Innovations

Comparative growth and best fit modelling of Albino and Black Clarias Gariepinus (Burchell, 1822) hybrid

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Abstract
As the world population increases, the demand for fish in the world also grows. It also entails mating fish with desirable traits, particularly if those traits might be inherited. The phenotypic crossing for this study was done in the following manner: Black female × Black male (BF × BM); White Female × White male (WF × WM); Black female × White male (BF ×WM) and White Female × Black male (WF × BM). Each phenotypic combination was replicated three times. The following growth parameters were evaluated: initial and final weight and length, mean weight gain, mean length gain, feed conversion ratio, relative growth rate, and specific growth rate. The length-weight relationship revealed that the offspring of all phenotypic combinations exhibited negative allometric growth (b<3) and a strong positive correlation (r=0.99) between their lengths and weights. There were no significant differences (p>0.05) in the growth parameters among all phenotypic cross combinations at the end of the study period. Lengths and weights of all experimental fish had a substantial positive correlation. The application of the Akaike Information Criterion (AIC) to the weight-age data in this study revealed that regardless of pigmentation, the logistic model is the most suitable for predicting the growth of Clarias gariepinus.

Keywords: *Hybridization, traits, phenotypic crossing, growth model, Akaike Information Criterion*

Introduction

Nigeria requires about 2.7 million metric tonnes of fish annually to satisfy the dietary needs of its citizens. However, the aggregate total domestic fish supply from all sources, both from capture and culture fisheries, is about 0.8 million metric tonnes per annum, creating a deficit of 1.9 million tons to fill the demand-supply gap (Emefiele, 2019). According to Thomas *et al.* (2006) and Edwin *et al.* (2009), fish accounts for about 34% of all animal protein sources in Nigeria, making it the country's largest source of animal protein. This drastic demand for fish products, among other animal proteins is related to the health benefits and its nutritious components (Oyedokun *et al.,* 2022).

Clarias gariepinus are easily recognized by their cylindrical body covered with a smooth scale-less skin, flattened bony head, highly ossified, small eyes, elongated spineless dorsal fin, and four distinctive pairs of unbranched barbels around a broad mouth (Oparaku *et al.,* 2021). Like many other vertebrates, the African sharptooth catfish (*Clarias gariepinus*), has an albino variety. The catfish with albinism has pinkish or yellowish body colouration, a white belly and red eyes. This (albinism) has been attributed to an autosomal recessive gene in the homozygous condition that causes a shortfall in melanin production (Onyia *et al.,* 2016; Umanah and Dapa, 2016). There are three different types of albinism: leucism, which has abnormal skin pigmentation but normal eye colour, and true (total or complete) albinism, which is characterised by the total absence of melanin and normal skin and eye pigmentation. Partial albinism is distinguished by restricted normal skin colour but normal eye colour (Wakida-Kusunoki and Amador-del-Angel, 2013). Albinism can also be induced artificially by exposing the eggs or broodstocks to heavy metals such as arsenic, cadmium, copper, mercury, selenium, or zinc (Umanah and Dapa, 2017). There is no doubt that commercial breeding of catfish in captivity has increased the amount of albino catfish available in the aquarium trade and in the wild due to different restocking efforts. However, it should be noted that albino specimens of all catfish species, including the albino channel catfish are naturally occurring (Goudie *et al.,* 2018; Nobile *et al.,* 2016).

Fish farming relies heavily on nutrition since feed accounts for 40–50% of production expenses (Safina *et al.,* 2012). Feeding frequency and nutrition are significant factors in aquaculture that influence fish development. The success of every aquaculture operation depends on identifying the ideal feeding rate (Omoruwou and Edema, 2011). Several variables such as fish size, species, and rearing systems influence the feeding rate. The feed's nutrient content also affect the feeding rate. For many fish species, the larval period is considered critical in their life histories (Ukwe, 2018).

Good nutrition is therefore, a factor for proper growth of fish and is more pronounced with fish in enclosures as they need adequate nutrition (Omoruwou and Edema, 2011). Feeding is a complex behaviour in animals including fish. In fish, it involves several responses associated with eating, including modes of feeding and feeding habits, mechanisms of feed detection, frequency of feeding, and preferences of feed provided or found. Fish feeding behaviour ranges from plant and detritus feeders to predatory feeding (Ekasari *et al.,* 2019).

