A Comparative Study of the Nutritional Composition, Fatty Acid Profiles and Organoleptic Evaluation of *Clarias gariepinus* (African catfish) and *Oreochromis nilotius* (Nile tilapia) raised under Wild and Pond-cultured Systems.

Abstract

Clarias gariepinus and *Oreochromis niloticus* are two important fish species that are widely consumed in many parts of the world. This study investigated the nutritional composition, fatty acid profiles and organoleptic evaluation of these two fish species raised under wild and pond-cultured systems. The proximate composition was determined using standard AOAC methods. Fatty acid profiles were analyzed using gas chromatography, while organoleptic evaluation was conducted using twenty panelists. *C. gariepinus* exhibited significantly lower (p<0.05) moisture content (77.76±0.45 and 79.06±0.36) and higher crude fat content (1.75±0.14 and 1.32±0.33) respectively in both wild and pond-cultured species compared to *O. niloticus*. *C. gariepinus* had higher protein content than *O. niloticus* in both wild and pond-cultured species. The carbohydrate content of *O. niloticus* was significantly higher (p<0.05) than in *C. gariepinus*, while the ash content of *C. gariepinus* and *O. niloticus* was not significantly different (p>0.05). Both species exhibited variations in their fatty acid profiles, with significant differences (p<0.05) observed in the levels of saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). All wild and pond-cultured fish species had the same pattern of fatty acid composition SFAs > PUFAs > MUFAs except wild *C. gariepinus* with SFAs > MUFAs > PUFAs pattern. Pond-cultured *O. niloticus* and *C. gariepinus* had higher total *n*-3 PUFAs and lower *n*-6 PUFAs values while wild *O. niloticus* and *C. gariepinus* had lower *n*-3 PUFAs and higher *n*-6 PUFAs values. This difference was statistically significant (p<0.05). The results indicated significant organoleptic differences (p<0.05) in consumer preference between wild and pond-cultured *C. gariepinus*, however, *O. niloticus* was found to be liked similarly regardless of its source (p>0.05). These findings suggest that the type of habitat, fish species and diets have significant impacts on the proximate composition, fatty acid profiles and organoleptic attributes of fishes.

Keywords: *Clarias gariepinus*, *Oreochromis niloticus*, Proximate composition, Fatty acid profiles, Organoleptic evaluation, Wild, Pond-cultured

Introduction

Fatty acids are important constituent of the human body due to their important function as a source of energy, membrane constituents and metabolic and signaling mediators [1]. Many of these fatty acids can be synthesized by the body with the exception of some polyunsaturated fatty acids (PUFAs) which require a dietary source [2]. PUFAs can be divided into two main groups: omega -3 (*n*-3) and omega -6 (*n*-6) based on the position of the first double bond starting from the methyl end group of the molecule [3]. The main n-6 PUFAs include linoleic acid (LA) and its metabolites arachidonic acid (AA), occurring particularly in animal tissue. The main n-3 PUFAs are α-linolenic acid and its metabolites eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) mainly found in fish oil [4]. Many researchers have reported the importance of *n*-3 PUFAs to human health. Omega -3 PUFAs particularly EPA and DHA play an important role in the prevention of many diseases including hypertension, diabetes, cardiovascular diseases, cancers and inflammatory diseases. They are also essential in fetal development and in delaying the onset of neurological degeneration of ageing [5-8]. Despite the health benefits of n-3 fatty acids, their intake is relatively low in human population while there is an increasing intake of n-6 fatty acids from vegetable oil and animal fats. This decrease in the intake of n-3 fatty acids has been connected with poor development of visual acuity [1, 9].

