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# Genetic and nutritional influence on the total lipid fatty acid profile of *Clarias gariepinus* muscle

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**Abstract**

The fatty acid profile of four different genetic strains of *Clarias gariepinus*: gold (G), Netherlands (N), RAU (R) and Wild (W) were evaluated. Fertilised eggs and larvae of the four strains were maintained under identical environmental conditions. After nine weeks, the two faster growing strains (G and W) had less total body lipid than the others (N and R). The total saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids of the four strains were: G – 32.1; 26.8 and 37.9%; N – 33.5; 27.8 and 35.5%; R – 32.7; 29.0 and 35.4%; W – 32.9; 27.7 and 36.8%, respectively. The major fatty acids that showed statistically significant differences between strains were: C16:0, C18:1$\omega$9, C22:5$\omega$3 and C22:6$\omega$3. The G strain had a significantly higher $\omega$3/$\omega$6 ratio (2.2) compared to that of the other strains (N – 1.9; R – 1.9 and W – 1.9). In a second trial, juveniles of strain G were fed an artificial diet for 60 days containing no lipid (A, control), or the following lipids at 10% of the diet, sunflower oil (B, a high level of C18:1$\omega$9 and C18:2$\omega$ 6), cod liver oil (C, a high level of 20 and 22 C$\omega$3 fatty acids) and tallow (D, predominantly SFA and MUFA). Muscle total lipid composition was strongly influenced by diet and contained the following SFA, MUFA and PUFA percentages, and a $\omega$3/$\omega$6 ratio of: A – 35.9; 45.3; 15.0% and 0.5; B – 30.6; 33.4; 33.6% and 0.1; C – 33.2; 37.2; 23.6% and 1.8; D – 38.7; 45.3; 12.1% and 0.4, respectively.

**Keywords:** *Clarias gariepinus*, genetic, nutritional, lipid fatty acid.

*Influence génétique et nutritionnelle sur le profil des lipides totaux du muscle de* Clarias gariepinus.

**Résumé**

Les profils d'acides gras de quatre souches génétiques différentes de *Clarias gariepinus*: gold (G), Netherlands (N), RAU-Rand Afrikaans University (R) et sauvage (W) sont analysés. Les oeufs et les larves des quatre souches ont été maintenues sous des conditions environnementales identiques. Après 9 semaines, les deux souches, dont les croissances sont les plus rapides (G et W), avaient des taux de lipides totaux inférieurs aux autres souches (N et R). Les acides gras totaux saturés (SFA), mono-insaturés (MUFA) et polyinsaturés (PUFA) des quatre souches sont G – 32,1 ; 26,8 et 37,9 % ; N – 33,5 ; 27,8 et 35,5 % ; R – 32,7 ; 29,0 et 35,4 % ; W – 32,9 ; 27,7 et 36,8 % respectivement. Les principaux acides gras qui montrent des différences significatives entre les souches sont C16 : 0, C18 : 1$\omega$9, C22 : 5$\omega$3 et C22 : 6$\omega$. La souche G a un taux significativement plus élevé de $\omega$3/$\omega$6 (2,2) comparé à ceux des autres souches (N – 1,9 ; R – 1,9 et W – 1,9). Dans une seconde expérience, les juvéniles de souche G sont nourris avec un aliment artificiel pendant 60 jours, ne contenant pas de lipide (A, témoin), ou avec un taux de 10 % des lipides suivants, de l'huile de tournesol (B, un niveau élevé de C18 : 1$\omega$9 et C18 : 2$\omega$6), de l'huile de foie de morue (C, un niveau élevé d'acides gras 20 et 22 C$\omega$3) et du gras végétal (D, SFA et MUFA en majorité). La composition en acides gras totaux du muscle est fortement influencée par le régime alimentaire et comprend les pourcentages suivants en SFA, MUFA et PUFA, et un taux de $\omega$3/$\omega$6 de : A – 35,9 ; 45,3 ; 15,0 % et 0,5 ; B – 30,6 ; 33,4 ; 33,6 % et 0,1 ; C – 33,2 ; 37,2 ; 23,6 % et 1,8 ; D – 38,7 ; 45,3 ; 12,1 % et 0,4, respectivement.