The fish morphometric traits are the primary characteristics used to analyze fish development patterns, resistance, and well-being in a particular ecosystem. The correlation between the average weight of a fish of a particular length is a crucial regular duty that offers explicitly helpful information on the condition of the fish stock (Iloba *et al.,* 2021). It is a crucial biological mechanism that unifies several processes and affects how fish live. Fish grow as they age, changing in size, which can easily be determined by mathematical models (Flinn and Midway, 2021; Bunonyo *et al.,* 2022). The von Bertalanffy growth model (VBGM) is the length-at-age model that has received the most attention and it is the most frequently used, the Gompertz growth model and the logistic model are additional options that are frequently used (Stelios, 2006).

Models are mathematical formulas created to match the characteristics required to represent the growth of fish. A Growth model can reveal the weight-at-age data of fish (Powell *et al.,* 2019; Janampa-Sarmiento *et al.,* 2020). When fish growth curves are described mathematically, information on the fish growth parameters is condensed into a few critical points of weight rise. It reveals that fish weight changes with age (Amancio *et al.,* 2014). Mathematical models that relate a fish species' size (usually measured in length) to its age are essential for other models, such as those used in stock assessments to keep track of a population and guide management choices like harvesting regulations and length limitations. (Smart *et al.,* 2016). According to Snipes and Taylor (2014), selecting the best-fit model is essential in model selection. Under-fitted model may not reflect the true nature of the variability in the outcome variable, while over-fitted model loses generality; AIC is hence a means to select the model that best balances these downsides.

A hybrid is formed by combining different strains through hybridization (Nwachi and Esa, 2016). It also entails mating fish with desirable characteristics, particularly if they might be inherited thereby, initiating a strain or line crossing. Success in hybridization attributable to external fertilization makes it feasible to produce monosex fish and fish with a different number of chromosomes (Nwachi and Irabor, 2022). According to Haque *et al.* (2016) and Lozano *et al.* (2014), interspecific breeding has been used to create desirable hybrids consistent with how readily accepting catfish are of related breeds. There need to be more information on the best-of-fit growth model selection for albino *Clarias gariepinus.* This study is the first to record the best-of-fit growth model for albino *Clarias gariepinus* and its hybridization with its black counterpart. Hence this study aims to compare the growth and selection of best-fit growth model of black and albino-pigmented *Clarias gariepinus* and their phenotypic hybridization.

Materials and Methods

Study Area

This study was carried out in the Aquaculture unit of the Department of Animal and Environmental Biology, Faculty of Science, Delta State University.

Experimental Tank and Feeding of the Fish

Twelve plastic aquaria of 24 × 47 × 33cm diameter were used for this study. 20 fries were used for the different phenotypic cross combinations for this study. The crossing was done in the following manner;

- Black female × Black male (BF × BM);
- White Female × White male (WF × WM);
- Black female × White male (BF ×WM) and
- White Female × Black male (WF × BM).

Each phenotypic combination was replicated thrice. The resultant fries were fed 0.5mm Aller Aqua twice a day for the first two weeks, and 0.8mm Aller Aqua was then used for another two weeks. The feed size was then increased to Aller Aqua 1.5mm for 3 weeks, 2.0mm for the next two weeks and lastlyprovided 3.0mm feed for the last three weeks of the experiment.

Growth Parameters

The growth parameters were monitored and measured weekly for 12 weeks. A measuring board (cm) was used to measure the length of the fish while an electronic weighing scale with calibration to 0.001g was used for weight. The following parameters were evaluated during the study;

Weight gain = Final weight minus (–) Initial weight

Mean daily weight gain = Final weight – Initial weight/Culture period in days

Relative growth rate (RGR) = Log (Final weight) – Log (Initial weight)/ Cultured period

Condition factor (K) = W × 100/ L^3, Where, W=weight of fish (mg), L=Length of fish (cm) (Iloba *et al.,* 2020).

Feed conversion ratio (FCR) = Total feed (mg)/ final weight gain (mg) (Teyfun and Esat, 2014)

Survival Rate = (Final number of fish/ Initial number of fish) × 100 (Onyia *et al.,* 2016)

Protein efficiency ratio (PER) = 100 (weight gain/protein fed) (Khadan *et al.,* 2017.