Nutritionally, fish is a rich source of digestible proteins, vitamins, minerals and a much better source of *n*-3 PUFAs especially DHA and EPA, hence it is an alternative to increasing the level of omega -3 fatty acids in human diet [10-14]. Fatty acid compositions of fish vary from species to species due to diet consumed, reproductive cycle, temperature, season, geographical location and whether fish are wild (captured) or farm-raised (cultured) [15-17]. There are significant differences in the nutritional compositions of wild and cultured fish. Studies suggest that the nutrient and fat contents of cultured fish are more uniform than in wild fish and thus, cultured fish are richer in *n*-3 fatty acids. This is because cultured fish in addition to natural food in the pond is provided with nutrient rich feeds while wild fish on the other hand depend totally on natural food for its survival [18-19].

As a result of the variation in nutrient and fat contents of cultured and captured fishes, it is thus important to measure the proximate and fatty acids profiles of commercially important fish species in order to evaluate their health benefits on the consumers. Two most important species *Clarias gariepinus* (catfish) and *Oreochromis nilotius* (tilapia) were chosen for this study based on the fact that they are most cultured fish in Nigeria. We investigated the proximate composition, fatty acid profiles and organoleptic properties of the two common freshwater fish species from Ashaka Town in Ndokwa East Local Government Area, Delta State, Nigeria.

Materials and Methods

Collection of Fish Samples

A total of 10 samples (five per species) of wild *Clarias gariepinus* and *Oreochromis niloticus* were bought by 8 am at different fishing landing sites of Ashibalam swamp area in Ashaka Town, Delta State, Nigeria. Five samples each of pond-cultured *Clarias gariepinus* and *Oreochromis niloticus* were also collected from a commercial farm ponds in Ashaka. Proximate analysis and fatty acid profile of the fish samples were evaluated immediately. All analyses were performed in quintuplicate.

Proximate Composition Analysis

The Association of Official Analytical Chemists' procedure was followed for the proximate composition analysis (moisture, ash, crude protein, crude fat carbohydrate contents) of the fish samples [20-23].

Fatty Acids Analysis

The total lipids were extracted BF_3-methanol by soxhlet extraction method [24]. The extracted lipids were esterified and then recovered in hexane. The fatty acid methyl ester (FAME) was analyzed by gas chromatography (Agilent Gas Chromatograph; model QP 6890N fitted with an Agilent Mass Selective Detector, 5973 series). Separation was carried out in a capillary column (30 x 0.25mm id x 0.25im DB wax): The starting temperature was 150°C maintained for 2minutes at a heating rate of 10 °C/minute. The total running time was 22 minutes. Helium was the carrier gas while the injection volume was 1 μL. By comparing the retention times of FAME mixtures, fatty acids were identified using Agilent Technologies software 5988-5871EN.

Organoleptic Evaluation

Twenty panelists evaluated the organoleptic quality of the smoked fish products of wild and pond-cultured *Clarias gariepinus* and *Oreochromis niloticus*. The organoleptic test was based on taste, texture, flavour, colour, sweetness and overall acceptability of the smoked fish products. Panelists were asked to complete questionnaires using the 6-point hedonic scale described in literature as follows: 1 (dislike very much), 2 (dislike moderately), 3 (dislike slightly), 4 (like slightly), 5 (like moderately) and 6 (like very much) [25].

Statistical Analysis

SPSS software version 20.0 and Excel were used to analyze the experimental data. The collected quintuplicate data were presented as mean value ± standard deviation (mean ± SD). In order to test for significant difference in proximate composition, fatty acids profiles and organoleptic properties among the captured and pond-cultured *Clarias gariepinus* and *Oreochromis niloticus*, analysis of variance (ANOVA) was used at 95% confidence level ($p < 0.05$). Fisher's Least Significant Difference (LSD) was to ascertain significant differences among the treatment means at $p < 0.05$.