**Mots-clés :** *Clarias gariepinus*, génétique, nutrition, acides gras, lipides.

## INTRODUCTION

With the increasing interest that fatty acids, especially long chained polyunsaturated fatty acids, play in the lessening of cardiovascular related diseases (Hearn, Sgoutas, Hearn and Sgoutas, 1987; Singh and Chandra, 1988; Ackman, 1989; Kinsella, Lokesh and Stone, 1990; Tichelaar, 1993), the lipid fatty acid composition of fish muscle has been scrutinised world wide. Factors that have been found to influence fish fatty acid profiles include species (Love, 1988), genetic strain (Smith, Kincaid, Regenstein and Rumsey, 1988; Erickson, 1992), environment (Gallagher, McLeod and Rulifson, 1989; Morishita, Uno, Araki and Takahashi, 1989), water temperature (Stickney and Andrews, 1971; Stickney and Hardy, 1989), physiological (Sasaki, Ota and Takagi, 1989) and nutritional status (Tidwell, Webster and Clark, 1992). However, the most dominant factor that influences the lipid fatty acid composition is the diet of the fish (Gatlin and Stickney, 1982; Watanabe, 1982; Stickney and Hardy, 1989; Greene and Selivonchick, 1990).

In the present investigation, the genetic and nutritional influences on the whole body muscle total lipid fatty acid profiles are investigated. In the genetic study, four different *Clarias gariepinus* genetic strains are evaluated and compared. In the nutritional study, three different, commercially readily available, lipid sources are fed to juvenile *C. gariepinus* and the resulting muscle total lipid fatty acid composition compared.

## MATERIAL AND METHODS

### Genetic study

*Parental stock*

The broodstock were identified as RAU (R), Netherlands (N), Wild (W) and Golden (G) catfish. The RAU strain was normal coloured and had been maintained at the Rand Afrikaans University; the selection of this strain is discussed in Van der Walt, van der Bank and Steyn (1993*a*) and was the strain designated **E**. The origins of the normal coloured Netherland strain is discussed in Van der Walt, van der Bank and Steyn (1993*b*). The normal coloured wild strain was netted in the Olifants River in the Kruger National Park. The history of the golden coloured catfish has been summarised in Schoonbee, Hecht, Polling and Saayman (1980). With the exception of the wild strain, the other three strains were tagged and maintained in the same environment, receiving the same diet for at least three months prior to breeding. The wild strain were maintained with the three other strains for three weeks before being bred.

With the exception of the Netherlands strain, the broodstock bred consisted of three fecund females and two males of the same strain, respectively. Due to a shortage of Netherland males, the Netherland females were crossbred with two RAU (R) males, the resulting progeny, designated N in this study, are therefore hybrids of the RAU and Netherland strains.

*Larvae*

Larvae of the four *C. gariepinus* strains were artificially spawned and reared concurrently, using standard hatchery techniques (Schoonbee *et al.*, 1980; Prinsloo, Hoffman and Theron, 1993), and were maintained in separate containers connected to a common water recirculating system. Batches of 200 larvae (in triplicate) from each strain were randomly selected and placed into 60 l aquaria, 24 d after hatching. These 12 aquaria were connected to a common water recirculating system.

*Sampling*

At the beginning of each week, three groups of 20 apparently healthy fish were randomly sampled from each aquarium and the total body mass determined. Mean mass was calculated for the computation of feeding rate. The experiment was terminated on day 56.

*Feeding regime*

Initially, the feeding regime of Schippers, Prajitno, Boon and Machiels (1992) was followed: satiation feeding of larvae during first 20 days with natural occurring plankton. From day 21 to 28, plankton was gradually replaced with a 52% protein trout fry (No 2) commercial diet (supplied by Upstream Industries, Greenside, RSA). From day 29 until day 56, the fish were fed at a level of 8% live weight per day (Hogendoorn, Jansen, Koops, Machiels, van Ewijk and van Hess, 1983) continuously over an 18 h period, using automatic feeders.

### Biochemical analysis

At termination of the study (56 d), 10 fish were randomly sampled and pooled. The whole body total lipid composition of the pooled samples were determined by the method of Folch, Lees and Stanley (1957) as adapted by Christie (1982).

