International Journal of Research in Environmental Science (IJRES)
Volume 9, Issue 3, 2023, PP 14-24
ISSN No. (Online) 2454-9444
DOI: http://dx.doi.org/10.20431/2454-9444.0903002
www.arcjournals.org

Physico-Chemical Evaluation and Survival Rate of *Clarias gariepinus* Fingerlings Fed Different Inclusions of Black Soldier Fly and Fish Meal

Amosu, A. O [1*], Hammed, A.M[2], Kuwande, S.B[3], Sunnuvu, T.F[4], Joseph, O.O[1], Dalmeida, L.O[1] and Ademuyiwa, E.F[2]

[1]*Department of Agricultural Science, Lagos State University of Education, Oto/Ijanikin, P.M.B 007 Festac Town, Lagos, Nigeria*

[2]*Department of Fisheries, Faculty of Science, Lagos State University, P.O. Box 0001, LASU Post office, Ojo, Lagos, Nigeria*

[3]*Department of Geographical & Environmental Education, Lagos State University of Education, Oto/Ijanikin, P.M.B 007 Festac Town, Lagos, Nigeria*

[4]*Department of Aquaculture and Fisheries Management, College of Agriculture, Lagos State University of Science and Technology, Sagamu Road, Ikorodu, Lagos, Nigeria*

***Corresponding Authors: Amosu, A. O,** *Department of Agricultural Science, Lagos State University of Education, Oto/Ijanikin, P.M.B 007 Festac Town, Lagos, Nigeria; amosuao@lasued.edu.ng*

Abstract: *This study examined the physico-chemical quality of water used for culturing the fingerlings of African Mud Catfish (Clarias gariepinus) and also evaluates the survival rates of the experimental fish fed locally formulated diet with Black Soldier Fly (BSF) inclusion. Six isonitrogenous 35% crude protein diets were formulated where BSF replaces fishmeal at 0%, 20%, 40%, 60%, 80% and 100% inclusions. Fingerlings of C. gariepinus of average body weight 5.95±0.5g were stocked at 20 fish/50 litres tanks, fed in triplicates twice daily to satiation and weight changes recorded weekly. Water quality and survivability was determined using YSI Incorporated US multi-parameter equipment and direct counting of fish respectively. The results showed variation in the observed parameters at the different rearing chambers. The mean temperature values observed was 27.09±28.22 (°C), dissolved oxygen (DO $mg.l^{-1}$) recorded was between 3.55±1.00 $mg.l^{-1}$ and 4.76±0.59 $mg.l^{-1}$, pH value ranged from 6.92± 10.05 was obtained. There were no significant differences ($p > 0.05$) temperature, DO, CO_2, pH, conductivity while there were significant differences (DNMRT; ANOVA; df = (n – 1); $p < 0.05$) in Alkalinity and Total suspended solid. All other water quality parameters measured such as Total suspended solids, CO_2, Conductivity, Salinity and Ammonia were within the permissible limit as stated by WHO/USEPA. The survival rate of the fish ranged from 16.67-40%. This study indicates that $Diet^1 > Diet^3 > Diet^5 > Diet^6$ appeared to be suitable for fish production. It could be deduced that all the listed physico-chemical parameters studied are optimal for fish production. Therefore, successful inclusion of black soldier fly and fishmeal in the diets of fish revealed optimal fish growth and survival rate without negative effects.*

Keywords: *Black soldier fly, C. gariepinus, Fishmeal, Physico-chemical, Survival.*

1. Introduction

The global human population is on the rise by over 70% [1] and projections have shown that by 2050 well over 9.7 billion people will be occupying the globe [2, 3]. This increase in population is directly impacting pressure on the global food basket especially protein. In addition, the global population expansion will be associated with an increased consumption of fish resources. For some decades, the global landings from the freshwater and marine water bodies' have reduced due largrly to overexploitation with no corresponding fish stock recruitment [4]. To meet the food demands of the increasing population, 70% more food needs to be produced globally [3, 5, 6]. Currently, there is food-feed competition, feed stuffs that are viable for direct human onsumption like soybean and fish are costly due to the demand with effects on feed production [7]. Fish food is required primary protein to feed fish in several regions [8]. There is an urgent need to find a high quality, cost efficient and sustainable alternative protein source for fishmeal [6] to be used in the formulation for fish feed diets. This increases the price of fishmeal and othersources of protein feed stuffs, which is not only used in feeding other animals are also a primary source of protein in aquaculture feed production [9,10] .