Results and Discussion

Proximate composition

The proximate composition of *C. gariepinus* and *O. niloticus* (wild and pond-cultured) is presented in Table 1. The moisture content of wild *C. gariepinus (*77.76 ± 0.45%) and *O. niloticus* (80.14 ± 0.60%) differ significantly ($p<0.05$) from that of the pond-cultured *C. gariepinus* (79.06 ± 0.36%) and *O. niloticus* (81.18 ± 0.61%). The pond-cultured fish species had significantly ($p<0.05$) higher moisture contents than the wild fish species leading to the wild fish species having higher concentrations of nutrients. Similar results for cultured and wild *C. gariepinus* collected respectively from Ondo State in Nigeria reported that the moisture content was significantly higher ($p < 0.05$) in the cultured *C. gariepinus* (6.24 ± 0.10%) than wild *C. gariepinus* (5.43 ± 0.11%) [26]. The findings also revealed that *O. niloticus* contains significantly higher moisture levels than *C. gariepinus* which is consistent with the findings of a previous study on the species where the values were lower than in the current study [27]. The pond-cultured *O. niloticus* and wild *C. gariepinus* exhibited the highest and lowest moisture contents respectively. This suggests that wild *C. gariepinus* is less prone to microbial contamination than pond-cultured *O. niloticus*. This is because high moisture content provides a breeding ground for bacteria, which increases the likelihood of fish spoilage [28-29].

Table 1. Proximate composition of *Clarias gariepinus* and *Oreochromis niloticus* (wild and pond-cultured).

Proximate composition	***C. gariepinus*** **(wild)**	***C. gariepinus*** **(pond-cultured)**	***O. niloticus*** **(wild)**	***O. niloticus*** **(pond-cultured)**
Moisture (%)	77.76 ± 0.45^{a}	79.06 ± 0.36^{b}	80.14 ± 0.60^{aa}	81.18 ± 0.61^{ab}
Crude Fat (%)	1.75 ± 0.14^{a}	1.32 ± 0.33^{b}	0.76 ± 0.07^{aa}	0.60 ± 0.12^{ab}
Crude Protein (%)	19.04 ± 0.24^{a}	18.16 ± 0.30^{b}	17.10 ± 0.5^{aa}	15.72 ± 0.50^{ab}

Ash (%)	1.10 ± 0.12[a]	1.14 ± 0.23[a]	1.18 ± 0.08[a]	1.26 ± 0.09[a]
Carbohydrate (%)	0.32 ± 0.13[a]	0.32 ± 0.08[a]	0.78 ± 0.33[b]	0.76 ± 0.09[b]
Energy (kcal/g)	93.46 ± 1.14[a]	85.80 ± 2.55[b]	77.22 ± 0.93[aa]	74.12 ± 2.02[ab]

*Results are expressed as mean values ± standard deviation (n = 5).
*Means in the same row with different superscripts are significantly different at $p < 0.05$.

The percentage of crude fat of wild *C. gariepinus* was found to be 1.75±0.14%, which was significantly higher (p<0.05) than the percentage crude fat in wild *O. niloticus* (0.76±0.07%). In contrast to the moisture content results, wild *C. gariepinus* had the highest and pond-cultured *O. niloticus* the lowest crude fat content ($p < 0.05$), supporting the inverse relationship between fat and moisture levels, which is in congruence with previous reports [30-31]. According to the Ackman classification system, the wild and pond-cultured *C. gariepinus* and *O. niloticus* tested were classified as very low-fat fish or lean fish (< 2% fat) [32]. It is important to note that the fat content reported in this study was likely due to differences in species. However, other factors such as diet, geographical origin, catch season, age and reproductive stage may also influence fat content [1]. Similar to the crude fat content, pond-cultured *O. niloticus* presented the lowest crude protein content, followed by wild *O. niloticus* and pond-cultured *C. gariepinus*, and wild *C. gariepinus*, which had the highest crude protein content (p<0.05; Table 1). The protein contents of the wild and pond-cultured fish species obtained in this study ranged from 15 to 28%, which was consistent with previous findings [33-34]. The ash content of all fish species ranged from 1.10±0.12 to 1.26±0.09%, thus the difference was not significant (p >0.05). The results of the study showed that *O. niloticus* had significantly high level of carbohydrates (p <0.05) than *C. gariepinus*. The low levels of carbohydrates (0.32±0.13 to 0.78±0.33%) in the fish species compared to the levels of protein could be attributed to the fact that carbohydrates make up very small percentage of the biochemical composition of fish.