Specific growth rate= $(\log W_2 - \log W_1)100$ / rearing period in days

Where ln W_2 = Natural Logarithm of final weight and ln W_1 = Natural Logarithm of initial weight (Saviour and Tony (2017).

Length-weight relationship

The length-weight relationship to deduce the growth pattern exhibited by each strain was determined by the formula;

$W=aL^b$.

The parameters "a" and "b" were estimated through a logarithmic transformation in the form

Log W = log a + b log L

Where w= Total weight of the fish (g)

L = Total length of the fish (cm)

a = intercept on the Y-axis

b = slope or regression coefficient (Iloba *et al.,* 2020).

Condition factor
The condition factor (k) revealed the health status of the experimental fish and was estimated with the following formula;
$k = W \times 100 / L^3$
Where k=condition factor
W= weight of fish (g)
L = Length of fish (cm) (Iloba *et al.,* 2020)

Plate 1: Black-pigmented and albino-pigmented Clarias gariepinus

Growth models
The non-linear model was used to estimate the best-fit growth modelling for the different phenotypic cross combinations of *Clarias gariepinus*. The three growth models (Logistic, von Bertalanffy and Gompertz) employed in this study were compared. The weight and age of fish were used for the growth modelling of the four phenotypic cross combinations as follows;
The Gompertz model; The Gompertz is represented by the formula;

$$L_t = L_\infty \cdot e^{-e^{[-G(t-t_0)]}}$$

Where L_t is the length at time t, L∞ is the asymptotic length, G is the instantaneous growth rate at the age t_o and t_o is the inflection point of the curve and the age at which absolute growth rate begins to decline (Flinn and Midway,2021).

Logistic function: The logistic model is represented by the formula;

$$L_t = L_\infty / [1 + e^{-G(t-t_0)}]$$

Where Lt is the length at time t, L∞ is the asymptotic length, G is the instantaneous growth rate at age t_o and t_o is the inflection point of the curve and the age at which absolute growth rate begins to decline.
Von Bertalanffy growth model: This model is represented by the formula;

$$L_t = L_\infty[1 - e^{-K(t-t_0)}]$$

Where Lt is the length at time t, L∞ is the asymptotic length, K is the growth coefficient and $t_o$is the inflection point of the curve and the age at which absolute growth rate begins to decline (Flinn and Midway, 2021).

Statistical Analysis

PAST (v3) was used for summary statistics, length-weight relationships, and growth modelling. Excel (2010) was used to evaluate all growth parameters. The Akaike Information Criterion (AIC) which states that the growth model with the lowest AIC is considered the best-fit for that organism.

Results

Growth Parameters

The fish growth parameters including initial weight; final weight; daily mean weight gain; weekly mean weight gain; monthly mean weight gain; initial length; final length; daily mean length gain; weekly mean length gain; monthly mean length gain; relative growth rate; specific growth rate and feed conversion ratio are shown in Table 1.

Table 1: Growth parameters of the experimental fish

Growth parameters	BF × BM	WF × WM	BF × WM	WF × BM	p-value	F-value
Initial weight (g)	0.191±0.09[a]	0.185±0.12[a]	0.200±0.08[a]	0.183±0.08[a]	0.76	0.40
Final weight (g)	206.90±76.45[a]	227.18±81.00[a]	167.79±107.84[a]	192.22±22.56[a]	0.63	0.76
Daily mean weight gain (g)	2.28±0.71[a]	2.16±0.30[a]	1.53±0.31[a]	1.73±0.19[a]	0.19	2.04
Weekly mean weight gain	16.02±4.93[a]	15.07±2.03[a]	10.69±2.16[a]	12.28±1.27[a]	0.18	2.09
Monthly mean weight gain	64.08±19.71[a]	60.29±8.15[a]	42.77±8.62[a]	49.13±5.07[a]	0.18	2.10
Initial length	2.62±0.50[a]	2.59±0.58[a]	2.62±0.38[a]	2.57±0.37[a]	0.92	0.17