Both capture fisheries and aquaculture sectors have been geared into providing fish and other aquatic products to the increasing population [11]. However, the capture fisheries have been over exploited, leading to massive reduction in the fish yields. [9] and [12] reported a decline in the capture fisheries yields from 81.2 million tons in 2015 to 79.3 million tons in 2016. The main reason attributed to this decline was the El Niño effects. With these declines, more focus is being put into aquaculture to increase the yields and hence bridge the gap. Currently, aquaculture is one of the fastest growing food sectors that is focused on providing quality, affordable and reliable protein sources to improve the livelihoods, curb malnutrition and reduce food insecurity [2,13,14]. However, the industry' s growth is slow, and this has been put into close context with the industry' s high dependency on high quality protein feeds [15]. Increased aquaculture production automatically increases the need for fish feed. Therefore, fish meal is one of the important protein sources in feed formulations experienced considerable obstacles in its supply because most of it was still imported. This condition causes the price of commercial feed to be expensive, while the cost of feed is the largest component in fish farming. For fish farmers, this is one of the critical factors for successful farming. In an intensive cultivation system, feed must always be available according to the needs of fish both in quality and quantity [2]. Fish feeds contribute to over 60% of the total operational costs in a fish farm [7] in which protein is the key nutrient needed in the feeds, and probably the most expensive one [7,16]. The proportion of protein in fish diets is higher than those of other cultured animals, thus making feeds very exorbitant. Studies have shown that the African catfish, *C. gariepinus*, requires about 40% crude protein in their diet and best results have been achieved with crude protein values ranging from 35-50% for all African catfish species [17,18]. In Nigeria, the bulk of the feed used in fish production is imported and this has led to a high production cost of farmed fish. Aquafeed production in most African countries is yet to be commercialized due to the ever-rising cost of fish meal. With the ever increasing demand for fish meal globally, it is expected that its cost will continue to rise in the world market [19, 20]. The use of soybean meal and fishmeal as diet ingredients is controversially discussed due to potentially adverse environmental effects of its cultivation such as deforestation, greenhouse gas emissions or high water expenditure [21, 22]. Fish meal has been an important component in fish diets due to its high digestibility and acceptance alongside its high protein, essential amino acids and fatty acids profiles [23]. Recent studies have shown that fish meal stocks particularly in Nigeria are declining due to over-exploitation. This scarcity is leading to increased prices of the product, hence increasing the fish production costs and further deterring the industry' s growth [12, 24, 25].

In response to this situation, the current research concentrates on alternative protein sources more sustainable than soybean which in addition do not compete with human food production. The production of insects as protein source for aquafeeds shows a series of interesting and eco-friendly characteristics. For example, insects can efficiently bioconvert low-grade organic substrates into high-quality protein [26]. They do not require arable land; no competion with human food/production; they have short life cycles and can grow on a wide range of substrates with high productivity; low risk of zoonotic infections; low demand for water and energy when compared to other livestock [27, 28]. Approximately 1,900 insect species are eaten worldwide, mainly in developing countries, quality food as a potential source of protein both for humans and livestock [29]. Research have shown that insects are good candidates as fish feed ingredients in partial or complete substitution for fish meal, with regard to their nutritional attributes, ease of rearing, and biomass production [30]. According to [31] larvae or pupae of Diptera black soldier fly (*Hermetia illucens*) and house fly (*Musca domestica*), larvae of mealworm *Tenebrio molitor* (Coleoptera), adult Orthoptera and pupae of silkworm *Bombyxmori* (Lepidoptera) has been used as replacement for fishmeal, and the results were positive. In particular, the black soldier fly larvae (BSFL, *Hermetia illucens*) are promising as they are rich in CP (370– 630 g/kg DM), energy (70– 390 g fat/kg DM), have a favorable amino acid profile and can be reared on various substrates like food industry side streams [32]. Its presence can be found in almost the entire world with a larval size of about 2 cm, pre pupae contain 42% crude protein and

