



Carcass-waste yields and nutritional composition of strains of *Clarias gariepinus* (Burchell, 1822) as index traits for selective breeding

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Abstract

The role of carcass evaluation techniques in aquaculture genetics and breeding cannot be over-emphasized. Knowledge of growth potentials concerning carcass quality has improved genetic selection techniques and management. Therefore, this study was conducted on the carcass yields, by-yields, anatomical separation, and nutritional quality of *Clarias gariepinus* strains collected from river Rima and two other population groups from two different fish farms with records of a pure cultured strain of *C. gariepinus* and another farm with a pedigree of artificial crosses. The flesh weight (FW) of the river Rima (55.50±2.97) population strain was higher ($p<0.05$) than the two cultured population strains. Population strain C (47.79±1.17) recorded the lowest significant ($p<0.05$) flesh weight (FW). In comparison, B (49.12±2.68) population strain had an intermediately significant ($p<0.05$) flesh weight. The coefficients of variations (CV) were almost the same for all the three population groups except the gutted weight, where the river Rima (wild) population strains had the highest CV. This study recommended that attention be given to improving the cultured stock/strains in terms of resistance to diseases, heritability for improving healthy growth rate, feed conversion efficiency, and general hardiness, harnessing the diverse wild strains. In addition, this study recommended further investigation, including the amino acid profile and organoleptic characteristics of the wild fish population groups from river Rima for additional knowledge to the interest of Fish Nutritionists.

Keywords: By-yield, Carcass yield, Genetic, Population, Selective breeding, Strain

Introduction

The important prerequisite for optimum utilization of the Nigerian fisheries resources is to understand the categorization of the biological, nutritional, and industrial potentials of the abundant fish species, including the flesh and waste yields of the various species (Ipinjolu *et al.*, 2004; Magawata, 2008). The growth rate of aquaculture species depends on

their genetic potential and several other factors. The growth of fish can be influenced by: genetic makeup, behaviour, and population character (Sahu *et al.*, 2000). According to Balogun & Adebayo (1996), there is a need for a database on the carcass and by-yields of Nigerian fish resources to promote the optimum utilization of fish resources in Nigeria.

The role of carcass evaluation techniques in aquaculture research programs, especially in genetics, breeding, production management, feeding, and nutrition, cannot be overemphasized. While capture fisheries will remain relevant, aquaculture has already demonstrated its crucial role in global food security, with its production growing at 7.5% per year since 1970 (FAO, 2020). Recognizing the capacity of aquaculture for further growth, but also the enormity of the environmental challenges the sector must face as it intensifies production demands new sustainable aquaculture development strategies. Such strategies need to harness technical developments in, for example, feeds, genetic selection, biosecurity disease control, and digital innovation, with business developments in investment and trade (FAO, 2020). Knowledge of production efficiencies and growth potentials concerning desired carcass attributes has provided an impetus to improvements in genetic selection techniques and management of aquatic food animals (Sahu *et al.*, 2000). A medium to a high positive correlation between growth rate and feed conversion rate has been recorded. Thus, selection for a high growth rate often results in improved feed conversion.

Moreover, poor fish quality can be very detrimental to consumption, marketing, and acceptance of fish, yet fish is one of the best sources of animal protein (Meiselman, 2001; Zengeya *et al.*, 2015). Information should be available on the effect of pedigree and ecotype on the carcass yields, waste yields, and nutritional quality of fish to serve as baseline knowledge for genetic improvement in the research area. Therefore, this study was conducted to compare the carcass yields, by-yields, and nutritional quality of three different strains of *C. gariepinus* collected from river Rima (one wild strain), two fish farms using the same pure cultured strain and the third farm with a pedigree of artificial crosses.

Materials and Methods

Study area

This study was conducted at Usmanu Danfodiyo University, Sokoto, located on 13° 07'38.9"N and 5 ° 12'19.0E within Sokoto. Sokoto is in the savannah agro-ecological zone about 350m above sea level. Rainfall establishes between mid-May to early June and peaks in August. The climate is semi-arid, with rainfall of between 550mm and 700mm. The dry season starts from mid-October to late April. Sokoto receives an average annual temperature of 30.26°C and average annual relative humidity of 48.54% (SERC, 2012).

Fish sample collection

A total of 90 live *Clarias gariepinus* weighing between 100g, and 600g were collected from the river Rima (Population strain A), the Kwalkwalawa area, and two other selected fish farms (Population strains B and C). The collected samples were collected irrespective of sex (male or female) and taken to the Department of Fisheries and Aquaculture laboratory, Usmanu Danfodiyo University, Sokoto, for anatomical separation, mass indices, and sample collection for carcass-by-yields nutritional quality assessment, respectively.