Fatty Acid Composition

The fatty acid profiles of wild and pond-cultured *C. gariepinus* and *O. niloticus* are displayed in Table 2. Seven fatty acids comprising three saturated fatty acids (SFAs), one monounsaturated fatty acid (MUFA), and three polyunsaturated fatty acids (PUFAs) where found across the different fish species studied, with SFAs present in higher proportion. The most abundant SFAs in the fish samples was palmitic acid (PA, C16:0), which is the usual trend in marine foods and accounted for 34.73 – 45.86% of the total fatty acids. PA was significantly (p<0.05) higher in wild fish species than in cultured ones. Pond-cultured *O. niloticus* (27.29±1.50%) showed significantly lower (p<0.05) PA than wild *O. niloticus* (29.85±0.89%), pond-cultured *C. gariepinus* (33.27±0.61%) and wild *C. gariepinus* (35.45±1.02%). Stearic acid was low for pond-cultured *O. niloticus* (7.01±0.78%) as well as behenic acid (0.43±0.14%), while high level was recorded for the wild *O. niloticus* (8.20±0.74%, 0.92±0.11%, respectively).

Table 2. Fatty acid profile (% of total fatty acid) of *Clarias gariepinus* and *Oreochromis niloticus* (wild and pond-cultured).

Fatty acids (%)	*C. gariepinus* (wild)	*C. gariepinus* (pond-cultured)	*O. niloticus* (wild)	*O. niloticus* (pond-cultured)

C16:0 Palmitic	35.45 ± 1.02^{a}	33.27 ± 0.61^{b}	29.85 ± 0.89^{aa}	27.29 ± 1.50^{ab}
C18:0 Stearic	9.20 ± 0.50^{a}	7.41 ± 0.41^{b}	8.20 ± 0.74^{c}	7.01 ± 0.78^{b}
C22:0 Behenic	1.21 ± 0.07^{a}	1.35 ± 0.12^{b}	0.92 ± 0.11^{aa}	0.43 ± 0.14^{ab}
ΣSFA	**45.86 ± 1.59**	**42.03 ± 1.14**	**38.97 ± 1.74**	**34.73 ± 2.42**
C18:1 *n*-9 Oleic	27.53 ± 0.80^{a}	27.68 ± 0.76^{a}	28.51 ± 1.25^{a}	32.05 ± 0.97^{b}
ΣMUFA	**27.53 ± 0.80**	**27.68 ± 0.76**	**28.51 ± 1.25**	**32.05 ± 0.97**
C18:2 *n*-6 Linoleic	13.98 ± 0.27^{a}	11.65 ± 0.45^{b}	18.97 ± 0.32^{aa}	17.25 ± 0.44^{ab}
C18:3 *n*-3 α-Linolenic	12.63 ± 0.50^{a}	16.93 ± 0.84^{b}	13.51 ± 0.44^{aa}	14.83 ± 0.59^{ab}
C20:4 *n*-6 Arachidonic	ND	1.71 ± 0.07^{a}	ND	1.14 ± 0.31^{a}
ΣPUFA	**26.61 ± 0.77**	**30.29 ± 1.36**	**32.48 ± 0.76**	**33.22 ± 1.34**
Σ*n*-3 PUFA	12.63 ± 0.50	16.93 ± 0.84	13.51 ± 0.44	14.83 ± 0.59
Σ*n*-6 PUFA	13.98 ± 0.27	13.36 ± 0.52	18.97 ± 0.32	18.39 ± 0.75
PUFA/SFA	0.58	0.72	0.83	0.96
n-6/*n*-3 ratio	1.11	0.79	1.40	1.24