(cm)						
Final Length (cm)	30.04±2.73[a]	30.46±4.01[a]	27.43±6.76[a]	29.63±3.29[a]	0.48	0.84
Daily mean length gain	0.26±0.027[a]	0.25±0.017[a]	0.22±0.015[a]	0.25±0.012[a]	0.26	1.64
Weekly mean length gain	1.81±0.17[a]	1.76±0.10[a]	1.57±0.16[a]	1.71±0.07[a]	0.21	1.92
Monthly mean length gain	7.26±0.67[a]	7.02±0.41[a]	6.27±0.64[a]	6.830.29[a]	0.20	1.93
Relative growth rate	3.12±0.16[a]	3.12±0.07[a]	2.93±0.10[a]	3.03±0.06[a]	0.16	2.21
Specific Growth Rate	2.79±0.14[a]	2.78±0,07[a]	2.61±0.09[a]	2.71±0.05[a]	0.16	2.21
Feed Conversion ratio	0.10±0.00[a]	0.09±0.00[a]	0.10±0.01[a]	0.09±0.01[a]	0.33	1.34

Means with a common superscript are not significantly different at $p \geq 0.05$

Length-Weight Relationship and Condition Factor

The length-weight relationships and condition factors of the various cross combination are presented in Table 2. All fish showed negative allometric growth pattern with a strong correlation between the length and weight of the fish. The fish growth condition factor in all four combinations was less than 1

Table 2: The length-weight relationship and condition factor of the experimental fish

Length weight relationship	**A**	**b**	**r**	**k**
BF × BM	-1.90	2.87	0.99	0.86
WF × WM	-1.91	2.86	0.99	0.87
BF × WM	-1.90	2.86	0.99	0.81
WF × BM	-1.95	2.88	0.99	0.71

Growth Modelling

The output and the comparison of the best-fit growth modelling (Logistic, von Bertalanffy and Gompertz) for the four phenotypic cross combinations of *C. gariepinus* are presented in Figures 1-4

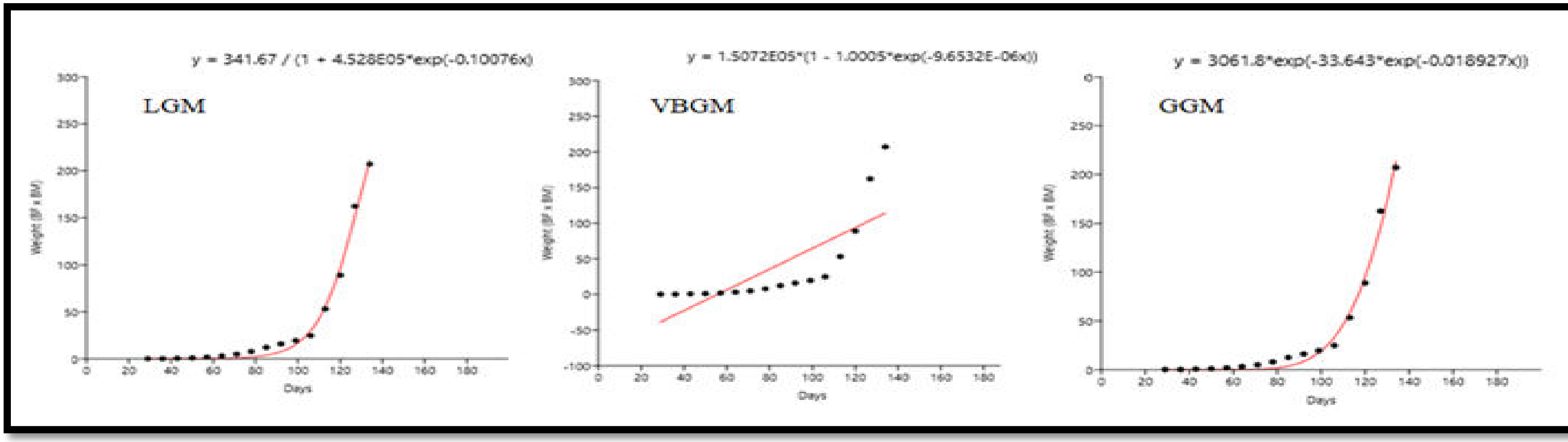

Figure 1: Logistic, von Bertalanffy and Gompertz growth models of BF and BM of Clarias gariepinus