Anatomical separation of the carcass

The collected fish samples were degutted, decapitated, and filleted using the standard dissecting kit. The fillets were categorized as the flesh yield or carcass yield, as these two words shall be used interchangeably throughout this paper. The fins, bones, head, visceral, and other internal organs were categorized as the waste yields (by-yields). The following data were collected for the assessment of carcass yields and by-yields; Body weight of the fish (BW), Gutted weight (GW), Carcass weight (CW), the weight of the gonads (GndW), weight of the head (HdW), weight of the visceral (VscW), Fins' weight (FnW) and Total by-yields (TBY). Meanwhile, 100g each of oven-dried fish tissue samples from the three population groups was taken to the Central Laboratory of the National Institute of Freshwater Fisheries Research (NIFFR) New-Bussa, for nutritional quality assessments. The tests of nutritional quality were conducted following the NIFFR Central Laboratory Protocols for proximate analysis.

Statistical analysis

The analyses were done between ecotypes and Strains (i.e. population strains A, B & C) for carcass and by-yields, using a one-way analysis of variance and a simple linear regression model. Means comparison for carcass yields in percentage body weight and by-yields in the percentage of the body weight was done by Duncan New Multiple Range Test (DNMRT), using Statistical Package for Social Sciences SPSS Version 20.

Yield equations: The regression equation of these relationships for carcass yields and by-yields with fish size for each provenance was calculated according to the method of Ipinjolu *et al.* (1988) using the formula;

$$Y = a + bX \text{ (Parker, 1973),}$$

Where Y= Flesh yield or waste yield (gm), X= Fish total weight (gm), b= Coefficient, a= intercept.

Table 1: Regression equations of carcass yields and by-yields of the three *C. gariepinus* population strains

Population strain	Flesh/Waste yield	N	Intercept 'a'	b-Value	SE of b	R	Sig.
Strain A	Flesh yield	30	49.70	0.31	0.056	0.72	***
	Waste yield	30	11.50	0.27	0.02	0.95	***
Strain B	Flesh yield	30	20.25	0.42	0.09	0.64	***
	Waste yield	30	23.50	0.23	0.05	0.66	***
Strain C	Flesh yield	30	7.00	0.45	0.04	0.92	***
	Waste yield	30	5.74	0.29	0.02	0.93	***

b: *=Significant, ** = Very significant ***= Highly significant

Results

Table 1 shows the result of the regression equations of the flesh and waste yields of each of the fish (*C. gariepinus*) population strains studied. All the prediction equations were highly significant ($P < 0.05$). The least 'b' value recorded for the flesh yield from the wild fish population strain from river Rima differentiated it from the cultured population strains. The 'b' value of the C population strain was the highest recorded, followed by that of the B. However, all the coefficients of determination from the three fish population strains were highly significant ($p < 0.05$). Similarly, the highest waste yield coefficient was also recorded from the C population strain, followed by the river Rima population strain. In contrast, the least waste yield was recorded from the B population strain.

Table 2 presents the result of Carcass yields and by-yields of the *C. gariepinus* population strains based on the percentage of body weight (%BW). The results revealed that the river Rima population strain recorded the highest mean gutted weight (84.63 ± 3.67), though not significantly higher ($p < 0.05$), than the two cultured fish population strains, while the B (76.50 ± 3.31) population strain was also insignificantly higher ($p < 0.05$) than the B (76.20 ± 1.63) population strain. Also, the flesh weight (FW) of the river Rima (55.50 ± 2.97) population strain was higher ($p < 0.05$) than the two cultured population strains. Population strain C (47.79 ± 1.17) recorded the lowest significant ($p < 0.05$) flesh weight (FW), while B (49.12 ± 2.68) population strain had an intermediately significant ($p < 0.05$) flesh weight. The wild population strain from river Rima recorded the lowest significantly different ($p < 0.05$) body weight, among the two cultured population strains, with the C population strain having the highest significant body weight ($p < 0.05$), while the B population strain had an intermediate significantly different ($p < 0.05$) mean body weight, between the two other population strains. Gonad weight of the B Population strain was significantly higher ($p < 0.05$) than the other two population strains, while the C population strain recorded the lowest significantly different ($p < 0.05$) Gonad weight to the percentage of body weight, the river Rima had an intermediately significantly

different ($p < 0.05$) Gonad weight to their body weight percentages.