*Results are expressed as mean values ± standard deviation (n = 5).
*Means in the same row with different superscripts are significantly different at $p < 0.05$.
*ND: Not detected
*ΣSFA = sum of saturated fatty acids; ΣMUFA = sum of monounsaturated fatty acids; ΣPUFA = sum of polyunsaturated fatty acids; Σ*n-3* = sum of *n-3* fatty acids; Σ*n-6* = sum of *n-6* fatty acids

Unsaturated fatty acids comprising MUFAs and PUFAs were the main fatty acids in the wild and pond-cultured *C. gariepinus* and *O. niloticus*, which accounted for 54.14 – 65.27% of the total fatty acids. The percentage of the only identified MUFA oleic acid (OA, C18:1 n-9) was significantly (p<0.05) higher in pond-cultured *O. niloticus* (32.05±0.97%) than wild *O. niloticus* (28.51±1.25%); however, the difference in the percentage of OA in pond-cultured *C. gariepinus* (27.68±0.76%) was not significant (p>0.05) with wild *C. gariepinus* (27.53±0.80%). In both wild and pond-cultured fish species, 26.61 – 33.22% of the total fatty acids were composed of PUFAs. Among the *n*-6 PUFAs identified, linoleic acid (LA, C18:2 *n*-6) was the major component, and was significantly (p<0.05) high in the *O. niloticus* (wild and pond-cultured) compared to *C. gariepinus* (wild and pond-cultured). Arachidonic acid (ARA, C20:4 *n*-6) was not detected in the wild *O. niloticus* and *C. gariepinus*, however, there was a significant difference (p<0.05) in the percentage of ARA in pond-cultured *O. niloticus* (1.4±0.31%) and pond-cultured *C. gariepinus* (1.71±0.07%). The α-linolenic acid (ALA, C18:3 *n*-3) was the only *n*-3 PUFA identified and its concentration was significantly (p<0.05) lower in the wild species than those of the cultured species.

In the lipids of the pond-cultured *C. gariepinus*, a higher proportion of PUFAs was typically observed accounting for 30.29% of the total fatty acids in the specie. Interestingly, the results indicated that the pond-cultured *C. gariepinus* contained significantly (p<0.05) higher levels of *n*-3 PUFAs compared to the wild *C. gariepinus*, however its total *n*-6 PUFAs was lower than the wild species. This disparity could be potentially attributed to the differences in the diets of the wild and pond-cultured. The high proportion of *n*-3 PUFAs in the cultured species could be due to its controlled diet. The wild *C. gariepinus* has access to a diverse range of food sources including plant materials, zooplankton, phytoplankton and similar small fish which are known to be rich in *n*-6 PUFAs. Similar results have been reported for the same fish species [4]. According to the Department of Health and Social Security, UK Department of Health, a healthy balance fatty acid intake is considered to have a minimum PUFA/SFA ratio of 0.45 and a maximum of *n*-6/*n*-3 PUFA ratio of 4.0 [35-36]. Thus, the analysed fish species could be considered beneficial to human health with ratios of PUFA/SFA ranging from 0.58 to 0.96 and *n*-6/*n*-3 ranging from 0.79 to 1.40. Consuming fishes with PUFA/SFA ratio higher than 0.45 is helpful in preventing cardiovascular diseases. Similar PUFA/SFA ratio was observed in *Epinephelus coioides* and *Sparidentex hasta* (wild and cultured) with PUFA/SFA ratio from 0.59 to 0.70 [10]. The results of the present study were also similar to a previous report on wild, pond-cultured, *gher*-cultured and cage-cultured *Oreochromis niloticus* with PUFA/SFA ratio ranging from 0.40 to 1.98 [37]. The higher *n*-6/*n*-3 PUFA ratio in wild *C. gariepinus* and *O. niloticus* is due to the significantly (p<0.05) higher amounts of *n*-6 fatty acids than *n*-3 fatty acids in the fishes. These results are in agreement with those reported for wild and farmed tropical freshwater fish rohu (*Labeo rohita*) [38].

