Phenotypic Colour Variants in Batches of Fingerlings of *Clarias gariepinus* from some Commercial Fish Hatcheries

ABSTRACT

Aims: This research seeks to determine the ratio of dark skin and pale skin coloured fingerlings in batches of fingerlings produced in commercial African catfish hatcheries in Makurdi, Nigeria

Study design: The study was designed based on a structured questionnaire that was administered to farmers that were selected using random sampling from a list of African catfish farmers.

Place and Duration of Study: The research was carried out in Makurdi town, Makurdi Local Government Area of Benue State, Nigeria. Data collection was done between October 2021 and January 2022.

Methodology: The current study used a blend of questionnaire and physical counting to determine the proportion of dark and pale offspring from five selected fish hatcheries in Makurdi, Local Government Area of Benue State. A sample of 140 to 300 offspring was made upon each visit to the farm (i.e. batch of production) with each farm being visited at least twice depending on the production timetable.

Results: Results show that the farms normally incubated a similar weight of egg ($p>0.05$) with the range between 258g to 550g in each batch of production. The number of fry produced was scaled to 90% and it ranged from 165075 to 351450. Percentage of dark hued offspring ranged from 80% to 86% while that of pale offspring was between 14% and 20%. There was no correlation between turbidity and the colour classification. There was no significant difference between the farms in terms of incidence of dark or pale hued fingerlings suggesting that the colour proportion is constant within batches of fingerlings.

Conclusion: Dark skin colour is dominant over pale skin colour in the African catfish *Clarias gariepinus* and water quality does not predict skin colour in these species under culture..

Keywords: Catfish, offspring, dark, pale

1. INTRODUCTION

In fish, skin colour is determined by a quintet of pigment cells otherwise known as chromatophores and they include melanophores (black or brown pigment) that enable colour change [1], xanthophores that control yellow colour [2], erythrophores that are responsible for red colour [3], iridophores or guanophores that cause iridescence [4] and leucophores which confer white colour [5]. Knowledge of the genetics that underpin the manifestation of various chromatypes or phenotypes of skin pigmentation has been based on qualitative traits through studies on natural or artificially activated colour mutants in species of fish that are used as models for study including zebrafish, *Danio rerio* [6] and medaka, *Oryzias latipes* [7]. Studies have shown that the genetic basis of skin pigmentation in fish can be any of monogenetic [8], polygenetic [9], pleiotropic and sex-linked [10, 11]. The evidence from these studies overwhelmingly supports the involvement of several genes in the manifestation

of a particular skin colour or colour pattern through modulation of chromatophores that lead to synthesis and expression of pigments. There is also some evidence of environmental and luminous control of skin colour in some species [3].

The global scenario in commercial fish farming is increasingly being focused on two important traits: body shape and skin hue or pigmentation. This is linked directly to the rise in market poise. To this end, earlier demanded traits such as size, freshness and taste are not the only phenotypic traits that inspire demand among consumers who usually buy whole fish or fish products.

In livestock agriculture, reports have shown that a good handling of skin colour or product colour traits elicits demand response from consumers of products such as whole pig [12], whole chicken [13], egg shell and yolk colour [14]. The relevance of skin colour in animal agriculture lies in its importance as a quality attribute that creates preference from consumers [15]. This can also be found in the field of fisheries and aquaculture. In salmon, fresh fillets that are bright red are preferred over pale coloured fillets [16] with willingness to pay more for this attribute among consumers [17]. Similarly, consumers prefer the pink hue in smoked salmon [18]. Consumer preference for tilapia in Samoa is mainly determined by freshness that is hinged on transluscent colour [19]. The concept of colur has not been investigated among consumers of fish in Nigeria but it is ideal to identify this trait since modernization that is driven by information technology is capable of changing consumer behaviour [20]. Interestingly there seems to be a disconnect between genetic traits that are important to the farmer and those that are important to the producer such that traits like body texture and nutrition are preferred by consumers and these traits are not part of known breeding programmes [21].

Breeding programmes that will involve body colour are not as straightforward as growth and disease resistance. This is because there is a complex interplay between genotype and environment in the expression of the phenotype of skin colour [22, 23]. Research into phenotypic and genotypic basis of inheritance for skin colour has been reported for salmon [24, 25], tilapia [26] and common carp [27]. This will pave the way for development of new strains of the African catfish just like in Thai red tilapia which was developed from a red variety of *O. mossambicus* [28]. This research therefore seeks to determine the proportion of dark-coloured to pale-coloured fingerlings of *Clarias gariepinus* from commercial farms and any effects of water quality on the skin pigment classification.

