determination of weight gain

Weights of fingerlings were determined at the beginning of each treatment and subsequently at weekly intervals basis using an electronic balance with sensitivity of 0.1g. The weight gain was determined by calculating the difference between the initial weight and final weight (g) of the experimental fish at the end of each week according to the following equation.

$$weightgain(g) = weight\ of\ week\ \mathrm{i} - weight\ of\ weekzero(0) \quad (2)$$

i= 1, 2, 3, 4, 5 and 6.

2.3.3. Fish length

The growth in length of fish in different treatments was determined weekly, the fish length was measured with the help of a tape. The length gain was determined using the following equation.

$$length\ gain(g) = length\ of\ week\ \mathrm{i} - length\ of\ weekzero \quad (3)$$

i= 1, 2, 3, 4, 5 and 6.

2.3.4. Temperature and pH determination

Water temperature and pH were measured weekly by using centigrade thermometer for temperature and Tintometer® group (pH/ORP, DO, CD/TDS, Nr: 00724200) for pH.

2.3.5. Collection and analysis of Fresh Water Samples

Water samples were collected from ponds water surface using sterile cap bottles. The water samples were transported to the laboratory, in an ice packed container for physicochemical analyses. The conductivity, turbidity, bicarbonate ions, BOD_5, nitrogen, nitrate, nitrite, sulphate, phosphate, hardness, iron, COD, carbonate, chloride and hardness of the different treatments were determined using standard [25]. Four water samples were analyzed: T1 (tap water), T2 (slaughterhouse wastewater using the composite sample made composed of T2R1, T2R2, T2R3), T3 (palm oil mill wastewater using the composite sample made composed of T3R1, T3R2, T3R3 and T4 (mix slaughter house and palm oil mill wastewaters using the composite sample made composed of T4R1, T4R2, T4R3). 200 mL of each sub treatment was sampled to prepare the composite sample for each wastewater type.

2.4. Statistical analysis

The Microsoft Excel 2010 version was used to record, compute the data from the study; SigmaPlot 12.0 was used for descriptive analysis while OriginLab 8.0 and SigmaPlot version 12.0 were used for graphical analysis. One-way ANOVA using SigmaPlot version 12.0 was used to determine the level of significance at 95% confidence level between measured values while R and R Commander Software was used to determine the Pearson correlation between different parameters.

3. Results and Discussion

3.1. Mortality rate (MR)

A low mortality rate of 4.16% (4 deaths) was obtained in the case of T3R3 (50% palm oil mill wastewater). This was probably due to the fact that water was changed after three days and the fact that the young fingerlings could not adapt to the concentrated palm oil wastewater in the first week. However, no death was recorded after the period to change the water was reduced to two days. No death was observed in the other treatments of palm oil wastewater as well as slaughterhouse wastewater and mixtures of the two wastewaters.

3.2. Influence of inclusion of slaughterhouse wastewater on the evolution of live body weight, weight gain, fish length and length of catfish

The result of weekly live body weight and weight gain of *Clarias gariepinus* grown in ponds with the inclusion of wastewater from the slaughterhouse is presented in Figure 3a while results of weekly weight gain of catfish are shown in Figure 3b. The result revealed that the highest weight gain was obtained with the control (tap water) followed by treatment T2R1 (30% slaughter waste), T2R2 (40% wastewater) and T2R3 (50% slaughter waste). At the end of six weeks of growth therefore, maximum live body weight was in the order T1> T2R1> T2R3> T2R2 with corresponding values of 13.33 g, 12.00 g, 10.50 g and 8.00 g respectively. This same trend was observed for weight gain (Figure 3b) 9.93 g, 8.60 g, 4.60 g and 6.90 g for T1, T2R1, T2R2 and T2R3 respectively (order T1> T2R1> T2R3> T2R2). Statistical analysis shows there was not a statistically significant difference (P = 0.759) between the control and other treatments for both live body weight and weight gain. There was also not a statistically significant difference (P = 0.464) between T2R1, T2R3 andT2R2. This statistical analysis thus indicates that the slaughterhouse water can be used for fish farming just like tap water.

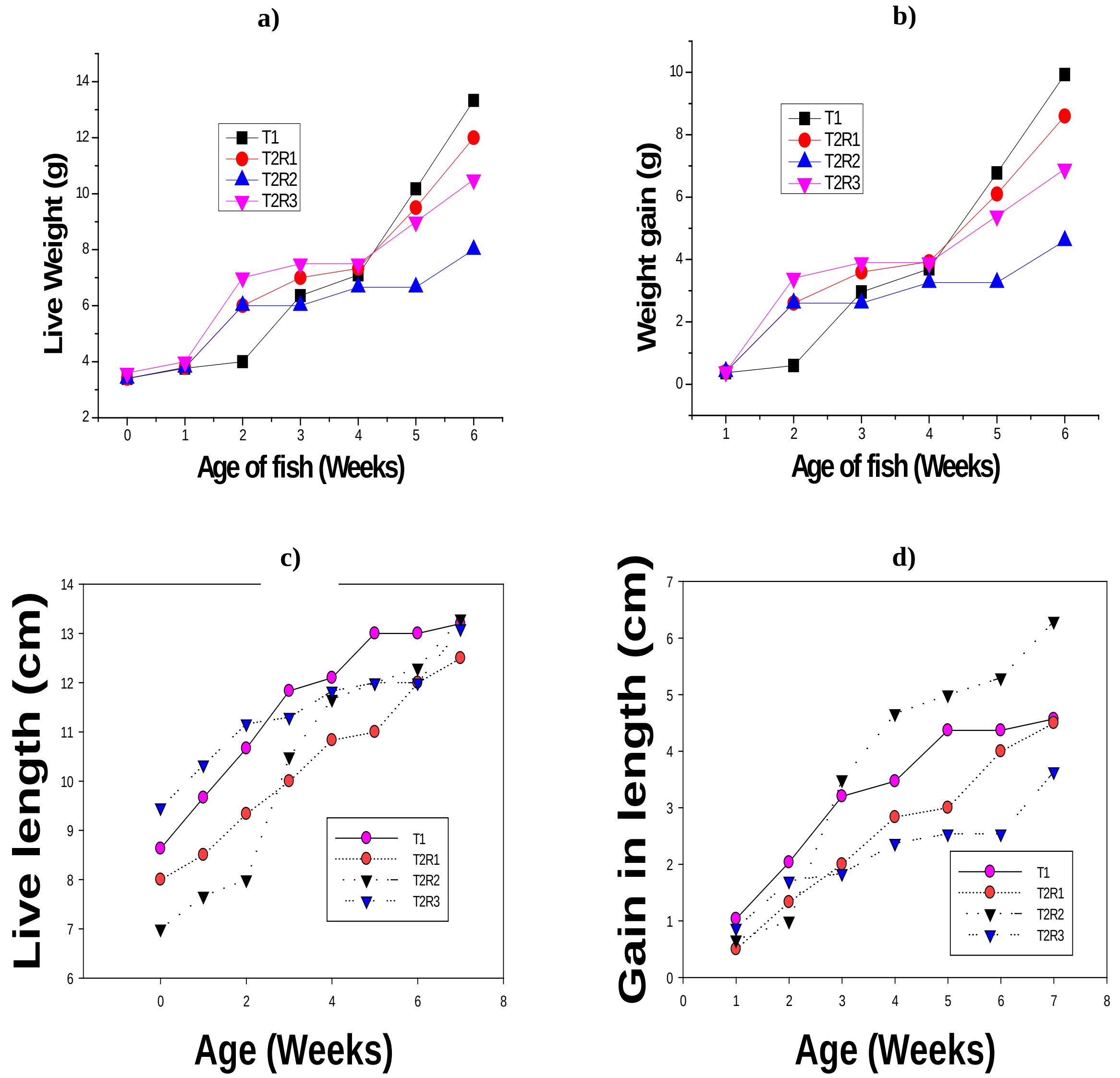

Figure 3. Weekly evolution of Influence of slaughterhouse wastewater on a) live body weight b) weight gain c) live body length, d) gain in length of African catfish as affected by wastewater from the slaughterhouse.