*Fatty acids*

The extracted muscle total lipids were analyzed for fatty acids. Fatty acid methyl esters were prepared according to A.O.C.S. (1991) standard methods. These esters were separated on a capillary column (60 m × 0.25 mm ID; supplied by Quadrex Corporation, USA, Cat No 007-23A-60-0,25F) in a Hewlett-Packard 5880A gas chromatograph fitted with a flame ionisation detector. A Hewlett-Packard 7673 automatic injector (split ratio 1:80) was used for sample injection. The run was isothermal (210°C) with helium (100 kPa) as carrier gas. Injector and detector port temperatures were 250°C. Fatty acids were identified by comparing retention times with those of known standards.

## Nutritional study

### *Holding facilities*

Twelve 250 l aquaria connected to a 12 $m^3$ volume water recirculating unit were each stocked with 20 catfish. Water temperature was maintained at 29°C at all times. Thrice weekly, 6 $m^3$ of the total recirculating water volume was replaced. A water flow rate of 4 $l.min^{-1}$ per aquarium was maintained. Weekly water ammonia, nitrite, nitrate and phosphate concentrations were determined according to APHA (1980) and were well below the accepted maximum limits for *C. gariepinus* (Viveen, Richter, Van Oordt, Janssen and Huisman, 1985).

### *Fish*

Fish of the golden strain were bred and raised in the Mobil Aquarium at the University of the North. Although the fish used in the nutritional study were of the same strain (G) as that of the genetic study, they were not of the same generation. The fish were fed a commercial catfish diet (6.6% moisture, 34.6% protein, 3.9% fat, 2.1% ash; Brennco Feeds, Louis Trichardt) until the commencement of the experiment. Prior to stocking, the fish were sorted into three size classes, with live body masses of 50-85, 90-130 and 150-250 g, so as to minimise intra-tank aggression.

### *Diet composition*

Four diets which were identical except for lipid composition (Diet A, the control diet had 0% lipid) were fed in triplicate to the fish. Diets were prepared from purified ingredients according to Stickney and Andrews (1971) and each contained 10% by weight of either sunflower oil (Diet B, a high level of oleic and linoleic fatty acids), cod liver oil (Diet C, a high level of 20 and 22 carbon $\omega 3$ fatty acids) or tallow (Diet D, predominantly saturated and monounsaturated fatty acids). The tallow was obtained from a commercial abattoir and contained cattle, pig and sheep fat.

### *Sampling*

At the beginning of each week, each individual fish was weighed. Mean weight was determined for the calculation of feeding rate. The experiment continued for 60 days.

### *Feeding regime*

Prior to the experiment, the fish were fed the experimental diets for a week at 0.1% body weight as a familiarisation period. Fish were thereafter fed at 3% (DM) of their live body weight, three times daily (08h00, 12h00 and 16h00).

## Biochemical analysis

Prior to feeding the fish with the experimental diet as a familiarisation period, four fish were randomly removed and the whole muscle (red, white and intermediate) biochemically analyzed (results designated as Z). At termination of the experiment, five fish from each tank were randomly removed and the muscle biochemically analyzed, using the same procedures as that used prior to the commencement of the experiment and in the genetic study. The lipids in the muscle of three fish per tank were analyzed for fatty acids.

## Statistical analysis

A linear model was fitted to the data with strain or diet as predictor. PROC GLM of the SAS package (SAS, 1985) was used and an analysis of variance was carried out. A mean and standard error was calculated for each strain or diet and a matrix of exceedence probabilities were calculated to test for pair-wise differences between strain or diets. The FISHER LSD test was used for testing pair-wise differences since it was recently shown (Saville, 1990) that this test is optimal.

# RESULTS

## Genetic

The final mean body mass (g±SD) of the strains were as follows: RAU 3.4±1.77; Golden 5.4±1.94; Netherlands 5.2±2.30 and Wild 6.1±2.88. A comparison of the means showed these final masses to differ highly significantly from each other ($p=0.0001$). The exception was the difference between strains G and N, which only differed statistically at the 10% level ($p=0.0721$).