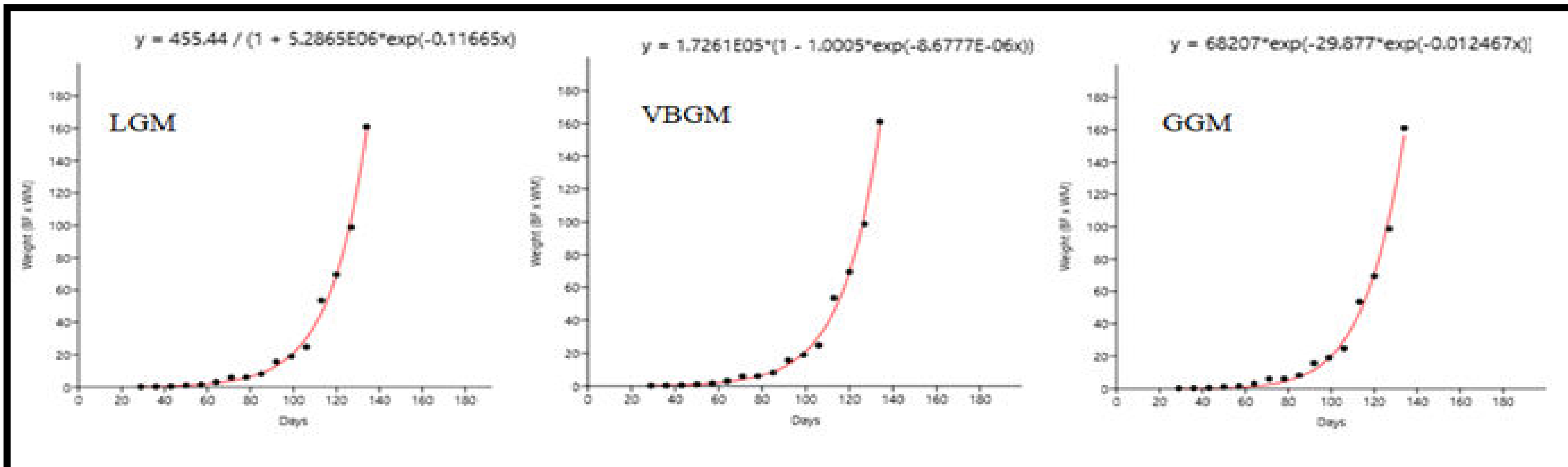

Figure 2: Logistic, von Bertalanffy and Gompertz growth models of WF and WM of *Clarias gariepinus*