However, there was no significant difference ($p < 0.05$) in the head weight (HdW), Visceral weight (VscW), Fin weight (FnW) and Total waste products (TW) expressed to the percentages of body weight across the three fish population strains. Also, the coefficient of variations (CV) was almost the same for all the three population groups except for the gutted weight, where the river Rima population strains had the highest CV, followed by that of the B and the least CV with respect to gutted weight was recorded from the C population strain. Similarly, the highest CV for gonad weight to the percentage of body weight was recorded from river Rima population strain, which was very high, with 166.10, followed lagging behind this was the CV of C population strain, with 150.60, while the least CV for gonad weight to body weight percentage was recorded from the B population strain, with 87.10. However, the CV recorded for the visceral weight percentage was highest in the B population strain, while the other two population strains were almost the same.

Table 3 contains the result of the nutritional composition of the *C. gariepinus* population strains studied. It was observed that the Protein and NFE constituents of the population strains vary across the population groups, with the Population strain C being of significantly ($p < 0.05$) highest mean value of 63.38 ± 0.03 than the other two population strains studied. In addition, the fat content was significantly different between the ecotypes, with the Population strain C having the highest value than the other two Population groups. The fillet colour observed were reddish colour and less green for the cultured population strains while the wild population strains appeared light and greener than the earlier population strains.

Discussion

The percentage flesh-waste yield analyzed irrespective of the sampling location revealed the 'b' coefficients obtained in this research were lower than 53.32% obtained by Magawata (2008), 70.57% by Fagbenro *et al.* (2005) and the 61% reported by Ketiku & Akinsiku (2000) but align with 40.96%

Table 2: Carcass yields and by-yields of the *C. gariepinus* population strains -based percentage of body weight (%BW)

	PS. A			PS. B			PS. C			CV	CV	CV
	Mean±SE	Range	SD	Mean ± SE	Range	SD	Mean±SE	Range	SD			
BW	248.33±18.49 ^a	100-450	101.27	306.67±19.44 ^{ab}	100-600	106.46	315.00±19.05 ^b	100-500	104.35	40.78	34.71	33.13
GW	84.63±3.67	55.50-128.000	20.06	76.50±3.31	30.62-138.17	18.13	76.02±1.63	56.31-93.40	8.93	23.70	23.70	11.75
FW	55.50±2.97 ^b	32.25-85.40	16.28	49.12±2.68 ^{ab}	20.27-98.34	14.69	47.79±1.17 ^a	31.67-60.47	6.43	29.33	29.91	13.45
GndW	3.37±1.02 ^{ab}	0.03-20.86	5.60	5.97±0.95 ^b	0.20-20.70	5.20	3.10±0.85 ^a	0.03-16.03	4.67	166.17	87.10	150.65
HdW	27.62±0.93	21.57-40.60	5.12	25.63±1.02	9.88-37.23	5.56	26.60±0.77	20.07-43.16	4.24	18.54	21.69	15.94
VscW	3.50±0.23 ^a	1.60-6.50	1.24	3.44±0.31	1.25-8.31	1.72	3.05±0.19	1.83-5.86	1.06	35.43	50.00	34.75
FnW	1.51±0.08 ^a	0.75-2.29	0.45	1.75±0.09	0.47-2.63	0.51	1.62±0.09	0.89-2.84	0.48	29.80	29.14	29.63
T. Waste	32.63±0.98	25.70-45.30	5.37	30.82±1.16	11.60-48.14	6.33	31.27±0.83	23.17-46.92	4.57	16.46	20.54	14.61

Means in rows with the same letters are not significantly different (P<0.05)

Key: PS. = Population Strain; BW = Body weight; GW = Gutted weight; FW = Flesh weight; GndW = Gonad weight

HdW = weight of the head; VscW = Visceral weight; FnW =Fin weight; TW = Total waste

obtained by Ipinjolu (2000). Considering the high significance in the mean body weight across the three *C. gariepinus* fish population groups as reported by Mikaheel *et al.* (2019a), one would expect more percentage of flesh yields, from the cultured population groups, contrary to this;

both the gutted weight and the flesh weight percentage of the body weight were not significantly distant from the wild to the cultured population groups. This revealed that even though by the record, the Dutch strain of *C. gariepinus* grows faster than the wild fish population group as also reflected in the mean body weight, Total Length to Standard lengths percentages of this same *C. gariepinus* population groups reported by Mikaheel *et al.* (2019b) and the Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoretic (SDS-PAGE) protein banding profiles of the three population groups (Mikaheel *et al.*, 2019a). The yields were still the same with respect to gutted weight and flesh yield to the percentage of body weight. According to Sahu *et al.* (2000), the growth rate of aquaculture species depends on their genetic potential as well as several other factors. Some of the factors that influence the growth of fish are: genetic makeup, behavior, or other population characters. By implication, the Dutch strain of *C. gariepinus* is greatly favored by this assertion of Sahu *et al.* (2000). Similarly, it was revealed in this research that the waste products from the three population groups were also not significantly different across the groups. Alas, the dorsal fin