The golden catfish had the highest total body moisture content (81.1%) whilst that of the other strains did not differ significantly from one another (±80%). None of the strains differed statistically in their mean percentage protein, with the wild strain having the highest (13.1%) and the golden strain the lowest (12.3%). The domestic strain had the highest percentage total lipid (3.3%) which differed from that of the golden (2.4%, $p=0.0132$) and the wild (2.7%, $p=0.0958$), but not from that of the Netherlands (3.2%, $p=0.7943$). The ash content did not differ significantly between any of the four strains and varied between 2.3% for the wild and 2.0% for the Netherlands strains.

The fatty acid profiles of the total body lipid for the four genetic strains are shown in *tables* 1 a and 1 b. With the exception of C18:0, C18:2$\omega$4, C18:2$\omega$6, C18:3$\omega$3, C20:0, C20:2$\omega$6, C20:3$\omega$3 and C20:3$\omega$6, the fatty acids of the total lipids differed significantly between various of the strain groupings. However, these differences, between groupings,

**Table 1a.** – The mean whole body total lipid fatty acid composition of four *Clarias gariepinus* strains (N = 30, fatty acid identified as % of total fatty acids measured).

| | LSMeans | | | | Standard error of mean |
|---|---|---|---|---|---|
| | RAU | Gold | Neth. | Wild | |
| C14:0 | 2.6 | 2.4 | 2.7 | 2.5 | 0.06 |
| C16:0 | 21.6 | 21.1 | 22.3 | 21.9 | 0.18 |
| C16:1ω7 | 4.6 | 4.3 | 4.5 | 4.2 | 0.10 |
| C16:2ω4 | 1.1 | 1.4 | 1.3 | 1.2 | 0.07 |
| C18:0 | 7.3 | 7.2 | 7.3 | 7.3 | 0.09 |
| C18:1ω7 | 0.1 | 0.1 | 0.1 | 0.3 | 0.04 |
| C18:1ω9 | 23.1 | 21.2 | 22.2 | 21.9 | 0.38 |
| C18:2ω4 | 0.1 | 0.1 | 0.1 | 0.2 | 0.01 |
| C18:2ω6 | 9.7 | 9.9 | 9.9 | 10.2 | 0.18 |
| C18:3ω3 | 3.8 | 3.6 | 3.6 | 3.7 | 0.15 |
| C18:3ω4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.01 |
| C18:4ω1 | 0.3 | 0.2 | 0.1 | 0.1 | 0.03 |
| C18:4ω3 | 0.6 | 0.5 | 0.6 | 0.6 | 0.02 |
| C20:0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.02 |
| C20:1ω9 | 0.5 | 0.4 | 0.3 | 0.4 | 0.02 |
| C20:2ω6 | 0.1 | tr | 0.1 | tr | 0.02 |
| C20:3ω3 | 1.1 | 1.7 | 1.0 | 1.0 | 0.28 |
| C20:3ω6 | 0.4 | 0.1 | 0.3 | 0.1 | 0.16 |
| C20:4ω3 | 0.5 | 0.4 | 0.4 | 0.4 | 0.01 |
| C20:4ω6 | 1.3 | 1.2 | 1.4 | 1.9 | 0.21 |
| C20:5ω3 | 4.0 | 4.2 | 4.3 | 4.1 | 0.07 |
| C22:0 | 1.0 | 1.1 | 0.9 | 0.9 | 0.06 |
| C22:1ω9 | 0.2 | 0.3 | 0.2 | 0.3 | 0.01 |
| C22:1ω11 | 0.5 | 0.5 | 0.5 | 0.6 | 0.02 |
| C22:5ω3 | 1.4 | 1.5 | 1.4 | 1.5 | 0.04 |
| C22:6ω3 | 10.8 | 12.9 | 10.8 | 11.6 | 0.38 |
| C24:0 | nd | 0.1 | 0.1 | 0.1 | 0.01 |
| SFA | 32.7 | 32.1 | 33.5 | 32.9 | 0.21 |
| MUFA | 29.0 | 26.8 | 27.8 | 27.7 | 0.43 |
| PUFA | 35.4 | 37.9 | 35.5 | 36.8 | 0.52 |
| ω3/ω6 | 1.9 | 2.2 | 1.9 | 1.9 | 0.10 |

where nd = not detected, tr = < 0.1%.