2. MATERIAL AND METHODS

2.1 Selection of fish farms

Five fish farms located at various parts of Makurdi in Benue State (7.7322°N and 8.5391°E) that specialize in African catfish aquaculture were selected randomly for this research. For the purpose of this publication, the farms will be coded as follows: 1. Farm AH (Farm 1, n=2), 2. Farm EE (Farm 2, n=2), 3. Farm TL (Farm 3, n=6), 4. Farm TF (Farm 4, n=2) and 5. Farm OF (Farm 5, n=2).

2.2 Fingerling data collection

Data was collected physically on each location using a prepared questionnaire (Appendix 1). Batches of fingerlings produced by each farm was used as source of samples. Information on fingerling production include: Number of eggs incubated, Number of fingerlings produced, Number of dark-coloured fingerlings and number of pale fingerlings. At least two batches of

fingerlings per farm was used as source of data for colour. From each batch, a random sample of 140 to 300 fingerlings were sampled for colour and count was converted to percentage. The number of hatchlings produced was estimated from a sample count of 10.1g of eggs which corresponds to 7171eggs. The weight of eggs incubated (Wt_{Egg}) was then converted to number using the following equation while making room for 90% hatchability in all cases:

$$No.of\ Hatched\ Larvae = \frac{Wt_{Egg} \times 7171}{10.1} \times \frac{90}{100}$$

2.3 Water quality data

Water quality data was also solicited from the farmers. The data acquired include: 1. Total Dissolved Solids (TDS), 2. Turbidity, 3. Dissolved Oxygen, 4. Electrical Conductivity (EC), 5. pH, and 6. Temperature.

2.4 Data analysis

Data was analysed using R version 4.0.0 [29]. Descriptive statistics for eggs incubated and water quality parameters were obtained using Rmisc package in R [30] and reshape2 [31]. Differences in the percentage colour across the farms were determined using one-way ANOVA in R via agricolae and emmeans packages [32, 33]. Mean separation was done using the Tukey HSD method implemented in multcomp package [34] and viewed using multcompView [35]. Correlation of water quality and colour classification was done using corrplot package in R [36].

3. RESULTS AND DISCUSSION

3.1 Results

Weight of eggs incubated and number of fingerlings hatched (Table 1), were statistically alike across the farms (*P*=.05). The range of egg weight incubated fell between 258g and 550g with a coefficient of variation (CV) of 0.45. The range of fingerlings hatched was between 165,075 and 351,450 with a coefficient of variation of 0.45 as well. Fingerlings that appeared dark ranged from 80% of the hatchlings to 86% with a coefficient of variation of 0.05 while pale-coloured fingerlings ranged from 14% to 20% with a coefficient of variation of 0.25.

Table 1. Egg yield and colour of fingerlings from different farms in Makurdi Metropolis

Farm #	n	Egg Weight (g)	Fingerling Production (No.)	Dark	Pale
Farm 1	2	325 ± 175	207675 ± 112000	86 ± 0.62	14 ± 0.62
Farm 2	2	450 ± 50	287550 ± 31900	80 ± 4.95	20 ± 4.95
Farm 3	6	258 ± 59	165075 ± 38000	84 ± 2.06	16 ± 2.06
Farm 4	2	550 ± 50	351450 ± 31900	83 ± 0.22	17 ± 0.22

Farm 5	2	500 ± 00	319500 ± 0.000	84 ± 0.55	16 ± 0.55
CV		0.451	0.451	0.0512	0.251
P-value		.13	.13	.70	.70

Probability level of test P = .05; CV = Coefficient of variation

Plate 1: Dark and pale coloured fingerlings of *C. gariepinus*

Water quality across the farms sampled (Table 2) shows that the Total Dissolved Solids (TDS) differed between the farms with the least value of 75mg.l^{-1} being recorded in Farm 1 and the highest value of 277mg.l^{-1} in Farm 5. Turbidity also differed across the farms with a coefficient of variation of 1.19 and the range of 1mg.l^{-1} to 38mg.l^{-1}. The values for electrical conductivity differed across the farms with a coefficient of variation of 0.49 and a range between 150µS.cm^{-1} and 554µS.cm^{-1}. Farmers reported dissolved oxygen levels, pH and temperatures that were similar across the farms.