35% fat which makes it a suitable source for fishmeal replacement in commercial fish feed production and also as a promising source for biodiesel due to its high fatty acid content [33, 34] stated that maggot has advantages, which can reduce organic waste (dewatering), can live in a fairly wide pH tolerance, do not carry disease/agent, contain high enough protein (40- 50%) [35], and does not require high technology [36]. The production process is known as Bioconversion, which is a process that converts forms from products/materials that are less valuable into valuable products using biological agents (living things: insect BSF [35, 37]. Black Soldier fly is known to reduce the presence of harmful bacteria from the food substrates and has a prebiotic effect on the fish [38]. Successful dietary inclusion of BSF larvae in fish diets has shown improved fish yields and reduced production cost, thus promoting profitability and resource utilization [37]. Successful replacement of Soybean meal with black soldier fly larvae meal in the diets of fish without any negative effects on the growth performance, cost effective [39, 40, 41, 42] and survival rates has been reported in previous studies [43,44]. This study there was aimed at determining the physicochemical quality of the water used for culture and to evaluate the survival rates of fish used for the experiment.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out at the Fish Hatchery unit, Lagos State University fish farm. The study was carried out on LASU Fish Farm situated in faculty of science, Ojo campus, Lagos State, Nigeria lying between 6º26''N and 3º12'E.

2.2. Collection of Fish Samples

A total of Three hundred and Sixty (360) *C. gariepinus* fingerlings of average body weight 5.95±0.5g, were purchased from Sej. Farm Ventures in Badagry, Lagos, Nigeria, transported to LASU fish farm, kept in a concrete tank for acclimatization and starved for 24hrs to empty their guts in preparation for the experiment.

2.3. Experimental Design

The experiment was carried out for twelve (12) weeks. The fish were stocked into 18 labelled culture units and stocked with 20 pieces of fingerlings of known weight. The experiment was designed for six (6) isonitrogenous diets with three replicates. Each treatment was fed different diet composition. The differences in feeds formulated lied in the percentage composition of fishmeal and black soldier fly. The feed was administered twice daily adlibitumly at 4% body weight, while weight changes were noticed and measured weekly.

2.4. Diet Composition and Feed Trial and Survivability

The fish samples were kept in hatchery for acclimatization and starved for 24hrs to empty their guts in preparation for the experiment. The diets varied with increase in the percentage of BSF inclusion. Diet[1] (0% BSF and 100% FM), Diet[2] (20% BSF and 80% FM), Diet[3] (40% BSF 60% FM), Diet[4] (60% BSF and 40% FM), Diet[5] (80% BSF and 20% FM) and Diet[6] (100% BSF and 0% FM) respectively with Soybean Meal, Maize, Oil, Vitamin, $CaCO_3$ and Premix had constant percentage diets' inclusions. The various diets were prepared with three replicates, while the treatment was fed different diet composition (Table 1). The differences in feeds formulated lied in the percentage composition of black soldier fly and fishmeal. The feed was administered twice daily adlibitumly at 4% body weight. The percentage survivability was calculated using the formular below:

Percentage Survivability

$$\% \text{ Survivability} = \frac{No\ of\ fishstocked - Mortality}{No\ of\ fishstocked} X\ 100$$

2.5. Physicochemical Parameters

The water chemistry was determined with YSI Incorporated, US multi-parameter equipment for the various physico-chemical water parameters given, which includes Dissolved Oxygen (DO), temperature, pH, Total Hardness, Carbon dioxide (CO_2), Alkalinity, Ammonia, Nitrite, Nitrate, conductivity and turbidity. Water chemistry was measured daily and included salinity (ppm), pH, temperature (°C), dissolved oxygen (DO, mg.l^{-1}). The Waterproof CyberScan Series 300 (Eutech

Instruments Pte Ltd, Singapore) - Dissolved Oxygen meter, specially designed to measure oxygen and temperature simultaneously, was used to measure DO and temperature to determine consistency in the measurements. pH was determined with the aid of a portable and digital pH meter (model 8414, Hangzhou rock biological technology Co. LTD) that also measures temperature at 0.1 °C. Salinity was determined with the aid of refractometer (S/Mill-E 0 ~ 100 ‰ ATAGO, Japan). Inorganic nutrients were measured included Ammonia (NH_4^+), Nitrate (NO_3^-) and Nitrite (NO_2^-) respectively were determined using a Spectroquant® Pharo 300M all parameters were carefully done, and the readings taken, and the results recorded and calculated.

2.6. Statistical Analysis

All data collected for physicochemical parameters and survivability were analysedfor significant differences ($p < 0.05$) (ANOVA) on Graph Pad Prism V. The results were expressed as mean±SD. The determined differences among treatments were partitioned by the Least Significant Difference (LSD) and the Duncan New Multiple Post Hoc Test.