**Table 1b.** – Student's *t* value, for testing the null hypothesis that the difference between two means equals zero, for the whole body total lipid fatty acid composition of four *Clarias gariepinus* strains (R = RAU, G = gold, N = Netherlands, W = wild).

| | $p > \|T\|$ HO: $LSMean_i = LSMean_j$ | | | | | |
|---|---|---|---|---|---|---|
| | R = G | R = N | R = W | G = N | G = W | N = W |
| C14:0 | 0.0937 | 0.1890 | 0.5046 | 0.0103 | 0.2634 | 0.0653 |
| C16:0 | 0.0570 | 0.0397 | 0.4255 | 0.0016 | 0.0155 | 0.1450 |
| C16:1ω7 | 0.0403 | 0.4806 | 0.0216 | 0.1268 | 0.6971 | 0.0682 |
| C16:2ω4 | 0.0144 | 0.1840 | 0.2706 | 0.1361 | 0.0901 | 0.7936 |
| C18:0 | 0.4178 | 0.9787 | 1.0000 | 0.4036 | 0.4178 | 0.9787 |
| C18:1ω7 | 0.9594 | 1.0000 | 0.0126 | 0.9594 | 0.0116 | 0.0126 |
| C18:1ω9 | 0.0075 | 0.1439 | 0.0553 | 0.0900 | 0.2279 | 0.5512 |
| C18:2ω4 | 0.9137 | 0.5920 | 0.2565 | 0.6309 | 0.2495 | 0.4758 |
| C18:2ω6 | 0.4819 | 0.3980 | 0.1165 | 0.8805 | 0.3366 | 0.4113 |
| C18:3ω3 | 0.4511 | 0.3874 | 0.6598 | 0.9060 | 0.7461 | 0.6598 |
| C18:3ω4 | 0.0020 | 0.2555 | 0.6938 | 0.0114 | 0.0035 | 0.4379 |
| C18:4ω1 | 0.0277 | 0.0146 | 0.0146 | 0.6858 | 0.6858 | 1.0000 |
| C18:4ω3 | 0.0039 | 0.0933 | 0.0585 | 0.0684 | 0.1088 | 0.7713 |
| C20:0 | 0.1950 | 0.7098 | 0.1615 | 0.3338 | 0.9009 | 0.2806 |
| C20:1ω9 | 0.4332 | 0.0108 | 0.0622 | 0.0384 | 0.2168 | 0.2894 |
| C20:2ω6 | 0.2818 | 0.4785 | 0.2428 | 0.6088 | 1.0000 | 0.5683 |
| C20:3ω3 | 0.1528 | 0.8841 | 0.9354 | 0.1218 | 0.1348 | 0.9483 |
| C20:3ω6 | 0.3210 | 0.9455 | 0.3033 | 0.3524 | 0.9673 | 0.3333 |
| C20:4ω3 | 0.0007 | 0.0014 | 0.0009 | 0.6875 | 0.8396 | 0.5847 |
| C20:4ω6 | 0.7242 | 0.8164 | 0.0896 | 0.5616 | 0.0508 | 0.1294 |
| C20:5ω3 | 0.1544 | 0.0111 | 0.1996 | 0.1251 | 0.8656 | 0.0958 |
| C22:0 | 0.5826 | 0.2304 | 0.0732 | 0.0983 | 0.0300 | 0.4670 |
| C22:1ω9 | 0.0472 | 0.8798 | 0.0768 | 0.0603 | 0.7828 | 0.0978 |
| C22:1ω11 | 0.0785 | 0.1878 | 0.0177 | 0.5804 | 0.3652 | 0.1531 |
| C22:5ω3 | 0.1475 | 0.2399 | 0.48.33 | 0.0207 | 0.4104 | 0.0800 |
| C22:6ω3 | 0.0044 | 0.9241 | 0.1613 | 0.0051 | 0.0450 | 0.1865 |
| C24:0 | nt | nt | nt | 0.3273 | 0.1414 | 0.0674 |
| SFA | 0.0453 | 0.0477 | 0.6557 | 0.0015 | 0.0211 | 0.1025 |
| MUFA | 0.0071 | 0.1269 | 0.0570 | 0.0956 | 0.2078 | 0.6180 |
| PUFA | 0.0048 | 0.6829 | 0.0674 | 0.0088 | 0.1184 | 0.1294 |
| ω3/ω6 | 0.0767 | 0.7165 | 0.7499 | 0.0427 | 0.0459 | 0.9642 |

where nt = not tested as fatty acid not detected in strain R.

showed no fixed trend. Statistical differences in the percentages of saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), and in the ratio of ω3 to ω6 fatty acids were noted between the RAU and golden strains, and the Netherland and golden strains. The Netherland strain had the highest concentration of SFA (33.5%) whilst the RAU strain had the highest MUFA concentration (29.0%). The golden strain had the highest concentration of PUFA (37.9%) and ω3/ω6 ratio (2.2).