Table 3: Nutritional quality of the three *C. gariepinus* population strains

Strain	Moisture	Fat	Protein	Crude Fibre	Ash	NFE	Flesh Colour
P. Strain A	6.09±0.24 ^a	24.09±0.24 ^b	62.90±0.02 ^b	0.61±0.01	5.19±0.13	1.14±0.17 ^a	Greenish-less red
P. Strain B	5.18±0.08 ^b	25.13±0.15 ^a	63.15±0.13 ^{ab}	0.57±0.02	5.16±0.01	0.82±0.06 ^{ab}	Reddish-less green
P. group C	4.26±0.01 ^c	25.72±0.60 ^a	63.38±0.03 ^a	0.65±0.32	5.41±0.01	0.55±0.01 ^b	Reddish-less green

Mean in columns with same superscripts are not significantly different (P<0.05)

counts/spines and the Ventral fin counts population groups' strains were significantly lower. This and the significance in the head morphometry might have accumulated to close the gap between the waste yield of the wild and the two cultured population groups. In another research by Saillant *et al.* (2009), genetic parameters were estimated from the sire half-sib variance and covariance components of *Oreochromis niloticus* the heritability of body weight and carcass processing traits (standardized to body weight) percent head weight, percent viscera weight and percent visceral fat weight were relatively high ranging from 0.48 ± 0.15 to Head%; the estimate of heritability for fillet yield was lower (0.25 ± 0.10) but was significantly greater than zero. Bodyweight was positively correlated to fillet percentage, Viscera percentage, and visceral fat percentage, and negatively correlated to Head percentage. These results indicate that these carcass processing traits can be modified by directional selection and that selection for greater body weight would lead to an increase of fillet percentage, viscera percentage, and Visceral Fat percentage, and a decrease of head percentage. The condition factors reported by Mikaheel *et al.* (2019a) of these

population groups strains were in agreement with that of Olopade *et al.* (2016) on fish from Lake Kariba that had a higher condition factor than those from Lake Chivero. Olopade *et al.* (2016) inferred that this might be due to the differences in water quality and the type of food available in the two water bodies. This foregoing research on the population strains of river Rima and the other strains under study asserts that higher condition factors reflect a better nutritional status and better adaptation of the fish to its immediate environment. This assertion explains why the primary target index for carcass yields trait in fish should be for the fast growth rate of high ontogenic genetic heritability.

The fillet colour observed were reddish colour and less green for the cultured population strains, while the wild population strains appeared lighter red and greener than the earlier population strains. This may be due to more supply of blood to the muscles and a similar difference was reported by Hamandishe *et al.* (2018) of some measured colour of *Oreochromis niloticus* samples between two lakes; the results reflected variability in terms of lightness. Fish fillets from Lake Chivero were significantly darker (lower lightness) than those from Lake Kariba for two different months. Fish fillets from Lake Chivero were greener and less red than those from Lake Kariba and the latter were redder and less green as shown by the chromatic component values (ranging from -120 to 120, from green to red). There were no differences in chromatic components (ranging from -120 to 120, blue to yellow) between fish fillets from the two lakes. However, fish fillets from Lake Chivero had more yellowness in October than in June. Therefore, the observed colour difference in the studied *C. gariepinus* population strains in this research could be directly linked to the difference in ecotype and the intensiveness of culture that the wild population strains lacked in the open ecological habitat.