Results of the weekly trend on fish length as affected by the inclusion of slaughterhouse wastewater (Figure 3c), revealed a steady increase in fish length with increase time with maximum of 13.20 cm in T1, 12.50 cm in T2R1, 13.30 cm in T2R2 and 13.10cm in T2R3. The live length is of the order T2R2≥T1> T2R3>T2R1. Meanwhile results of the weekly evolution in length gain of *Clarias gariepinus* as affected by the inclusion of slaughterhouse wastewater are shown in Figure 3d. Results revealed the control treatment dominating among other treatment during week 1 through week 3. From week 3 onward treatment T2R2 dominated among all treatments closely followed by the control treatments and T2R3. The weekly trends are due to the fish trying to adapt to pond conditions. The maximum values of gains in length were 4.57 cm for the control, 4.50 cm for T2R1, 6.30 cm for T2R2 and 3.64 cm for T2R3, giving the order T2R2> T1>T2R1>T2R3. The trend in live length and length gain are also similar but shows a variation with T2R1 and T2R3 treatments. As observed from Figure 3c, T2R1 shows a steadily live length increase throughout the study period against T2R3 that also had a steady increase up to week 6 followed by a sharp rise in the last week. This sharp rise in the last week for the more concentrated T2R3 probably due to adaptation conditions for the fish. There is no statistically significant difference (P = 0.341) between the control and other treatments for live length. There was also not a statistically significant difference (P = 0.248) between the control and other treatments for length gain.

Live body weight is in the order T1> T2R1> T2R3> T2R2 while live length is of the order T2R2≥T1> T2R3>T2R1. While there is a statistically significant difference ($P \leq 0.001$) between live body weight and live length treatments, there is no statistically significant difference ($P \leq 0.573$) between weight gain and length gain treatments.

3.3. Effect of palm oil mill wastewater on the evolution of live body weight, weight gain, fish length and length of Clarias gariepinus *fingerlings*

Figure 4a illustrates the effect of inclusion of wastewater from palm oil mill on live body weight of catfish. The results show that treatments with low concentration of palm oil wastewater had higher live body weights (T1, the control and T3R1 with 30% palm oil mill wastewater) with 13.33 g for T1 and 14.0 g for T3R1. The live body weight of the fish in each of the treatments T3R2 and T3R3 was 9 g. However, there is no statistically significant difference (P = 0.986) between the control and other treatments. The oily nature of this wastewater may be responsible for the reduced live body weight as it prevents oxygen penetration into the pond at higher concentration. However, a high value of 14 g in T3R1 suggests the palm oil wastewater contain some valuable nutrients for the fish. The order of live body weight is T3R1>1 T1>3 T3R2=T2R3. The same trend for live body weight was also obtained for weight gain (Figure 4b) as values of T3R2 and T2R3 were almost the same. Values for weight gain are 9.93 g, 10.40 g, 5.40 g and 5.20 g for T1, T3R1, T3R2, T2R3 respectively giving the following order: T3R1>1 T1>3 T3R2>T2R3. There is also no statistically significant difference (P = 0.955) between weight gain in the control and the other treatments.

Figure 4c and 4d illustrate the weekly evolution of fish length as influenced by inclusion of palm oil mill wastewater. Results obtained revealed a steady increase in live length (Figure 4c) and length gain (Figure 4d) throughout the study period. For live length the following values were obtained; 13.20 cm, 12.76 cm, 13.70 cm and 13.50 cm for T1, T3R1, T3R2 and T3R3 respectively (T3R2> T3R3> T1> T3R1). For length gain the values obtained are 4.57, 3.67, 4.70, 4.50 for T1, T3R1, T3R2 and T3R3 respectively (T3R2> T1> T3R3> T3R1). There is no statistically significant difference (P = 0.520) in live length between the control and other treatments and same trend for length gain (P = 0.140).

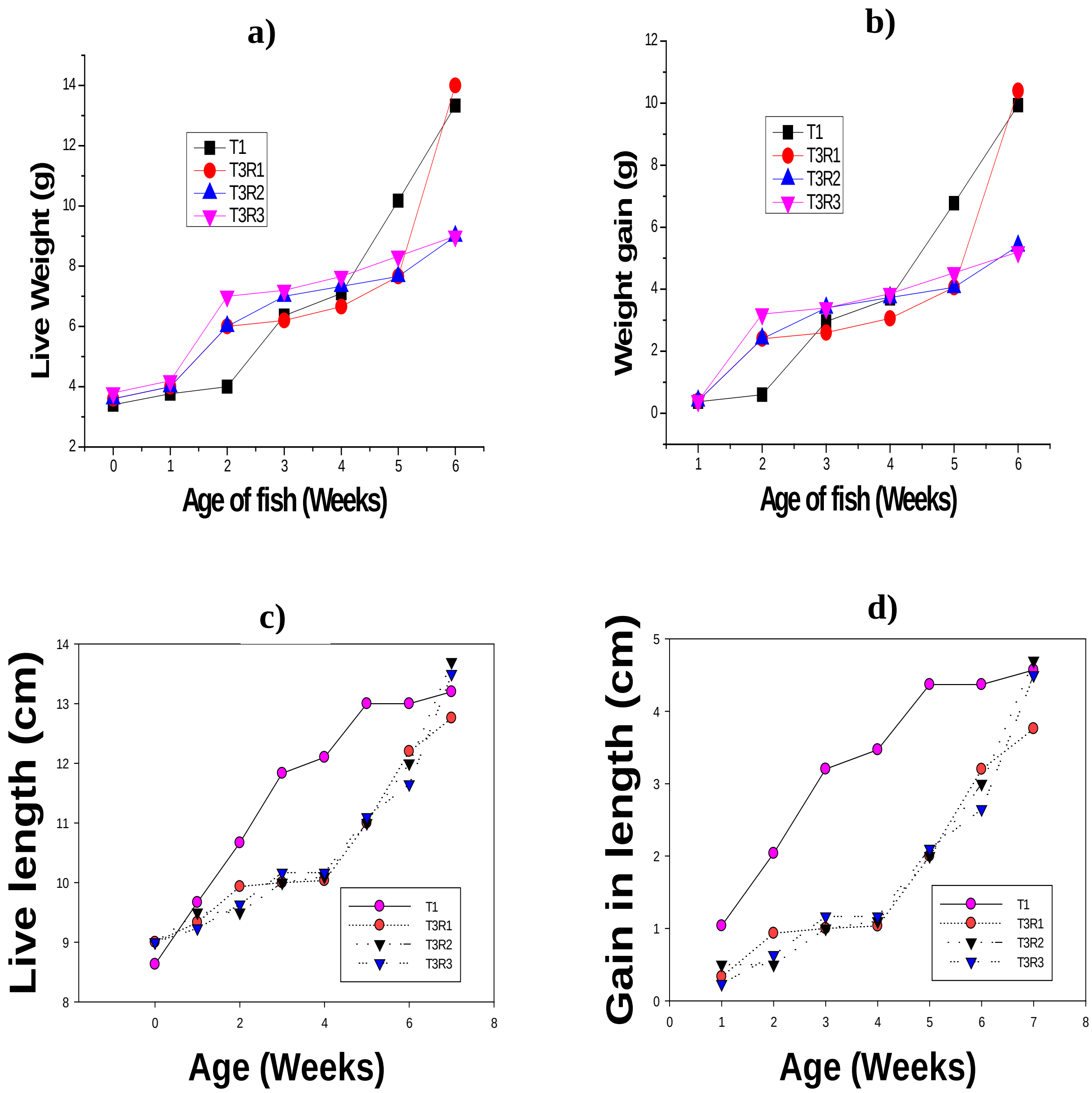

Figure 4. Weekly evolution of a) live body weight b) weight gain c) live body length d) gain in length of African catfish as affected by wastewater from palm oil mill wastewater.