3. Results

Table 1 below shows the percentage composition of each feed ingredients used in the diets formulation. The diets varied with increase in the percentage inclusion of BSF i.e. Diet^{1} (0% BSF and 100% FM), Diet^{2} (20% BSF and 80% FM), Diet^{3} (40% BSF 60% FM), Diet^{4} (60% BSF and 40% FM), Diet^{5} (80% BSF and 20% FM) and Diet^{6} (100% BSFand 0% FM) respectively. On the other hand, Soybean Meal, Maize, Oil, Vitamin, $CaCO_3$ and Premix had constant percentage diets' inclusions.

This study evaluates the physico-chemical parameters of the water samples used for culturing African catfish (*Clarias gariepinus*) fed with locally formulated diet with the inclusion of Black Soldier Fly in Lagos State University, Fish Hatchery. Table 2 shows the mean concentration of the physico-chemical parameters (Dissolved oxygen, Carbondioxide, Temperature, pH, Alkalinity, Total suspended solids, Total dissolved solids, Total Hardness, Conductivity and Ammonia) of the experiment. The result revealed the highest mean of dissolved oxygen 4.79±1.59 mg.l^{-1} was observed in T5, 4.76±0.59 mg.l^{-1} been the second highest was recorded inside the plastic tank one while the lowest dissolved oxygen of 3.55±1.00 mg.l^{-1} was obtained from T3. Significant difference established at ($p < 0.05$) was observed for DO across all treatments. The highest mean CO_2 of 28.11±5.19 was observed from T4 tank while the lowest value of 7.04±1.42 was recorded in T1. Electrical conductivity level of 150.11±27.34 ppm was observed from T2, followed by 133.58±18.73 ppm observed in T5 while the lowest mean of 110.25±18.62 ppm was recorded from T4. Highest temperature (°C) level of 28.22±1.90 mg.l^{-1} was obtained in T6 (significant difference, $p < 0.05$) was observed to all other treatments, while the lowest level of temperature of 26.93±1.69 mg.l^{-1} was observed in T1.

Table 1: *Diets composition (g).*

Ingredient	Diets composition					
	Diet^{1}	Diet^{2}	Diet^{3}	Diet^{4}	Diet^{5}	Diet^{6}
Fishmeal	51.5	41.2	30.9	30.9	10.3	0
BSFM	0	10.3	20.6	20.6	41.2	51.5
SBM	25.2	25.2	25.2	25.2	25.2	25.2
Maize	15.8	15.8	15.8	15.8	15.8	15.8
Vitamin C	1.0	1.0	1.0	1.0	1.0	1.0
Oil	5.0	5.0	5.0	5.0	5.0	5.0
$CaCO_3$	0.5	0.5	0.5	0.5	0.5	0.5
Premix	1.0	1.0	1.0	1.0	1.0	1.0
% Total	100	100	100	100	100	100

Table 2: *Results of water quality samples for culturing fingerlings of Clarias gariepinus.*

Parameters	T1	T2	T3	T4	T5	T6
DO	4.76±0.59^{a}	4.09±0.37^{a}	3.55±1.00^{b}	3.92±0.75^{c}	4.79±2.59^{b}	4.15±0.38^{a}
CO_2	7.04±1.42^{a}	10.32±2.01^{b}	23.17±6.80^{c}	28.11±5.19^{c}	13.99±2.85^{b}	17.53±6.21^{b}
Conductivity	129.85±20.95^{a}	150.11±27.34^{b}	131.86±30.45^{a}	110.25±18.62^{b}	133.58±18.73^{a}	118.85±14.54^{ab}
Temperature	27.19±1.57^{a}	26.93±1.69^{a}	28.22±1.90^{ab}	27.09±1.56^{a}	27.92±2.01^{a}	27.25±5.53^{b}
pH	7.24±0.97^{a}	8.78±1.05^{a}	8.90±1.28^{a}	10.05±1.95^{b}	7.18±2.66^{a}	6.92±1.37^{a}
Alkalinity	126.75±22.93^{a}	223.10±28.56^{b}	150.35±30.40^{c}	185.37±16.57^{c}	140.14±27.54a^{c}	169.02±28.04^{c}
Ammonia	0.61±0.14^{a}	0.15±0.03^{b}	0.57±0.21^{a}	0.20±0.15^{b}	1.01±0.37^{d}	0.30±0.07^{b}
TDS	56.44±7.15^{a}	80.55±10.86^{b}	121.29±29.07^{c}	97.05±14.56^{ab}	107.90±23.41^{c}	51.83±6.21^{a}