Organoleptic Evaluation

The average organoleptic scores for wild and pond-cultured *C. gariepinus* and *O. niloticus* were presented in Table 3. The results indicated significant differences (p<0.05) in consumer preference between wild and pond-cultured *C. gariepinus*, however, *O. niloticus* was found to be liked similarly regardless of its source (p>0.05). The mean values for flavour, colour, texture and overall acceptability for the wild and pond-cultured *O. niloticus* did not show any significant difference (p>0.05). However, there was a significant difference (p<0.05) in the mean value of taste between wild and pond-cultured *O. niloticus*. In the case of *C. gariepinus*, significant differences (p<0.05) were observed in flavour, colour, texture and overall acceptability between the wild and pond-cultured *C. gariepinus*, while no difference was observed in their taste (p>0.05). Specifically, the wild *C. gariepinus* and *O. niloticus* received highest scores for all the organoleptic parameters (6.60± 0.16) while pond-cultured ones had the lowest values.

Table 3. Organoleptic properties of *Clarias gariepinus* and *Oreochromis niloticus* (wild and pond-cultured).

Organoleptic property	*C. gariepinus* (wild)	*C. gariepinus* (pond-cultured)	*O. niloticus* (wild)	*O. niloticus* (pond-cultured)
Taste	5.48 ± 0.33^{a}	5.36 ± 0.33^{a}	5.44 ± 0.26^{a}	4.84 ± 0.22^{b}
Flavour	5.60 ± 0.20^{a}	5.12 ± 0.30^{b}	5.08 ± 0.36^{b}	4.76 ± 0.26^{b}
Colour	5.42 ± 0.11^{a}	4.68 ± 0.28^{b}	4.84 ± 0.36^{b}	4.78 ± 0.33^{b}
Texture	5.68 ± 0.16^{a}	5.42 ± 0.11^{b}	4.36 ± 0.22^{aa}	4.34 ± 0.09^{aa}
Overall Acceptability	5.80 ± 0.27^{a}	5.30 ± 0.27^{b}	5.10 ± 0.42^{b}	5.10 ± 0.65^{b}

*Results are expressed as mean values ± standard deviation (n = 5).

*Means in the same row with different superscripts are significantly different at $p < 0.05$.

The organoleptic evaluation conducted by a panel of twenty evaluators indicated a preference for the wild fish species compared to those cultured in ponds. These findings align with a previous study on sensory analysis of wild and pond-raised *Oreochromis karongae* and *Oreochromis shiranus* [39] and that of wild and cultured finfish [40]. Studies have shown that the proximate composition of fish can influence its organoleptic parameters such as taste, flavour, colour and texture. For example, the fat content of fish can impact its flavour and juiciness while protein content can affect its texture and tenderness. The moisture content is crucial for maintaining its freshness and succulence. Therefore, higher fat content results in better taste and flavour while lower moisture content and higher protein content result in firmer texture [40-41]. This explains why the taste, flavour and texture of the wild *C. gariepinus* and *O. niloticus* are higher than those of pond-cultured *C. gariepinus* and *O. niloticus*.

Conclusion

This study provided valuable insights into the nutritional composition, fatty acid profiles and organoleptic evaluation of *Clarias gariepinus* and *Oreochromis niloticus* raised in both wild and pond-cultured systems. The findings revealed distinct differences in the nutritional composition, with *C. gariepinus* exhibiting higher protein and fat contents in the wild type and *O. niloticus* displaying higher moisture content, particularly in pond-cultured type. Fatty acid profile analysis showed variations in the composition of *n*-3 and *n*-6 PUFAs between the wild and pond-cultured *C. gariepinus* and *O. niloticus*, with *C. gariepinus* from the pond-cultured showing significantly higher levels of *n*-3 PUFAs. Organoleptic evaluation highlighted differences in taste, flavour, texture, colour and overall acceptability, with preferences varying among the wild and pond-cultured fish species. The findings indicate that the nutritional values vary between the fish species which may be due to diet and environment.

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