3.4. Influence of palm oil mill wastewater and slaughterhouse wastewater mixture on growth performance of catfish

For every treatment tested, equal amounts of slaughterhouse and palm oil mill wastewaters were mixed and effects on live body weight of fish is shown in Figure 5a while corresponding weight gain is presented in Figure 5b. Similar to slaughterhouse and palm oil mill wastewaters studied separately, their mixtures also show increase in live body weight with time in all treatment. However, the values are very similar to those obtained with slaughterhouse 12 g for T2R1, 8 g for T2R2 and 10.50 g for T2R3. The values obtained in this mixture are; 12 g for T4R1, 10 g for T4R3 and 8 g for T4R2 (T1>T4R1> T4R3>T4R2). These findings suggest conditions in the mixture were controlled by slaughterhouse wastewater. There is no statistically significant difference (P = 0.872) in live body weight between the control and other treatments employing mixtures of the two wastewater types tested. Similar trend is observed for weight gain using the mixtures of two wastewater types tested, 9.93 g for T1, 8.20 T4R1, 4.40 g for T4R2 and 6.60 g for T4R3 (T1>T4R1> T4R3>T4R2). There is also no statistically significant difference (P = 0,694) between weight gain in the control and the treatments; T1, T4R1, T4R2, T4R3. The weight gain for slaughterhouse wastewater is of the order T1> T2R1> T2R3> T2R2. This order is the same las that obtained with the mixture of the wastewater form the slaughterhouse and palm oil mill; equally suggesting the properties of artificial ponds containing different mixtures of these two wastewaters was controlled by properties of slaughterhouse wastewater.

Results presented in Figure 5c for live length and Figure 5d for length gain revealed a steady increased during the study period with live length values of 13.20, 12.80, 12.70 and 12.50 corresponding respectively to T1, T4R1 T4R2 and T4R3 (T1>T4R1>T4R2>T4R3) and length gain values of 4.57 cm, 3.80 cm, 4.50 cm and 4.50 cm corresponding respectively to T1, T4R1 T4R2 and T4R3 (T1> T4R2=T4R3>T4R1). However, it was observed that gain in length decreases with combination of both wastewater sources. There is no statistically significant difference (P = 0.134) in live length, likewise length gain (P = 0.302) between the control and the other treatments.

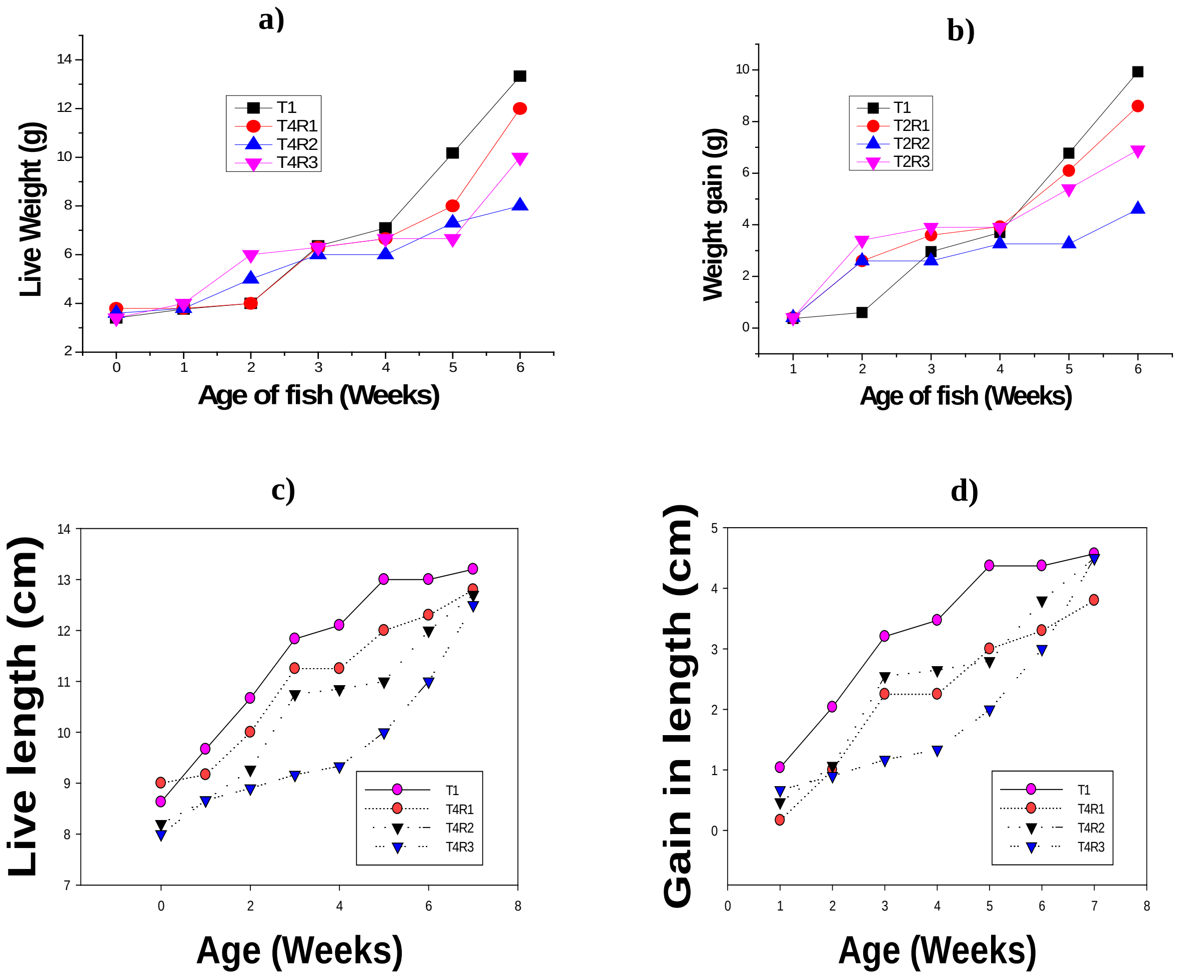

Figure 5. Effect of palm oil mill wastewater and slaughterhouse wastewater combination on a) live body weight b) weight gain c) live body length, d) gain in length of catfish (*Clarias gariepinus*).

A summary of the maximum live body weight, weight gain, live length and length gain values obtained from different wastewater treatments are presented in Table 1. It is observed from this table that higher live body weight and weight gain values are obtained for TiR1 treatments involving 30% wastewater Ti (defined in Table 1). The second observation is that the live length and length gain values obtained are higher in TiR2 treatments with 40% wastewater. The fact that live body weight is high with 30% wastewater suggests the studied wastewaters have nutrients that can enhance fish growth. However, decrease in weight at high wastewater content is probably due to stress due to factors such as high turbidity which reduces light penetration in the ponds and reduce dissolve oxygen needed by the fish. The high live length and length gain values for 40% wastewater concentration confirms the fact that stress may be responsible for reduction in weight at higher wastewater concentration because the fish length is increasing meaning it is growing.