## Nutritional study

The means of the fatty acid profiles of the muscle total lipids of the fish receiving the different diets are presented in *table* 2a whilst the statistical analysis of the differences between the means are summarised in *table* 2b. For simplification, the fatty acid profiles of the different oils incorporated into the diets, are also included in this table in parenthesis. For diet A, values of 0.0 are displayed as this was the control diet with no lipid. The sum of the saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids, as well as the ratio of ω3 to ω6 fatty acids are also included. The following fatty acids were present in the muscle lipids at concentrations below 1.0%, and were therefore not included in *table* 2a: C16:2ω4, C18:1ω7, C18:4ω1, C20:0, C0:1ω9, C20:2ω6, C20:3ω3, C20:4ω3, C22:1ω9, C22:1ω11 and C24:0.

No significant differences were noted in the muscle fatty acid profiles of the fish from the three tanks (three different size classes) receiving the same diet. The data was then pooled for further statistical analysis.

The fatty acid profiles of the total lipids of the muscle of the fish receiving the different diets were strongly influenced by the dietary lipid. Generally, that fatty acid that was highest in the diet, caused the highest presence thereof in the muscle. Similarly, that fatty acid that was lowest in the diet, was also present in low concentrations in the muscle.

**Table 2a.** – The fatty acid composition of the muscle total lipid from catfish receiving different dietary lipids (% diet lipid fatty acid concentration in parenthesis), (fatty acid identified as % of total fatty acids measured).

| Fatty acid | Z | A | B | C | D | Standard error of mean |
|---|---|---|---|---|---|---|
| C14:0 | 1.2 | 1.7 (0.0) | 1.4 (0.1) | 3.4 (6.5) | 2.5 (3.1) | 0.16 |
| C16:0 | 22.2 | 26.6 (0.0) | 19.2 (6.8) | 22.4 (16.1) | 24.7 (23.7) | 0.35 |
| C16:1ω7 | 5.3 | 10.0 (0.0) | 3.8 (0.1) | 7.5 (9.9) | 7.2 (3.8) | 0.31 |
| C18:0 | 7.3 | 6.5 (0.0) | 7.5 (5.8) | 6.7 (4.2) | 10.5 (23.9) | 0.23 |
| C18:1ω9 | 24.6 | 35.3 (0.0) | 29.6 (22.9) | 29.7 (17.1) | 38.1 (37.2) | 0.81 |
| C18:2ω6 | 15.3 | 6.6 (0.0) | 25.7 (62.6) | 5.6 (2.9) | 6.0 (4.0) | 0.45 |
| C18:3ω3 | 1.4 | 2.2 (0.0) | 1.2 (0.2) | 5.0 (5.2) | 1.6 (0.4) | 0.07 |
| C18:3ω4 | 0.9 | 0.4 (0.0) | 2.7 (tr) | 0.3 (0.3) | 0.6 (tr) | 0.08 |
| C20:3ω6 | 0.4 | 1.9 (0.0) | 0.4 (0.8) | 0.3 (0.1) | 1.1 (tr) | 0.10 |
| C20:4ω6 | 1.8 | 1.1 (0.0) | 1.6 (nd) | 2.3 (0.8) | 1.1 (0.1) | 0.21 |
| C20:5ω3 | 1.3 | 0.4 (0.0) | 0.3 (0.2) | 3.7 (13.8) | 0.3 (tr) | 0.08 |
| C22:0 | 2.5 | 1.1 (0.0) | 2.5 (nd) | 0.7 (3.3) | 1.0 (0.1) | 0.12 |
| C22:5ω3 | 1.2 | 0.5 (0.0) | 0.4 (nd) | 1.5 (1.3) | (0.4) (0.1) | 0.05 |
| C22:6ω3 | 7.3 | 1.9 (0.0) | 1.3 (nd) | 4.9 (7.1) | 1.0 (0.1) | 0.28 |
| SFA | 33.2 | 35.9 (0.0) | 30.6 (12.8) | 33.2 (30.8) | 38.7 (51.1) | 0.49 |
| MUFA | 29.9 | 45.3 (0.0) | 33.4 (23.1) | 37.2 (30.4) | 45.3 (41.2) | 1.05 |
| PUFA | 29.6 | 15.0 (0.0) | 33.6 (63.9) | 23.6 (33.2) | 12.1 (4.9) | 1.14 |
| ω3/ω6 | 0.6 | 0.5 (0.0) | 0.1 (0.0) | 1.8 (7.4) | 0.4 (4.3) | 0.04 |