Total Hardness	40.07±10.35ᵃ	43.36±12.67ᵃ	60.85±28.2ᵃ	63.65±22.30ᵃ	73.23±35.66ᵃ	57.19±11.77ᵃ
TSS	188.80±43.71ᵃ	140.54±42.21ᵇ	167.05±39.07ᵃ	110.15±39.50ᶜ	148.50±33.17ᵇ	102.15±23.87ᵇᶜ

Values in the same row followed by the same letter are not significantly different at p<0.05

The pH level of 10.05±1.95, 0.04 ±0.051493 and 8.78±1.05 were recorded in T4, T3 and T2 respectively while the lowest mean of pH was obtained from T6. For pH content, no significant difference ($p < 0.05$) was established. The highest mean total alkalinity of 223.10±28.56 $mg.l^{-1}$ was observed in T2 while the lowest mean total alkalinity of 126.75±22.93 $mg.l^{-1}$ was observed in T1. The highest level of ammonia (1.01±0.37 $mg.l^{-1}$) was obtained in T5 while the lowest level of ammonia was observed from T2. Total hardness values ranged from 73.23±35.66 from T5 while the lowest (40.07±10.35) from T1. The highest total suspended solid of 188.80±43.71 (µS/cm) was recorded in T1 while the highest total dissolved solid (121.29±29.07) was recorded in T3. Significant difference ($p < 0.05$) was established for TDS and alkalinity contents across all treatments.

The survival and mortality rates throughout the course of the experiment were recorded as shown in Table 4. T1 and T3 have the same survival rates 40.00% representing the highest survival, this outcome further illustrated that both treats had the lowest mortality rate. T4 had the highest mortality rates of 83.33% and 16.67% survival rate while T2 had the second highest mortality rate 66.67%. Thus, this table depicted that the total survival rate is equal to 33.89% while the percentage total mortality was 66.11%.

Physico-chemical quality of water samples from various culturing chambers.

Figures 1-3 present the variations that existed in temperature, pH, dissolved oxygen, conductivity, alkalinity, total dissolved solid and total suspended solid determined in the water samples from various culturing plastic tanks during the duration of the study. In addition to spatial differences, it also shows the significant changes that occurred across treatments i.e. the temporal variations.

Table 3: *Standards for physico-chemical parameters.*

Parameters	Maximum permissible limits in water					
	NAFDAC	SON	FEPA	NSDW	WHO	EU	USEPA
Conductivity	1000	1000	170	1000	200	400	-
Total dissolved solids	500	500	500	500	1000	-	500
pH	6.5– 8.5	6.5– 8.5	6.0– 9.0	6.5– 8.5	6.8	6.5– 9.5	6.5– 8.5
Total hardness	100	100	-	150	100	-	-
Alkalinity	100	100	-	-	100	-	-
Total suspended solids	10	10	20	50	50	50	10
Temperature	-	<35	26	-	40	25-32	30
CO_2	25	-	20-30	30	25	-	< 30
Ammonia	-	-	0.5	0.6-2.6	1.0	2.0	0.5-1.5

NAFDAC-National Administration for Food, Drugs and Control, SON-Standard Organization of Nigeria, FEPA-Federal Environmental Protection Agency, NSDW-Nigerian Standard for Drinking water, USEPA-United States Environmental Protection Agency, EU-European Union, and WHO-World Health Organization

Table 4: *Survival and mortality records.*

Week	T1	T2	T3	T4	T5	T6
1	6	4	3	5	3	5
2	7	5	5	8	7	8
3	5	-	3	7	3	-
4	-	1	2	3	3	3
5	2	3	3	6	4	5
6	5	1	4	6	6	5
7	5	8	2	2	2	-
8	-	4	3	5	-	4
9	3	5	2	3	3	3
10	3	5	5	2	-	3
11	-	2	1	2	-	4
12	-	2	2	4	6	-
Motality	36	40	36	50	37	39
Survival	40	33.33	40	16.67	38.33	35

% Survivability	92.91±6.38[a]	88.42±15.2[a]	92.25±6.39[a]	87.95±14.92[a]	91.71±7.39[a]	90.86±6.16[a]
Total No. of fish	60	60	60	60	60	60

Values in the same row with the same superscript are not significantly different. (p>0.05)

Figure 1 shows that there were no significant variations across all treatments, although a significant difference was established for temperature in T3 and T5. Figure 2 shows that there was remarkable difference in the electrical conductivity of the water samples collected from the six culturing tanks the duration of sampling although this was not the case with the statistical differences as it was only observed in T4. The pH of water samples did not change across treatments except for T4 as shown in Figure 3.