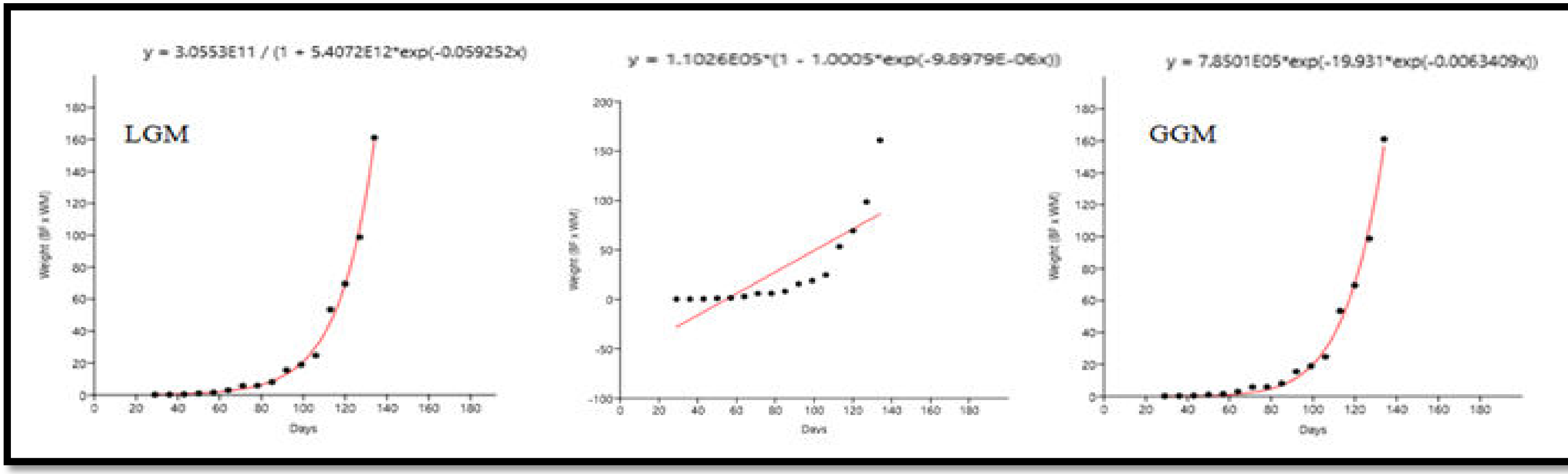

Figure 3: Logistic, von Bertalanffy and Gompertz growth models of BF and WM of *Clarias gariepinus*

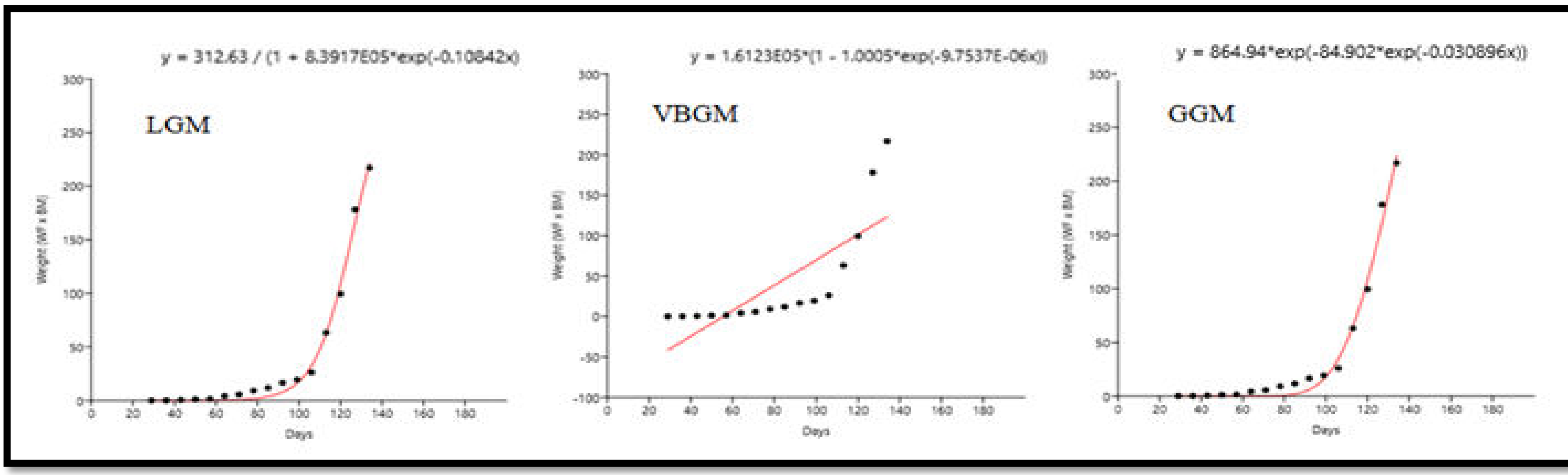

Figure 4: Logistic, von Bertalanffy and Gompertz growth models of WF and BM of *Clarias gariepinus*

The Akaike Information Criterion for selecting the best fit growth model is presented in Table 3. The logistic growth modelling is found to have the lowest AIC among the three growth models.

Table 3: Akaike Information Criterion (AIC) for selecting best fit growth modelling

Phenotypic crossing	Logistic Growth Model	Von Bertalanffy Growth Modelling	Gompertz Growth Modeling	p-value	F - value
BF × BM	449.48	655.13	23382	0.01	2.72
WF × WM	662.44	33782	847.76		
BF × WM	151.91	11159	199.29		
WF × BM	543.62	26276	827.09		