The results obtained in this study are similar to those of Ogunji and Awoke [26], who performed a 56-day study to evaluate the effects of temperature changes on the survival, growth performance and hematology of *Clarias gariepinus* fingerlings with an initial weight of 4.33 g. According to their findings, 25–28°C is a suitable temperature range for the growth and well-being of *Clarias gariepinus*. with optimum growth occurring at 26°C, with a final body weight of 13.10 g. The highest body temperature in this study was obtained for treatments with 30% wastewater (TiR1) (Table 1) and the control, where the temperatures were within the 26°C zone. Weight gain between this study performed for 42 days and that of Ogunji and Awoke [26] performed for 59 days was very similar, with T3R1 being higher. Temperature is related to dissolved oxygen levels in water (Yosmaniar et al. 2021) [19]. If the temperature increases, the dissolved oxygen levels will decrease because with an increase in temperature, fish metabolism will increase and the level of oxygen consumption is higher. The optimal water temperature can therefore affect the rate of respiration and the metabolic rate, which greatly affects the appetite of the fish to make the fish grow faster due to great improvements in FCR and FCE (Kasihmuddin et al.) [27]. The temperature of water-based ecosystems is critical for guaranteeing the existence, production and adequate metabolic activity of fish. Inability to get used to temperature variations may result in fish mortality.

Awoke et al. [17] grew catfish using rainwater, bore hole water and well water for 28 days. The highest weight gains (0.57 g) was obtained in borehole water, 0.37 g) well water 0.37 and lowest (0.18 g in rainwater. Their study also reported that total body length gain followed the same trend with values of 1.08 for borehole water, 0.65 cm for well water 0.44 cm and rainwater. This trend according to the authors is due to the fact that underground water is usually free from suspended matter, pollutants and fish disease organisms and because its temperature and chemical composition are relatively constant. In this study, the weight and length gains were significantly higher than those reported by Awoke et al. [17] (Table 1) and Figure 3b. Figure 4b, 5b and 3d, respectively. Contrary to the results of Awoke et al. [17], weight gain and length gain did not follow the same trend (Table1). This difference was probably due to the composition of the growth media.

Yosmaniar et al. [19] evaluated the optimal growth and survival performance of catfish reared with the application of nitrifying and denitrifying bacteria NP2-DP1, nitrifying and denitrifying bacteria NP2-DP2, commercial bacteria and without bacterial isolates (control) for 30 days. The highest weight gain (12.36 grams was found in the treatment with nitrifying and denitrifying bacteria NP2-DP1, whereas the lowest value of 10.03 grams was found in the control. Similar weight gain values were obtained in the present study (Table 1). This trend was the same as the survival rate, where catfish grown in the denitrifying bacteria NP2-DP1 treatment had a 95.56% survival rate and the lowest survival rate of 80% in the control. They reported that the temperature of the water media in all the treatments ranged from 26.8–32 to ºC, which is suitable for catfish growth. They reported that it plays an important role in the survival and growth of catfish. The pH value of water media in their study ranged from 6.10 to 6.71, which is safe for catfish growth, as the water pH for catfish rearing ranges from 6.5 to 9.0, with an optimal pH of around 7–8.5. The favorable growth in other treatments of their study was also due to low nitrite and nitrate levels which were all < 0.06 mg/L and < 10 mg/L respectively, the standard required for catfish water growth medium. These values were very high for the control, 0.02–0.09 mg/L for nitrite and14.52 mg/L for nitrate. In this study nitrite and nitrate were zero in all the media except palm oil wastewater (136.44 mg/L and 92.43 mg respectively for nitrate and nitrite) (Table 2). The fact that 4.16 % mortality occurred in one of the treatments using palm oil wastewater may be due to its high nitrite and nitrate content.

Ghozlan et al. [21] also studied effects of fresh water, agricultural drainage water and well water on the growth performance of Nile tilapia for 192 days. The survival rates with fresh water and well water were 98.53% and 98.31%, respectively; however, it was 95.05% with agricultural drainage water. This trend was attributed to the water quality and temperature, which was within the temperature range for fish farming and constant for well water throughout the year, and had the best quality of water. A low mortality rate of 4.16% was obtained in the case of T3R3 (50% palm oil mill wastewater) for this study with other treatments having a 100% survival rate, further suggesting that these wastewater samples probably have some nutrients that enhance fish health.

Akinwole et al. [28] studied the growth performance of African catfish (*Clarias gariepinus*) juveniles cultured with wastewater (collected from an earthen pond stocked with African catfish) treated by solid removal, using alum and Moringa oleifera seeds as coagulants, with freshwater from deep wells as the control. Their main finding was that a higher catfish survival rate of 93.33 % was obtained with Moringa oleifera seed-treated water compared with the control (90.78 %) and 30 % with alum-treated wastewater. Thus, the performance of catfish cultured in moringa-treated water was similar to those raised in deep well water, but better than those cultured in alum-treated water. The use of alum as a coagulant led to a significant reduction in the pH of the water, whereas the pH in moringa-treated water was not affected. Similarly, Ubuoh et al. [29] observed that wastewater treated with Moringa oleifera seeds did not exhibit pH fluctuations, irrespective of the dosage. This is due to the ability of moringa seeds to remove solid waste without negatively impacting water quality.

Syaku and Solomon[30] investigated the effects detergent on the growth rate of C. gariepinus for a period of 2 months. Although the pH and temperature in the study were all within the permissible limits for catfish rearing, the detergent had a detrimental effect on the growth and survival of the African catfish (C. gariepinus), with the highest mortality rate (43.3%) observed in catfish exposed to 9 mL of detergent and 23.3% lowest mortality rate observed in catfish exposed to 1 mL of detergent, with no mortality occurring in the control. According to the authors, the reduction in the growth rates of the exposed catfish supports the findings of Esenowo and Ugumba [31], who reported that sub-lethal concentrations of a detergent in an aquarium tank reduced the weights of catfish (*Clarias gariepinus*). This is caused by an increase in metabolism due to detoxification and impaired health, which leads to loss of appetite and energy loss during exposure. Detergents have been discovered to induce poisonous effects, such as xenobiotic compounds, which could be persistent and more mobile in water; hence, they are known to be one of the most common terrestrial and aquatic contaminants. Results of their study are contrary to this study which used slaughterhouse and palm oil mill wastewaters and further shows these wastewaters can be used for fish growth pending further investigations.

Copatt et al. [32] also investigate the effects of exposure to low water hardness (0, 25 and 50mg $CaCO_3$ L^{-1}) in the 6.0–8.0 pH range to silver catfish juvenile's survival and growth after 32 days. Juveniles kept at zero water hardness presented higher mortality at pH 7.0 and 8.0, than those subjected to other treatments. The weight of juveniles exposed to pH 6.0 and zero water hardness was significantly higher than those kept at the same water hardness and other pH values. The survival and growth of juveniles exposed to 25 and 50 mg $CaCO_3$ L^{-1} were not affected in the 6.0–8.0 pH range. They recommended that the best water hardness for silver catfish juvenile growth is 25–50 mg $CaCO_3$ L-1 and at low water hardness (next zero), pH must be reduced. In this study, hardness varied from 3.2 to 6.2 mg/L and pH was dominant between 6.6 to 7.5 for all treatments (Table 2). Neyjan et al [33] studied the effect of different water hardness levels on growth indices, survival rate, hematological parameters and water quality of Caspian Kutum (Rutilus kutum) fingerlings was investigated with six water hardness treatments (350, 600, 650, 700, 800 and 900 mg of $CaCO_3$) for 56 days. Water hardness of 650 mg/L $CaCO_3$ led to the highest values of final weight, body weight gain and daily growth rate.