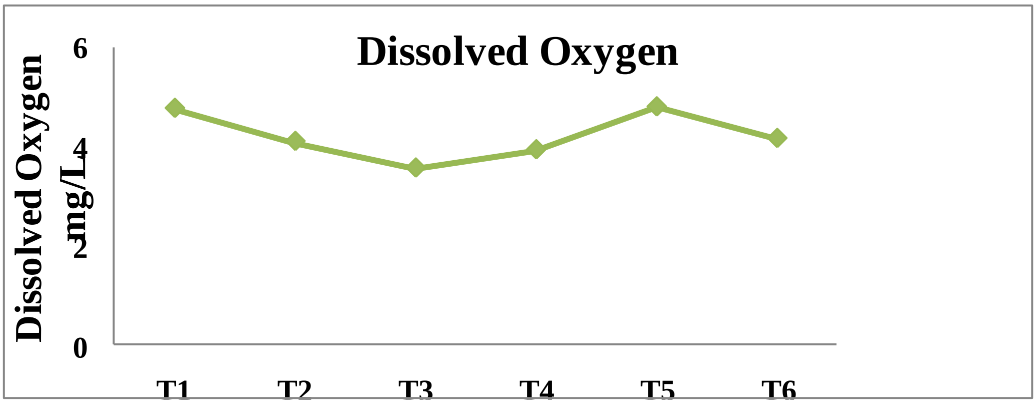

Figure 1: *Variations in dissolved oxygen across various feed treatments.*

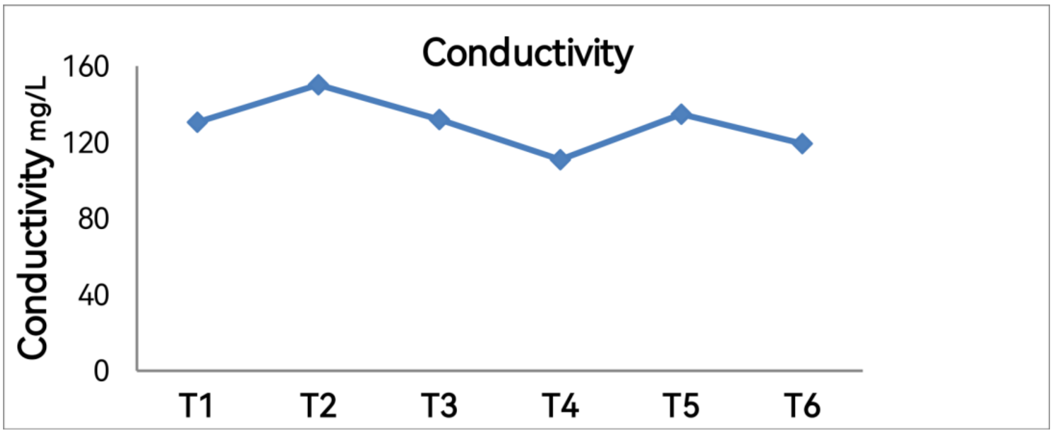

Figure 2: *Electrical conductivity observed in different feed treatments.*

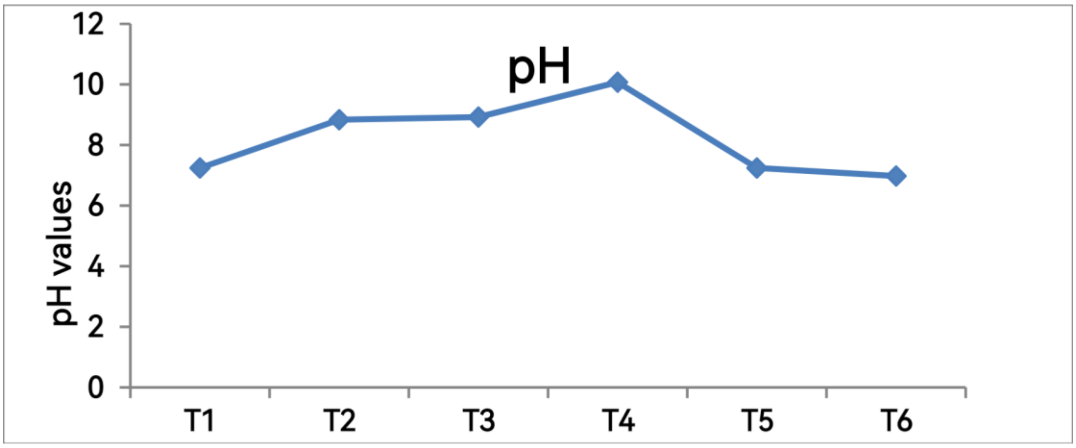

Figure 3: *pH values observed in different feed treatments.*

4. DISCUSSION

Physico-chemical properties of water quality usually reveal the status, productivity, sustainability and survivability of aquatic organisms, influenced by natural and anthropogenic processes [45]. In this study, the mean temperature of water samples in the study were within permissible limit or standard as provided in table 3 as being most suitable for the existence and development of aquatic life, this is in conformity with the result of [46]. [47] suggest an optimum growth temperature range of 26-28^{o}C for fishes in tropical and subtropical waters. However, there were significant differences ($p < 0.05$) between the culture chambers values (Table 2). Temperature has a large impact on the biological activity of aquatic organisms. It affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviours of aquatic organisms [48]. Conductivity is a measure of water' s ability to conduct electrical current. It is also an indicator of dissolved ions or solutes such as metals present in the water. The conductivity level of 129.85±20.95, 150.11±27.34, 131.86±30.45, 110.25±18.62, 133.58±18.73 and 118.85±14.54µS/cm were observed in T1 to T6 respectively. The values obtained were within µS/cm limit stipulated by [49] and WHO for the survival of aquatic organisms in fresh water. A significant difference ($p < 0.05$) was observed across all sampling stations. This higher level of conductivity in T2 may be due excess feed present in this water. The study by [50] lends credence to this assumption, where higher mean conductivity level of 426.3µS/cm in Omoku creek was also recorded due to industrial effluent discharged into the creek. However, [51] noted that the low conductivity of 69.20 µS/cm recorded in their study was indicative of infertile water. According to [52], a high surface electrical conductivity of about 400.00µS/cm of a water body could be used to assign a high morphoedaphic index and therefore a high fish production potential. Water can be classified according to [53] by the amount of TDS per litre of water: freshwater < 1500 mg.l^{-1} TDS, brackish water 1500 to 5000 mg.l^{-1} TDS and saline water > 5000 mg.l^{-1} TDS. Most often, high levels of TDS are caused by the presence of potassium, chlorides and sodium, these ions have little or no short-term effects, but toxic ions such as lead ions, arsenic ions, cadmium ions, nitrate ions and others may also be dissolved