Table 2: Water quality from different African catfish farms in Makurdi Metropolis

Farm#	TDS (mg.l^{-1})	Turbidity (mg.l^{-1})	DO (mg.l^{-1})	EC (µS.cm^{-1})	pH	Temp (°C)
Farm 1	75 ± 6^{a}	9 ± 0.88^{b}	5 ± 0.35	150 ± 12.5^{a}	7.08 ± 0.00	29 ± 0.10
Farm 2	77 ± 1.5^{ab}	38 ± 1.98^{c}	5 ± 0.35	180 ± 31^{a}	7.13 ± 0.11	28 ± 0.50
Farm 3	203 ± 5.4^{c}	1 ± 0.64^{a}	4 ± 1.33	406 ± 10.4^{b}	7.07 ± 0.02	29 ± 0.09

Farm 4	106 ± 5[b]	35 ± 0.06[c]	5 ± 0.20	201 ± 3[a]	7.07 ± 0.01	28 ± 0.55
Farm 5	277 ± 2.5[d]	1 ± 0.52[a]	3 ± 0.40	554 ± 5[c]	7.11 ± 0.00	29 ± 0.05
CV	0.511	1.19	0.362	0.491	0.007	0.019
p-value	.00	.00	.76	.00	.82	.33

Probability level of test =0.05; CV = Coefficient of variation

Correlations between water quality parameters and skin colour variants of fingerlings of *C. gariepinus* (Figure 1) shows that water quality parameters such as turbidity and TDS did not correlate significantly with dark or pale colour of fingerlings. However, TDS and turbidity have strong (*P*=.05) negative correlation (–0.73) while electrical conductivity (EC) and turbidity also share a strong (*P*=.05) negative correlation (–0.69). A strong negative (p<0.05) correlation (–0.65) was found between water temperature and pH while a perfect positive correlation was estimated between TDS and electrical conductivity. Also, there was a perfect negative correlation between percentage dark and percentage pale-colour fingerlings.

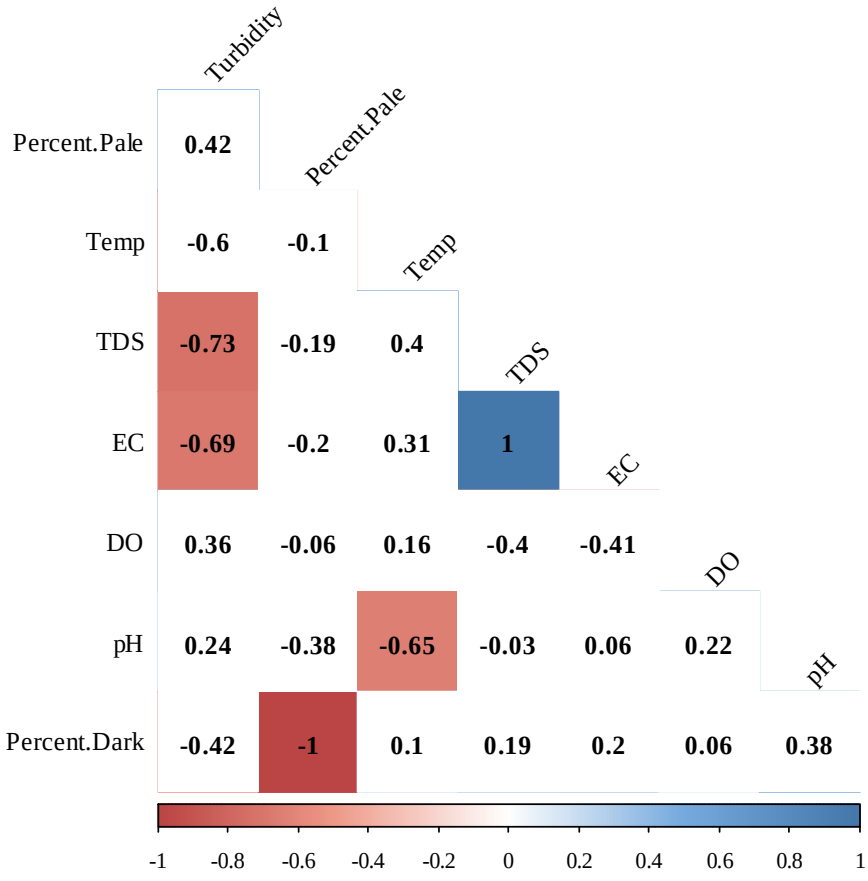

Figure 1: Correlation plot for water quality parameters and skin colour of *C. gariepinus* fingerlings *(Increasing colour intensity depict increasing p-values and correlations without colour have probability P=.05; Blue colour = positive correlation and Red colour = Negative correlation)*