Discussion

Evaluation of the Growth Parameters of the experimental fish throughout the study period indicated there was no significant difference in the final weights (p =0.63), daily mean weight gain (p=0.19), weekly and monthly mean weight gain (p=0.18), final length (p=0.48), monthly mean length gain (p=0.20), relative growth rate and Specific Growth Rate (p=0.16), and feed conversion ratio (p=0.33) in the different groups (Table 1). The results of this study agree with Tayfun and Esat's (2014) report of no significant differences in the standard growth rate and feed conversion ratio in the assessment of growth and feed conversion ratio of albino and normal pigmented Rainbow Trout (*Onchorynchus mykiss*). The non significant difference however, contradicts the report of Onyia *et al*. (2018) of a higher growth rate in crossing between black female and black male of *Clarias gariepinus*. The non-existence of significant difference in the growth parameters among the different cross combinations in this study indicates that pigmentation does not affect the growth of *Clarias gariepinus.*

The condition factors in all cross combinations were below 1 ranging from 0.71 in WF × BM to 0.87 in WF × WM. The condition factor less than 1 (k<1) is, however, not good enough for the growth of the four combinations indicating that the interactions between the fish and the abiotic variables in the plastic aquaria affected the physiological state of the fish. The effect of abiotic variables on the health of aquatic live have been documented by several researchers including Iloba *et al.,* 2016; Iloba *et al.,* 2018; Tiogue *et al.,* 2020 (This may be due to the small size of the plastic aquaria used which restricted the free movement of the fish. The high stocking density in the plastic aquaria may have also altered the welfare of the fish. A similar report was giving by Dan-Kishiya, (2013) and Fafioye and Ayodele, 2018 in assessing Length-weight relationship and condition factor of five fish species from a tropical water supply Reservoir in Abuja and Length-Weight Relationship and Condition Factor of Four Commercial Fish Species of Oyan Lake, Nigeria respectively.

The k<1 index noted in the present study corroborates the research of Tiogue *et al.* (2020) who recorded 0.58 – 0.58 values for condition factor when evaluating recorded 0.58 – 0.58 values for condition factor when evaluating the hybridization in *Clarias gariepinus* and *Clarias jaensis* under controlled hatchery conditions in Cameroon. This condition factor also correlates with Ayo-Olalusi (2014) research who investigated the Length-weight relationship, condition factor and sex ratio of African Mud Catfish (*Clarias gariepinus*) reared in flow-through system tanks and reported a condition factor of 0.78 – 0.81. However, the condition factor of this study negates the report of Ameh *et al.* (2020), who recorded 1.0 and 0.99 condition factors while assessing the length-weight relationship and condition factors of *Clarias gariepinus* fingerlings reared in structured and unstructured water, respectively.

The b value of all the phenotypic cross combinations showed a negative allometric growth pattern with b values ranging from 2.86 - 2.88. There was also a strong positive correlation (r=0.99) between the length and weight of the fish among all phenotypic cross combinations. The near isometric growth pattern revealed by the b values could be a pointer that the fish could do well in a non-restricted space. The growth pattern recorded in this study is similar to that recorded in Iloba *et al.* (2020), assessing the length-weight relationship and wellness of *Clarias gariepinus* fed different kinds of feeds. The study's negative allometric growth pattern also agrees with Ameh *et al.* (2020), in which negative allometric growth with 2.51 – 2.83 b values were reported in *Clarias gariepinus* reared in structured and unstructured water. However, the negative allometric growth pattern in the current study negates the positive allometric growth report on *Clarias gariepinus* in the flow-through system tanks by Ayo-Olalusi (2014).

Of the three models investigated, the Logistic model proved to be the best-of-fit tool for modelling the growth of *Clarias gariapinus* as it has the lowest AIC values for all combinations (449.48 for BF × BM, 662.44 for WF × WM 151.91 for BF × BM and 543.62 for WF × BM). When compared the three models, statistical analysis showed an outstanding level of significant difference ($p<0.05$) in the three models. This contradicts the report of Babatunde *et al*. (2021), who noted Gompertz as the best growth modelling for *Clarias gariepinus* when determining a predictive growth model for *Clarias gariepinus*. Babatunde *et al*. (2021) did not consider the Logistic model in their assessment; hence, the variation in the best-fit model selected in their study. Sukran *et al.* (2002) opined that the growth model might be bias if there are only a few or no old fish in the fish data to be modelled; hence it is essential to have fish belonging to different age groups capturing all stages of the fish life to get rid of bias in goodness-of-fit model selection. Stelios (2006) also noted that wrong model selection could cause biased point estimation and erroneous precision evaluation.

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