in the water [52]. [49] stipulates 450 mg.l^{-1} while WHO recommended <600 mg.l^{-1} as the standard limit in freshwaters for optimum growth and development of aquatic organisms (Table 3). The mean TDS level observed across all stations were within the standard level for the sustenance of aquatic organisms as shown in Table 2. There was significant difference ($p < 0.05$) in all sampling stations. When TDS levels exceed 1000 mg.l^{-1} it is generally considered unfit for human consumption as observed by Lawson (2011) who recorded a very high average TDS value of 836.78 mg.l^{-1} for Lagos swamps, which revealed organic sources such as leaves, silt, plankton, industrial waste and sewage. pH of the water body is affected by several factors [54] such as decomposed feed present in water, agricultural runoff, mining, or infiltration of untreated wastewater. The pH across all culture units was within permissible limit for the protection, survival and development of aquatic life (Table 2). It is also within the natural background level of 6.5-8.5 that exist in most natural waters [55]. No significant difference ($p < 0.05$) was observed in all treatments. pH value obtained in this study agrees with those documented by [56] as values most suitable for maximum productivity of aquatic organisms. Furthermore, the value is within the range commonly found in oligotrophic and eutrophic lakes where typical reading lies between pH 6.0 and 9.8 [57]. It is also in accordance with the result obtained by [58] that pH 5.5– 8.0 is the most suitable range for freshwater. [46] however recorded average pH value of 6.97 which is slightly higher than the average pH value recorded in this study. Considering these guidelines, the mean pH value of all culturing units shows suitability for sustenance of the aquatic ecosystem. The DO level of T3 and T4 water (3.55±1.00 and 3.92±0.75) falls below the permissible range of WHO and FEPA but the values obtained across all treatments are below the standard level of EU (5.0 mg.l^{-1}) (Table 3) showing that these water samples are burdened with a lot of organic matter. It also falls below the range of 5.0- 9.0 mg.l^{-1}documented by [59] and [47] for good water quality suitable for aquatic organisms. Similarly, Dissolved oxygen level recorded in this study is lower compared to 4.94-5.9 mg.l^{-1} for Ogun River and 5.4-7.0 mg.l^{-1} for Calabar River recorded by [60]. However, low values of DO have been observed by [61] in lakes or creeks in Western Nigeria which may be a reflection of the high amount of decomposing materials within the water arising from the surrounding derived vegetation. Dissolved oxygen (DO) level recorded in this study is also similar to those reported for many other polluted