Table 1 Comparison of maximum values of growth performance parameters in different media.

Pond water condition	T1	TiR1	TiR2	TiR3
	Live body weight (g)			
Slaughterhouse water; i=2	13.33	12.00	8.00	10.50
Palm oil mill water; i=3	13.33	14.00	9.00	9.00
Slaughterhouse/palm oil mill water mixture; i=4	13.33	12.00	8.00	10.00
	Weight gain (g)			
Slaughterhouse water; i=2	9.93	8.60	4.60	6.90
Palm oil mill water; i=3	9.93	10.40	5.40	5.20
slaughterhouse/palm oil mill water mixture; i=4	9.93	8.20	4.40	6.60
	Live length (cm)			
Slaughterhouse water; i=2	13.20	12.50	13.30	13.10
Palm oil mill water; i=3	13.20	12.76	13.70	13.50
Slaughterhouse/palm oil mill water mixture; i=4	13.20	12.80	12.70	12.50
	Gain in length (cm)			
Slaughterhouse water; i=2	4.57	4.50	6.30	3.64
Palm oil mill water; i=3	4.57	3.76	4.70	4.50
Slaughterhouse/palm oil mill water mixture; i=4	4.57	3.80	4.50	4.50

3.5. Influence of wastewater type on fish growth media temperature and pH

3.5.1. Influence of slaughterhouse wastewater

The weekly trend in water temperature as affected by wastewater from the slaughterhouse is shown in Figure 6a while Figure 6b shows variation in pH. From Figure 6a, it can be observed that temperature was constant in the control at 25 °C and T2R2 at 28 °C but varied from 26 to 27 °C in T2R1 and 25 to 26 °C in T2R3. Results revealed a temperature range from 25 °C to 28 °C. Kasihmuddin et al. [34] reported that 26 °C to 32 °C water temperatures is very satisfactory for the growth of African catfish while Britz and Hecht [35] reported a high African catfish growth rate between 25 and 33 °C with the maximum growth occurring at 30 °C. There is a statistically significant difference ($P \leq 0.001$) in pond water temperature between the different treatments, however, they were all with the range required for catfish growth. The pH varied from 6.9 to 8 in T1, 6.7 to 7.6 in T2R1, 6.8 to 7.5 in T2R2 and 6.9 to 7.3 in T2R3. Santhosh and Singh [36] have reported that ideal pH for fish culture is between 7.5 and 8.5 and above and below this is stressful to the fishes. Observing the different curves in Figure 6b shows pH was not stable in each treatment (as most values were out of the ideal zone), hence possibly stressing the fish. However, there is no statistically significant difference ($P = 0.917$) in the pH of the different treatments.

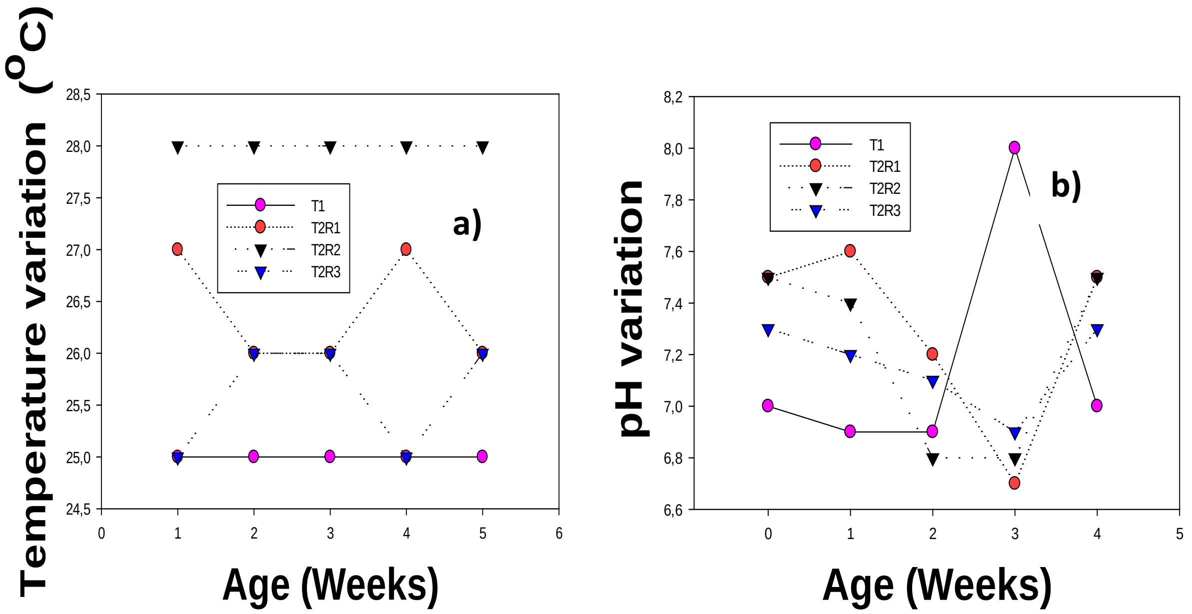

Figure 6. Influence of slaughterhouse wastewater on fishpond water a) temperature b) pH.

3.5.2. Influence of palm oil mill wastewater

The variation of temperature in adapted fish growth media containing palm oil wastewater is shown in Figure 7a while pH variation is shown in Figure 7b. From Figure 7a temperature was constant in T1 and T3R3 at 25 °C but varied from 26 to 27 °C in T3R1 and T3R2. The pH varied from 6.9 to 8 in T1, 6.3 to 7.2 in T3R1, 6 to 7.2 in T3R2 and 6 to 7.5 in T3R3. There is no statistically significant difference ($P = 0.650$) in pH values between the different treatments. The growth performance parameters for T3R2 and T3R3 were very similar (Table 2) suggesting the pH role of influencing fish growth in fishpond. Meanwhile there is a statistically significant difference ($P \leq 0.001$) in pond water temperature between the different treatments.

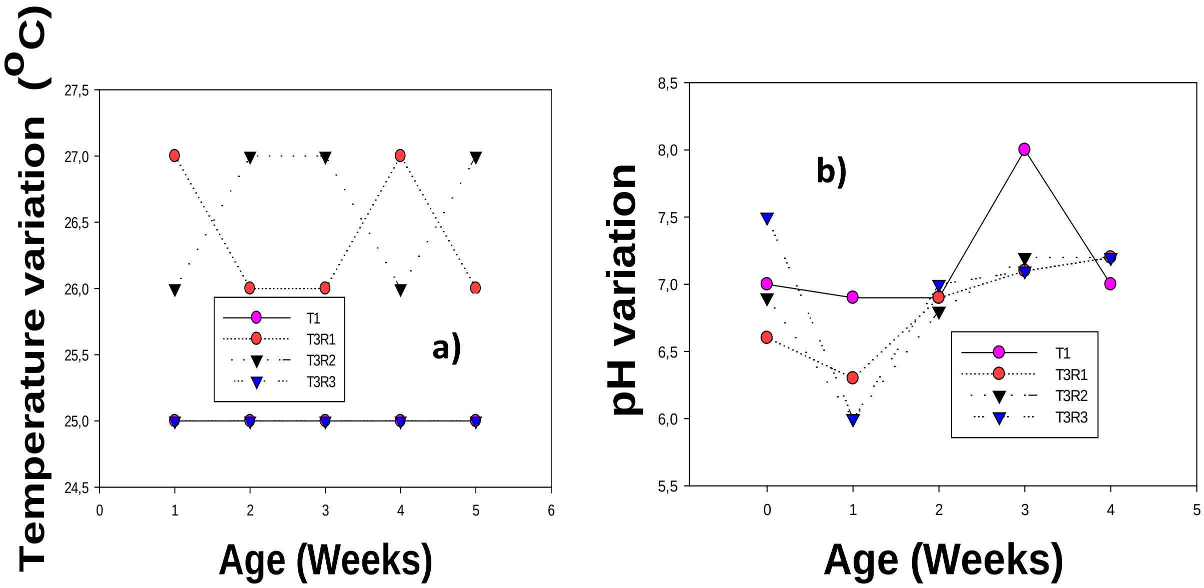

Figure 7. Influence of palm oil mill wastewater on fishpond water a) temperature b) pH.