where tr < 0.1%, nd = not detected.

In all the muscle samples (Z, A-D), the principle fatty acid present was oleic (C18:1ω9), with concentrations varying from 24.6% (Z) to 38.1% (D). All the muscle samples on the different diets had significantly higher oleic acid concentrations than Z. Diet D had the highest oleic acid (37.2%) concentration, as did the muscle of the fish fed this diet (38.1% – significantly higher than other diets, *table* 2).

In general, the SFA concentration of the diets were mirrored in that of the lipids from the muscle. Diet D had the highest SFA concentration (51.1%) as did the corresponding fish muscle (38.7%). Of the three oils, B had the lowest SFA concentration (12.8%) which resulted in a 30.6% SFA concentration in the muscle. There was a significant ($p=0.0018$) increase in the percentage SFA between the control (35.9%) and that at the onset of the experiment (33.2%). The same trend was noted for the MUFA, diet D having a concentration of 41.2% and 45.3% in the muscle, whilst diet C had the second highest concentration thereof (30.4 and 37.2%, respectively). The higher MUFA concentration in A (45.3%) was significantly higher ($p=0.0001$) than that in Z (29.9%). Diet B had the highest concentration PUFA (63.9% and 33.6% in the diet and muscle respectively) whilst diet D had the lowest (4.9 and 12.1% respectively). There was a significant ($p=0.0001$) decrease in percentage PUFA between Z (29.6%) and A (15.0%).

The ratio of ω3 to ω6 fatty acids differed significantly between the diets and the total lipids of the muscle of the fish receiving the different diets. Diet B had a low ratio (<0.01%) resulting in a 0.1 ratio in the muscle lipid. Diet C had the highest ratio (7.4) resulting in an 1.8 ratio in the lipid muscle. Diet D had a ratio of 4.3 which resulted in the second lowest muscle lipid ratio (0.4) which differed significantly from that of Z, B and C. There was a decrease in the ratio between Z (0.6) and A (0.5), this decrease being significant at $p=0.0842$.

## DISCUSSION – CONCLUSION

### Genetic

The occurrence that the faster growing strains (wild and golden in this investigation) show body total lipid concentrations lower than the other strains has also been reported for rainbow trout (*Oncorhynchus mykiss* – Ayles, Bernard and Hendzel, 1979; Smith *et al.*, 1988). Gjerde (1989) however, found no correlation between growth rate and body composition in rainbow trout. Although a number of authors (Austreng and Refstie, 1979; Gjerde, 1989; Gjerde and Schaeffer, 1989) also noted a genetic influence on the body protein content of rainbow trout, Shearer (1994) on re-evaluation of their data, concluded that the authors did not take size as a covariant when analysing the data and that size (and diet), rather than strain, influences the body protein composition of fish. The present investigation supports the conclusion of Shearer (1994), in that no significant difference in body protein content was noted between the four strains who were all similar sized.