Nigerian waters including, 4.00-7.50 $mg.l^{-1}$ for Luubara creek in Niger Delta [62] and 5.20 - 9.40 $mg.l^{-1}$ documented by [63]. Turbidity or Total Suspend Solids (TSS) is the material in water that affects the transparency or light scattering of the water. The TSS recorded in this study is within the permissible limits and significant difference ($p < 0.05$) was observed. [64] reported a temporal variation in turbidity of Woji Okpoka and Taylor creeks respectively while [6] did not observe a variation between dry and wet seasons. [64] recorded a range of 1.74±0.34 to 5.67±1.42 NTU with a mean value of 3.59±0.32 NTU in the Woji-Okpoka creek for a two year period. [50] reported a high mean turbidity of 29.3 NTU at Omoku creek as a result of inputs from industries. [66] reported the effect of influx of particulate materials into Ekpan creek on turbidity. Turbidity, caused by suspended soil particles, seldom have direct effects on fish, though may adversely affect fish populations according to[47]. Alkalinity of a water body is a measure of its capacity to neutralize acids to a designated pH [67]. The highest Alkalinity level recorded in this study was 223.10±28.56 $mg.l^{-1}$ in T2 two while lowest (126.75±22.93) was obtained from T1. This means that the results obtained in all samples are above the permissible level as shown in Table 2. While [68] observed 70 – 1400 $mg.l^{-1}$, however, [65] reported low alkalinity range of 70 – 90 $mg.l^{-1}$ for Amadi Creek, 23.29 – 31.60 $mg.l^{-1}$ for Taylor creek and [66], 7– 20 $mg.l^{-1}$ for Ekpan Creek respectively. [68] reported higher alkalinity in the dry months than wet months with a value of 70 $mg.l^{-1}$ recorded in October and November to 1400 $mg.l^{-1}$ recorded in March with a mean value of 583.33 $mg.l^{-1}$. The survivability observed in this study indicates that $Diet^1 > Diet^3 > Diet^5 > Diet^6$ appeared to be suitable for fish production, which was the same values dicteted by [42]. Therefore, it could be deduced that all the listed physico-chemical parameters studied are optimal for fish production. Studies on aquatic ecosystem impairment have been reported and most of the researchers established that knowledge of hydrological conditions of any body of water is not only useful in assessing its portability but will also permit a better understanding of the nutrition, population and life cycle of the fish community [69].

5. Conclusion

Successful inclusion of black soldier fly and fishmeal in the diets of fish without any negative effects on the growth performance shows the overall results obtained from this study revealed optimal fish growth and survival. Therefore, it can be deduced that all the listed physico-chemical parameters studied are optimal and should be monitor at all-time to enhance the performance of the organism as well as survivalbility of fish production.

Authorship Contribution Statement

Amosu A.O and Hammed A.M: Conceptualization, Methodology, Software, Validation, Writing – original draft. **Kuwande, S.B, Dalmeida L.O and Sunnuvu T.F**: Formal Analysis, Investigation, Writing – review & editing, Project administration. **Joseph O.O and Ademuyiwa, E.F**: Methodology, Resources, Supervision, Review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or conflict of interest.

Acknowledgement

We are grateful and need to show appreciation to the Department of Fisheries, Faculty of Science, Lagos State University; Department of Agricultural Science, Fisheries Unit of the Department of Agricultural Science, Lagos State University of Education and Department of Geographical & Environmental Education, Lagos State University of Education, Lagos, Nigeria.

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Citation: *Amosu, A.O et .al., " Physico-Chemical Evaluation and Survival Rate of Clarias gariepinus Fingerlings Fed Different Inclusions of Black Soldier Fly and Fish Meal", International Journal of Research in Environmental Science (IJRES), vol. 9, no. 3, pp. 14-24, 2023. Available: DOI: http://dx.doi.org/ 10.20431/2454-9444. 0903002*