3.5.3. Influence of palm oil mill and slaughterhouse wastewater mixture

Figure 8a illustrate the weekly trend in water temperature as affected by combination of wastewater from the slaughterhouse and palm oil mill. Results revealed a temperature range from 24 to 25 ^{0}C in T4R1, 26 to 27 °C in T4R3 and constant temperature of 25 °C in T1 and T4R2. There is a statistically significant difference ($P \leq 0.001$) in temperature between the treatments. pH varied from 6.8 to 7.5 in T4R1, 7.5 to 8 in T4R2, 7.2 to 7.5 in T4R3 (Figure 8b). There is not a statistically significant difference ($P = 0.064$) in pH values between the treatments. T4R2 had pH values within the ideal range for catfish growth [37] but the fact that it had the least body weight suggest other components of the pond influenced the growth performance in this medium.

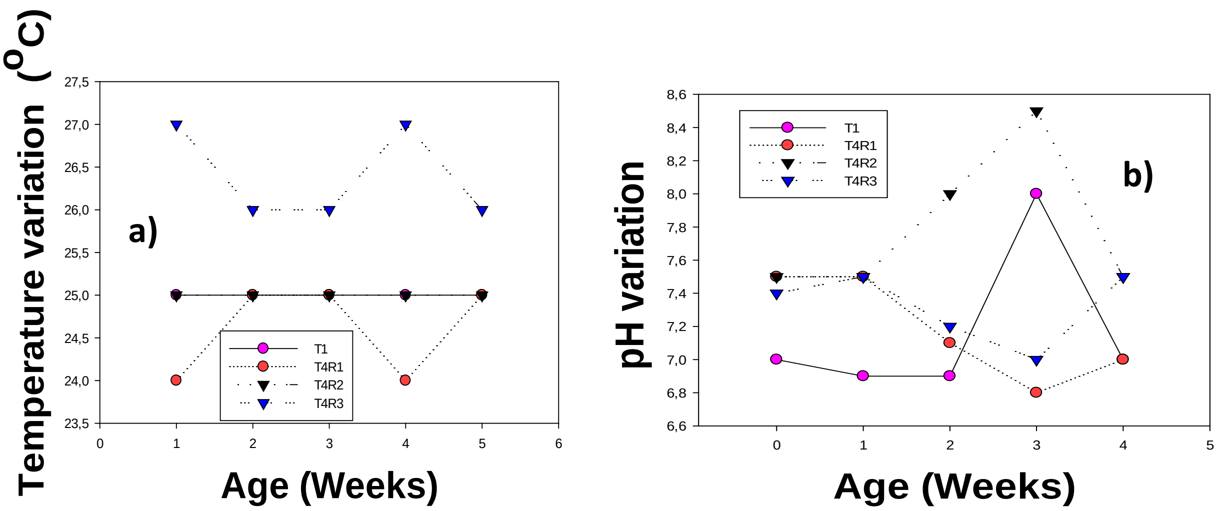

Figure 8. Influence of palm oil mill/slaughterhouse wastewater mixture on fishpond water a) temperature b) pH.

3.6. Physico-chemical properties of the water media used

The results of the physico-chemical parameters of the water samples are shown in Table 2, where it is observed that apart from the chloride and hardness in the ponds involving wastewater and tap water samples, all other parameters were above the reference values for fishponds [37]. The high BOD (Biological oxygen demand) and COD (chemical oxygen demand) in tap water compared to treatments with wastewater samples may be due excreta of the fish, feed use or high organic matter [38]. The low turbidity value in the tap water permitted light into the pond, permitting a healthier environment for the fish to feed and leading to generation of more excreta.

Pearson correlation coefficient was used to determine the effects of different parameters on the live body weight and live length of fish and the results are presented in Table 3. From this table it can be seen that there was a slight negative correlation between live body weight and Tap water, all treatments containing slaughterhouse water and palm oil wastewater. There was also a slight negative correlation between live length and tap water as well as slaughterhouse wastewater. However, there is a strong positive correlation between live body weight and live length with wastewater samples containing mixtures of slaughterhouse and palm oil wastewaters. Salinity is defined as the total concentration of electrically charged ions (cations –Ca^{++}, Mg^{++}, K^+, Na^+; anions –CO_3^{2-}, HCO_3^-, SO_4^-, Cl^- and other components such as NO_3^-, NH_4^+ and PO_4^-). According to Jamabo [39], salinity is a major driving factor that affects the density and growth of aquatic organism’s population. The total amount of salinity contributed by each treatment (SO_4^-, Cl^-, CO_3^{2-}, HCO_3^-, NO_3^-, N and hardness) is 1014.95. 1716.35. 947.85. 651.14 for T1, T2, T3 and T4. This shows that salinity was the controlling factor for fish growth in the ponds as T4 had the lowest value with strong r values and followed by T3.

There was a strong positive correlation between the duration of the study and the live body weight and live length for all treatments, with highest live body weight of r = 0.99 in T4R2 and highest live length of 0.996 in T2R1 (Table 3). This demonstrates that the different treatments could continue to support fish growth for as long as possible as no death was recorded during the period of study.

A positive correlation was obtained for tap water while negative correlation was obtained for other treatments with slaughterhouse wastewater between the pH of the pond water and the live body weight (r = 0.52, –0.56, –0.47 and –0.50 for T1, T2R1, T2R2 and T2R3 respectively), as well as the live length (r = 0.48, –0.37, –0.09 and –0.34 for T1, T2R1, T2R2 and T2R3 respectively), Table 3. Meanwhile a positive correlation was obtained for all T3 treatment for both live body weight and live length. There was a positive correlation with pH and live body weight as well as live length for T4R2, a strong negative correlation for 4TR1 and weak correlation for T4R3. The positive correlation for T4R2 shows that there is a maximum mixture of slaughterhouse and palm oil mill wastewaters that gives better conditions for fish growth. As presented in section 3.4.3, T4R2 had pH values within the ideal range for catfish growth.

From Table 3, there was no correlation between live weigh, live length and temperature in T1, T2R2, T3R3 and T4R2 but positive correlation between temperature and live body weight for T2R1 and T3T1. Weak correlation was obtained between temperature and other treatments suggesting temperature condition were generally within the acceptable limits for fish growth. As said in section 3.5.1, 26 °C to 32 °C water temperatures is very satisfactory for the growth of African catfish with the maximum growth occurring at 30 °C as temperatures in this study varied from 25 to 28 °C.

Table 2. Physicochemical parameters of the fishpond composite water used.