3.2 Discussion

There was no difference between the farms in terms of egg weight incubated per batch of breeding. This shows that the farms operated similar pattern of breeding with regards to facility and market demand. The farms seem to be of small scale with low egg weights fertilized and incubated. It has been observed that many African farmers are still using low-yielding agricultural technologies, which lead to low productivity [37, 38]. Farm location greatly affects farm size and productivity. According to Miller and Atanda [39], development of medium scaled farms in peri-urban areas in Nigeria using tanks has taken advantage of large markets and access to credit to establish fish farm estates that yield more profit as a result of high market prices. The use of less sophisticated recirculating systems by fingerling producers sampled is related to cost since a high variable cost is associated with use of recirculating systems for fry production [40].

Dark-coloured fingerlings predominate over the pale-coloured fingerlings. According to Booth, Warner-Smith [41] and Han, Xie [42], dark skin pigmentation is a morphological adaptation to intense light (434 lux) in *Leiocassis longirostris* and juvenile *Pagrus aurata* respectively. Although luminance was not measured directly in the fingerling tanks, the low turbidity of water across the farms could explain the incidence of more dark fish compared to pale fish. This will allow for high light intensity in the tanks hence more dark-coloured fingerlings. Exposure to intense light (luminosities above 400 lux) in *L. longirostris* was reported to cause a higher intensity of color and less whiteness of the skin [42]. Teleosts can adjust the color of its skin in response to changes of the environment light incidence [43], and changes in the pigmentation occur by the alteration of the number of chromatophores and the mobilization of its pigments [44].

The genetics of recessive genes entails the presence of homozygous genotypes for a phenotypic expression [45]. The pale-colour in the African catfish can be classified a recessive trait since its frequency of occurrence is lower than the dark-coloured strain. However, the control of skin colour in fish seems to be environment regulated although the presence of genes is necessary. Genotypes and associated phenotypes are not transmitted from parents to offspring, only genes are transferred [46]. The effect of the environment on colour is also noteworthy [47, 48]. Previous reports show that the Chinese long snout catfish under culture had a darker hue than the wild strains [42], a situation that has also been reported in another species, the red porgy [49]. In the current study, there was no correlation between water quality parameters and skin colour. The body of knowledge on influence of environment on skin pigmentation in fish suggest that there is a temporal pattern of change that is controlled by the endocrine system [50]. This means that the determination of the effect of environment (water quality) on changes in skin colour can best be done with time series data of water quality and visual perception of skin pigmentation. The ontogeny of fish skin pigmentation is differentiated by the presence and effects of chromatophores. In the current study, the interaction between melanophores and leucophores can be proposed as the cause of differentiation between pale-coloured and dark-coloured *C. gariepinus* offspring. There seems to be a progressive timing for expression of each chromatophore [51]. This may explain why the proportion of dark-coloured fish is higher than that of pale-coloured fish. On the other hand, the inherent genetic code for chromatopores in the two classes of fish may be different with the incidence of leucophores being more in the pale-coloured fish than the dark-coloured fish which may have more expression of melanophores.

4. CONCLUSION

There were more dark-coloured (79.95% to 86.34%) *C. gariepinus* in the fingerling population sampled than the pale-coloured (13.66% to 20.05%) fish. There was also no significant difference between the farms in terms of incidence of dark or pale-coloured fingerlings suggesting that the colour proportion is constant within batches of fingerlings. However, the scale of operation and the similarity of production facilities can be highly influential to light penetration which is an important factor in the activation of iridophores.

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APPENDIX

Questionnaire used for data collection

Farm Name:……

Date of Sample Collection……

Batch No.	No. of eggs Incubated	No. of fingerlings Produced	No. of dark fingerlings	No. of pale fingerlings
Batch 1				
Batch 2				
Batch 3				
Batch 4				
Batch 5				
Batch 6				
Batch 7				
Batch 8				
Batch 9				

Water Quality

Water Quality Parameters	Fry Tank 1	Fry Tank 2	Fry Tank 3	Fry Tank 4
TDS				
Turbidity				
DO				
Conductivity				
pH				
Temperature				