The strong genetic influence of strain on the total lipid fatty acid composition reported (*table* 1), has also been noted for the channel catfish (*Ictalurus punctatus* – Erickson, 1992). In a study on the fatty acid profiles of total lipids from three channel catfish strains, significant differences were found in the levels of PUFAs, ω3 and ω6 fatty acids. These differences were attributed to genetic factors, as age, diet and environment were similar between the strains (Erickson, 1992). Erickson (1992) also noted work done on rainbow trout (Lampi, 1986) where strain

**Table 2b.** – Student's *t* value, for testing the null hypothesis that the difference between two means equals zero, for the muscle fatty acids of catfish receiving different dietary lipids.

| Fatty acid | $p>\|T\|$ HO: $LSMean_i = LSMean_j$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Z=A | Z=B | Z=C | Z=D | A=B | A=C | A=D | B=C | B=D | C=D |
| C14:0 | 0.1176 | 0.5204 | 0.0001 | 0.0005 | 0.2348 | 0.0001 | 0.0099 | 0.0001 | 0.0003 | 0.0007 |
| C16:0 | 0.0001 | 0.0003 | 0.7128 | 0.0018 | 0.0001 | 0.0001 | 0.0030 | 0.0001 | 0.0001 | 0.0002 |
| C16:1$\omega$7 | 0.0001 | 0.0211 | 0.0001 | 0.0103 | 0.0001 | 0.0024 | 0.0001 | 0.0001 | 0.0001 | 0.0099 |
| C18:0 | 0.1368 | 0.7434 | 0.2550 | 0.0001 | 0.0226 | 0.5677 | 0.0001 | 0.0534 | 0.0001 | 0.0001 |
| C18:1$\omega$9 | 0.0001 | 0.0064 | 0.0038 | 0.0001 | 0.0001 | 0.0001 | 0.0503 | 0.9505 | 0.0001 | 0.0001 |
| C18:2$\omega$6 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.1487 | 0.4172 | 0.0001 | 0.0001 | 0.5992 |
| C18:3$\omega$3 | 0.0001 | 0.0207 | 0.0001 | 0.2144 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| C18:3$\omega$4 | 0.0044 | 0.0001 | 0.0008 | 0.0686 | 0.0001 | 0.5916 | 0.1898 | 0.0001 | 0.0001 | 0.0554 |
| C20:3$\omega$6 | 0.0001 | 0.9851 | 0.5868 | 0.0035 | 0.0001 | 0.0001 | 0.0002 | 0.4901 | 0.0003 | 0.0001 |
| C20:4$\omega$6 | 0.1372 | 0.6275 | 0.2510 | 0.1336 | 0.1990 | 0.0006 | 0.9574 | 0.0314 | 0.1940 | 0.0008 |
| C20:5$\omega$3 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.8524 | 0.0001 | 0.7190 | 0.0001 | 0.8576 | 0.0001 |
| C22:0 | 0.0001 | 0.8387 | 0.0001 | 0.0001 | 0.0001 | 0.0228 | 0.6230 | 0.0001 | 0.0001 | 0.0904 |
| C22:5$\omega$3 | 0.0001 | 0.0001 | 0.0068 | 0.0001 | 0.1258 | 0.0001 | 0.1575 | 0.0001 | 0.9405 | 0.0001 |
| C22:6$\omega$3 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.2020 | 0.0001 | 0.3361 | 0.0001 | 0.7790 | 0.0001 |
| SFA | 0.0018 | 0.0034 | 0.9565 | 0.0001 | 0.0001 | 0.0001 | 0.0007 | 0.0001 | 0.0001 | 0.0001 |
| MUFA | 0.0001 | 0.0984 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.9490 | 0.0033 | 0.0001 | 0.0001 |
| PUFA | 0.0001 | 0.3983 | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.1172 | 0.0001 | 0.0001 | 0.0001 |
| $\omega$3/$\omega$6 | 0.0842 | 0.0001 | 0.0001 | 0.0073 | 0.0001 | 0.0001 | 0.1887 | 0.0001 | 0.0001 | 0.0001 |

was shown to affect the degree of saturation of the lipid fatty acids.

### Nutritional

The reflection of the dietary lipid composition in the muscle indicates that the fatty acid profile of *C. gariepinus* can be manipulated to make the muscle more nutritionally desirable. Feeding the sunflower oil increased the PUFA concentration of the muscle lipid from 13.1 (tallow) to 34.0%. However, from a human nutritional viewpoint, it is not only the concentration of PUFA present, but also the relationship between $\omega$3 and $\omega$6 fatty acids that are important (Tichelaar, 1993). The present investigation shows that this ratio can be manipulated (manipulated from 0.1 for the sunflower oil diet to 1.8 for the cod liver oil diet).

*Clarias gariepinus* muscle total lipid fatty acid composition is influenced by genetic strain and strongly influenced by dietary lipid source.

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