Parameter	Wastewater type				Reference values for fishponds [38]
	T1	T2	T3	T4	
SO_4(mg/L)	617.13	1234.25	349.7	0	250
Alu (mg/L)	2.16	1.44	5.04	2.88	
Fe(mg/L)	0.22	2.58	16.38	6.8	0.30
Carbonate (mg/L)	80.24	13.2	83.28	49.2	2.5–10
Bicarbonate ions (mg/L)	18	22.5	29	37.5	0.2 (cap)
Cl(mg/L)	56.8	39.05	78.1	71	250
NTU(NTU)	10	480.5	84.5	193.5	5–25
Cond(µS/Cm)	330	360	1510	770	200
P(mg/L)	169.38	396.75	93.13	480.24	0.30–2
NO_3(mg/L)	0	0	136.44	0	45
N(mg/L)	70	7	175	7	
COD(mg/L)	5600	4160	2200	2520	<10
BOD_5(mg/L)	3600	3200	2500	2640	<10
$N0_2$(mg/L)	0	0	92.43	0	<0.02
Hardness (mg/L)	3.4	3.6	3.2	6.2	2.5–20

Notes: T1 (tap water), T2 (slaughterhouse wastewater using the composite sample made composed of T2R1, T2R2, T2R3), T3 (palm oil mill wastewater using the composite sample made composed of T3R1, T3R2, T3R3 and T4 (mix slaughterhouse and palm oil mill wastewaters using the composite sample made composed of T4R1, T4R2, T4R3).

Table 3. Pearson's correlation coefficient between fish growth parameter (Live body weight and light length) and different treatments tested.

Growth media		T1	T2R1	T2R2	T2R3	T3R1	T3R2	T3R3	T4R1	T4R2	T4R3
Parameter	Pearson coefficient	Correlation of live body weight, live length with period of growth									
Live body weight	r	0.95	0.98	0.95	0.97	0.87	0.97	0.95	0.92	0.99	0.93
Live length	r	0.96	0.996	0.97	0.96	0.95	0.93	0.94	0.98	0.98	0.94
		Correlation of live body weight, live length with Composition of wastewater									
Live body weight	r	–0.39	–0.23	–0.40	–0.35	–0.23	–0.42	–0.46	0.98	0.86	0.92
Live length	r	–0.41	–0.23	–0.27	–0.43	0.61	0.74	0.74	0.67	0.73	0.90
		Correlation of live body weight, live length with pH of growth media									
Live body weight	r	0.52	–0.56	–0.47	–0.50	0.91	0.69	0.28	–0.83	0.57	–0.43
Live length	r	0.48	–0.37	–0.09	–0.34	0.83	0.43	0.20	–0.95	0.49	–0.27
		Correlation of live body weight, live length with Temperature of growth media									
Live body weight	r	NA	0.615	NA	–0.62	0.76	–0.76	NA	–0.09	NA	–0.26
Live length	r	NA	–0.27	NA	0.43	–0.31	0.25	NA	0.007	NA	–0.40

NA = no effect.

4. Conclusions

In this study the feasibility of using wastewaters from slaughterhouse and palm oil mills for fish growth was investigated. Each wastewater type was diluted three time 30%, 40% and 50% and tap water serving as the control were used as ponds and catfish grown within them for six weeks period. The pH and temperature of the ponds were monitored weekly. Live body weight, weight gain, live length and length gain were used to test fish growth performance in the artificially created ponds. Statistical analysis shows there was not a statistically significant difference between the control and other treatments for both live body weight and weight gain as well as live length and length gain for the treatments of each wastewater type. However, there was a statistically significant difference ($P \leq 0.001$) between live body weight and live length in slaughterhouse wastewater treatments but no statistically significant difference ($P \leq 0.573$) between weight gain and length gain. This same trend was obtained for wastewater mixture treatments containing slaughterhouse and palm oil. Most of the physicochemical parameters of the water samples were apart from the chloride and hardness in the ponds involving wastewater and tap water samples above the reference values for fishponds. However, Pearson's correlation coefficient shows that salinity contributed by each treatment from the ions SO_4^-, Cl^-, CO_3^{2-}, HCO_3^-, NO_3^-, N and hardness were 1014.95. 1716.35. 947.85. 651.14 for T1 (control), T2 (slaughterhouse wastewater, T3 (palm oil mill waster and T4 (mixture of the two wastewaters) respectively. This shows that salinity was the controlling factor for fish growth in the ponds as T4 had the lowest value with highest r values and followed by T3 (Table 3). From this result it is a clear that the different wastewater sources and their combination did not significantly have a negatively effect on the growth performance of the catfish. It is therefore evident that these wastewaters can be used in fish production as the aquaculturist can reduce the cost of fish production and the environment is less polluted by recycling these wastewaters. However, more studies are needed to determine the nutrients in the fish fed with these wasters for better field applications.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Acknowledgments

The authors would like to express their gratitude toward the Nazareth agro-pastoral training and production center (NAPTPC) in Menteh Nkwen in Bamenda III Subdivision-Cameroon for allowing us to carry out this work in their company.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Resources Department, Wastewater as a resource, EIB Projects Directorante - SECTOR PAPERS, European Investment Bank, (2022) ISBN 978-92-861-5335-8; 1–29. file:///C:/Users/TSANGO/Downloads/wastewater-as-a-resource-en.pdf (Accessed 10 August 2023)

2. Sato T, Qadir M, Yamamoto S, et al. (2013) Global, regional, and country level need for data on wastewater generation, treatment, and use. *Agric Water Manag* 130: 1–13. http://dx.doi.org/10.1016/j.agwat.2013.08.007
3. Bustillo-Lecompte C, Mehrvar M (2017) Slaughterhouse wastewater: Treatment, management and resource, recovery. *In book: Physico-Chemical Wastewater Treatment and Resource Recovery Chapter: 8 Publisher: InTech Open Access Publisher, Editors: Robina Farooq, Zaki Ahmad*. http://dx.doi.org/10.5772/65499
4. Tsamo C, Assabe M, Argue J, et al. (2019) Discoloration of methylene blue and slaughter house wastewater using maize cob biochar produced using a constructed burning chamber: A comparative study. *Sci Afr* 3: 1–13. https://doi.org/10.1016/j.sciaf.2019.e00078
5. Dangwang Dikdim JM, Germain VD, Tsamo C (2022) Batch mode treatment of wastewater from the Maroua artisanal tannery using silica extracted from rice husks and silica/sand mixture. *Equilibrium J Chem Eng* 6. https://doi.org/10.20961/equilibrium.v6i1.61211
6. Hasanudin U, Setiadi T (2016) Sustainable Wastewater Management in Palm Oil Mills, *Green Technologies for Sustainable Water Management*, Editor: Ngo et al 2016: 955–973, ASCE Publisher http://dx.doi.org/10.1061/9780784414422
7. Kospa HSD, Lulofs KRD, Asdak C (2017) Estimating Water Footprint of Palm Oil Production in PTP Mitra Ogan Baturaja, South Sumatera. *Int J Adv Sci Eng Inf Technol* 7: 2115–2121. https://doi.org/10.18517/ijaseit.7.6.2451
8. Bashir MJK, Sheen OS, Ng CA, et al. (2022) Advanced Treatment of Palm Oil Mill Effluent Using Thermally Activated Persulfate Oxidation. *Separations*. 9: 171. https://doi.org/10.3390/separations9070171
9. Ng M, Dalhatou S, Wilson J, et al. (2022) Characterization of Slaughterhouse Wastewater and Development of Treatment Techniques: A Review. *Processes*, 10: 1300. https://doi.org/10.3390/pr10071300
10. Jones ER, van Vliet MTH, Qadir M, et al. (2021) Country-level and gridded estimates of wastewater production, collection, treatment and reuse. *Earth Syst Sci Data* 13: 237–254, https://doi.org/10.5194/essd-13-237-2021.
11. Rusˇanescu CO, Rusˇanescu M, Constantin GA (2022) Wastewater Management in Agriculture. *Water*. 14: 3351. https://doi.org/10.3390/w14213351
12. Al-Hazmi HE, Mohammadi A, Hejna A, et al. (2023) Wastewater reuse in agriculture: Prospects and challenges. *Environ Res* 236: 116711. https://doi.org/10.1016/j.envres.2023.116711
13. Heck S, Béné C, Reyes-Gaskin R (2007) Investing in African fisheries; building links to the Millenium Development Goals. *Fish Fish* 8: 211–226. https://doi.org/10.1111/j.1467-2679.2007.00251.x
14. Christopher D, Gardner JC, Hartle RD, et al. (2019). Maximizing the intersection of human health and the health of the environment with regard to the amount and type of protein produced and consumed in the United States. *Nutr Rev* 77:197–215. https://doi.org/10.1093/nutrit/nuy073
15. Edwards P (1992) Reuse of Human Wastes in Aquaculture.Washington, D.C.: UNDP-World Bank Water and Sanitation Program. https://www.susana.org/_resources/documents/default/3-3062-7-1521807299.pdf
16. (WHO) World Health Organization, (2006). Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume 3: Wastewater and Excreta Use in Aquaculture. Geneva: World Health Organization.