Fish provide varying nutritional qualities based on the species or seasons (Hassal, 1982; Dani *et al.*, 2001). It is however important to note that the varying seasons dictate the water quality parameters of the fish's habitat. This habitat may also have varying Physico-chemical parameters based on the water body's location and biotic habitats. Either wild or culture ecotype system has an important role in the constituent solution of aquatic habitat. Moisture, dry matter, protein, lipids, vitamins, and minerals are the most important components that act as sources of nutritive value of fish products (Omoniyi *et al.*, 2002). The moisture content also varies across the group, while thinking of assertions that varying

moisture content can result from exposure time to drying facility, intensity of drying (temperature), and the average initial moisture content of the fish. The latter assertion agreed with Aberoumad & Pourshafi (2010), who reported that the Moisture content of flesh could be a good indicator of its relative content of energy, protein and lipid. Songa *et al.* (2022) reported interaction between genetic, breeding, feeding, slaughtering, and processing factors results in the final quality of pork. The complex determinism of meat quality makes it hard to predict ante-mortem or quickly after slaughter. Fish meat contains significantly low lipids and higher water than beef or chicken and is favored over other white or red meats (Nestel, 2000). The total lipid and ash content of fish varies with the increasing weight or length of the fish, it may also vary with the season and varied habitats and feed (Solomon & Oluchi, 2018). In another, Siagian & Nugroho (2020) reported that the body composition of fish fed certain experimental diets had increased body protein constituents, lipid composition, and energy constituents with an increasing protein to energy ratio. High dietary lipid levels generally resulted in low moisture and protein but high energy as reported by Raj *et al.* (2007). Body lipid contents of 9.2, 9.4 and 13.2% have been reported by Sanjayasari & Kasprijo (2010) for gilthead sea bream, which were fed experimental diets containing 13 -16% lipid from fish meal. Siagian & Nugroho (2020) also reported that 33.60 -37.90% of body lipid was detected in fish fed a dietary lipid level of 5.3 -11.9%. these authors asserted that the positive correlation between body lipids and dietary lipid may indicate that when dietary lipid was supplied in excess, a proportion of this lipid was deposited as fats (Raj *et al.*, 2007). results showed that the substitution of fish meal by salted trash fish meal up to 75% did not give a significant effect on pelleted diet water stability, growth performance (survival rate, weight gain, specific growth rate, feed efficiency, protein efficiency) and carcass quality (body proximate composition, amino acid profile, edible flesh, dress-out percentage, carcass waste and sensory quality) of the fish ($P > 0.05$) (Hasan *et al.*, 2019). However, complete substitution (100%) reduced protein retention and fish body protein ($P < 0.05$). Therefore, the nutritional quality of fish can be optimally dependent on the diet fed to the fish, whether it has the required constituent to enhance the healthy growth rate, efficacy of feeding, and in return better carcass yields and composition for a more profitable and successful culture of any farmed fish.

This research by inference drew that there was no significant difference in the carcass yield of the

three *C. gariepinus* population groups studied across the fish population groups. Also, the waste yields of the three population groups did not vary across the population groups. The variation in the total weight of the cultured *C. gariepinus* was a mere function of the fin weight and head sizes of the cultured *C. gariepinus*, which are of lesser value to man as a source of aquatic sourced meat proteins, and thereby referred to, as the by-yields or waste-yields, in another word. On the other hand, the flesh yield of the *C. gariepinus* population strains from river Rima and that of the crossed strain varied significantly in the between body weight statistics of the two fish population groups, which further consolidates the evidence of a genetic relationship between these two *C. gariepinus* population strains. There was no significant variation between the bodyweight statistics of the fish population strains. Therefore, it will be more beneficial to focus on the improvement of the cultured stock/strains, in terms of growth rate by adequate nutrition for more resistance to diseases and consequently, heritability for improved healthy growth rate, feed conversion efficiency and general hardiness, harnessing the diverse wild strains. It is more so recommended that further investigation into the amino acids profile, minerals composition and organoleptic characters of the wild fish population groups from river Rima should be carried out by other researchers, for additional knowledge to the interest of Fish Nutritionists.

In conclusion, the results obtained from the *C. gariepinus* population groups studied revealed that effects of the fish body weight were the primary factors that influenced the carcass yields and waste yields. The nutritional quality of the *C. gariepinus* population groups studied were perceived to have been majorly affected by feeds and diets in the culture system and the level of natural foods available for the wild fish population groups in the open water at the current stage before capture during sample collection for this research. This finding was based on the current body weight of the fish population groups' strains. The outcome showed that, the ones with higher body weights which was the cultured had highest flesh weights which were not significant when compared in terms of the body weight percentages. All nutritional information too indicated that, the cultured population groups were only better fed than the wild population conspecifics. Therefore, it was recommended that fish geneticist should give priority to developing fisheries stocks for growth rate and feed conversion efficiency to get the highest fish carcass yield at the cheapest cost of production. That the wild *C. gariepinus* stocks can

be used to develop the cultured population stocks for disease resistance and hardiness, for maximum survival rate at production stages.

Conflict of interest

The authors declare that there is no conflict of interest.

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