17. Awoke JS, Oti EE, Nwakpa JN (2023) Effect of Different Water Media on Growth and Production Performance Parameters of African Catfish Clarias gariepinus (Burchell 1822) Fry *Oceanogr Fish Open Access J* 16.
18. Ssekyanzi A Nevejan N, Kabbiri R, Wesana J, et al. (2023) Knowledge, Attitudes, and Practices of Fish Farmers Regarding Water Quality and Its Management in the Rwenzori Region of Uganda. *Water* 15: 42. https://doi.org/ 10.3390/w15010042
19. Yosmaniar Y, Sumiati T, Mulyasari M (2021) Growth Performance and Survival Rate of Catfish (Pangasius sp) with the Application of the Nitrifying and Denitrifying Bacteria, *IOP Conf Ser: Earth Environ.* 934: 012004. https://doi.org/10.1088/1755-1315/934/1/012004
20. Krishnakumar A, Anton ESP, Jayawardena UA (2020) Water hardness influenced variations in reproductive potential of two freshwater fish species; Poecilia reticulata and Betta splendens, *BMC Res Notes* 13: 542. https://doi.org/10.1186/s13104-020-05382-x
21. Ghozlan AA, Zaki MM, Gaber MM, et al. (2018) Effect of Different Water Sources on Survival Rate (%) Growth Performance, Feed Utilization, Fish Yield, and Economic Evaluation on Nile Tilapia (Oreochromis niloticus) Monosex Reared in Earthen Ponds. *J Oceanogr* 6. https://doi.org/10.19080/OFOAJ.2018.05.555676
22. Elnady M.A, Abdel-Wahed RK, Salem MA, et al. (2021) Influence of Water Temperature and Salinity on Rearing of Nile Tilapia Fry under Biofloc Culture System. Egyptian Journal of Aquatic Biology & Fisheries, *Oceanogr Fish Open Access J* 25: 61–77. https://doi.org/10.21608/ejabf.2021.210384
23. Jemal F, Van Hulle SWH (2020) Wastewater reclamation and reuse potentials in agriculture: towards environmental sustainability. *Environ Dev Sustain* https://doi.org/10.1007/s10668-020-00732-y
24. Girard JJ (2011) Feasibility of Wastewater Reuse for Fish Production in Small Communities in a Developing World Setting, *Graduate Theses and Dissertations* https://scholarcommons.usf.edu/etd/3119
25. APHA, AWWA & WPCF (1998) Standard methods for the examination of water and wastewater 20th Edition. APHA, NY, USA.
26. Ogunji JO, Awoke J (2017) Effect of environmental regulated water temperature variations on survival, growth performance and haematology of African catfish, Clarias gariepinus. *Our Nature* 15: 26–33. https://doi.org/10.3126/on.v15i1-2.18791
27. Kasihmuddin SM, Ghaffar MA, Das SK (2021) Rising Temperature Effects on Growth and Gastric Emptying Time of Freshwater African Catfish (Clarias Gariepinus) Fingerlings. *Animals* 11: 3497. https://doi.org/10.3390/ani11123497
28. Akinwole AO, Dauda AB, Ololade OA (2016) Growth Performance of African Catfish (Clarias gariepinus) Juveniles Reared in Wastewater Treated with Alum and Moringa oleifera Seed. *J Aquac Res Development* 7: 12. https://doi.org/10.4172/2155-9546.1000460
29. Ubuoh EA, Akhionbare SMO, Onifade AO (2013) Potential of Moringa oleifera seed powder as a coagulation agent for refinery wastewater treatment in warri, delta State, Nigeria. *IJABR* 3: 17–20.
30. Isyaku B, Solomon JR (2016) Effect of detergent on the growth of African catfish (Clarias gariepinus) *DRJAFS.* 4: 351–360.
31. Esenowo IK, Ugwurnba OA (2010). Growth response of catfish exposed to water soluble fraction of detergent and diesel oil. *Environ Res* 4: 298–301. https://doi.org/10.3923/erj.2010.298.301

32. Copatti CE, de Oliveira Garcia L, Kochhann D, et al. (2011) Low water hardness and pH affect growth and survival of silver catfish juveniles. *Cienc Rural Santa Maria* 41: 1482–1487. https://doi.org/10.1590/S0103-84782011005000101
33. Neyjan F, Khalesi MK, Eskandari KE (2023: Effects of different water hardness levels on, growth indices, survival rate, hematological parameters and culture water quality of Caspian kutum fingerlings (Rutilus frisii). *J Util Cultiva Aquatics* 11: 61–80.
34. Kasihmuddin SM, Ghaffar MA, Das SK (2021) Rising Temperature Effects on Growth and Gastric Emptying Time of Freshwater African Catfish (Clarias Gariepinus) Fingerlings. *Animals* 11: 3497. https://doi.org/10.3390/ani11123497
35. Britz P J, Hecht T (1987) Temperature preferences and optimum temperature for growth of African sharptooth catfish (Clark gariepinus) larvae and postlarvae. *Aquac* 63: 205–214. https://doi.org/10.1016/0044-8486(87)90072-X
36. Santhosh B, Singh NP (2007) Guidelines for water quality management for fish culture in Tripura. *ICAR Research Complex for NEH Region, Tripura Center, Publication* 29
37. Bhatnagar B, Devi P (2013) Water quality guidelines for the management of pond fish culture, *Int. J Environ Sci* 3: 1980–2009. doi: 10.6088/ijes.2013030600019
38. Kay RNB, Sharman GAM, Hamilton WJ, et al. (1981) Carcass characteristics of young red deer farmed on hill pasture. *J Agric Sci* 96: 79–87. https://doi.org/10.1017/S0021859600031890
39. Jamabo NA (2008) Ecology of *Tympanotonusfuscatus* (Linnaeus, 1758) in the Mangrove Swamps of the Upper Bonny River, Niger Delta, Nigeria. *Ph.D. Thesis,Rivers State University of Science and Technology, Port Harcourt, Nigeria*, 231.