

NEW INSIGHTS ON GROWTH, FEEDING AND SOCIAL INTERACTIONS IN TILAPIA (*OREOCHROMIS NILOTICUS*).

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Summary

Growth data reported here have been obtained in a work aiming to analyze the determinism of differential growth between male and female of *Oreochromis niloticus*. Growth indices such as white muscle RNA/Protein and uptake of ¹⁴C-glycine by scales have been implemented and tested as predictors of short term individual growth rate. A method of scale labelling based on the incorporation of Sr supplied by the diet during early stages has also been tested. Growth has been characterized through morphology analysis and muscle development. At early stages, growth of tilapia resulted in height growth associated with an important hyperplastic growth capacity of muscle. Structure of muscle at microscopic level and muscle contractile proteins composition seemed to be original in tilapia as compared to other teleost.

Voluntary feeding behaviours have been characterized. Feeding activity was observed only during the light period and peak of activity were observed related either to a disappearance of social hierarchy (morning) or to a compensatory feeding activity after daily social interactions (evening). The effects of increasing feeding rate have been tested in different experimental facilities to obtain differential growth at short term scale (15 d) and long term scale (from first feeding to sexual dimorphism). High feeding rate (above ad libitum) resulted in reduce growth individual variation.

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Mixing male and female of the same cohort or fish from different cohorts resulted in lowering of growth performances. These results demonstrated the contribution of individual interaction related to social and feeding behaviour on the expression of growth potential in tilapia.

I. Introduction

Differential growth between male and female is well known in many tilapia species and in *Oreochromis niloticus* growth of male is higher than that of female. Although many works have described this sex related differential growth, there are few data on mechanisms involved (Guerrero, 1975; Hanson *et al.*, 1983; Mélard *et al.*, 1989; Toguyéni *et al.*, 1996). It has been emphasized that this difference in growth is not directly related to reproduction but would be expressed at early stages. Analysis of this process required a better characterization of tilapia growth.

Growth heterogeneity within the same cohort is currently observed in fish as a result of feeding or territory competition (Jobling, 1985; Koebele, 1985) or social hierarchy (Li et Brocksen, 1977; Jobling et Wandsvick, 1983). Feeding behaviour of tilapia has not been characterized further but this fish is known to present strong social interactions. Thus social interactions between individual and sexual interaction between the two sexes could modulate individual growth potential and especially differential growth between male and female.

This work aimed to characterize growth of tilapia especially at stages where sexual differential growth is observed. Specific methodologies for individual growth rate assessment and group identification have been implemented. Contribution of feeding and social behaviour on growth have also been analysed.

II. Growth indices

II.2. RNA/protein ratio in muscle

Metabolic activity and protein synthesis rate of a given tissue is related to its RNA content. RNA content or RNA/protein ratio has been demonstrated to reflect protein synthesis capacity of muscle which is the main tissue involved in whole body growth (Fauconneau *et al.* 1990, Mathers *et al.* 1992). Thus RNA/protein ratio in muscle is often used as a better index of specific growth rate in fish than RNA/DNA (Bulow, 1987) especially in order to analyze the effect of genetic factors at early stages and metabolic factors at all stages (Mathers *et al.* 1992, 1993).

RNA content was measured after extraction in HClO₄ 2 %, solubilization in NaOH 0.3M then in HClO₄ 4% and measurement by UV absorbance at two wave-lengths according

to Mathers *et al.*(1992). Protein content was measured after solubilization in NaOH 0.3 M according to Lowry *et al.* (1951). RNA/protein ratio was analysed at different stages starting from 2 g up to 100 g and in an experiment where fish were fed starting from the first feeding at two feeding rate, a low level supposed to correspond to *ad libitum* and a high level calculated as twice the low level.

RNA/protein ratio decreased during development (Fig. 1) as a result of the decrease in growth rate with aging. This decrease tended to be more rapid in female than in male but such a difference was not significant. RNA/protein ratio was also significantly increased by high level of feeding applied since first feeding (Fig. 2). We have also demonstrated that RNA/protein ration is affected by short term change in growth rate induced by different feeding rate (0 to 4 %. d^{-1}) applied only during 2 weeks (Toguyéni *et al.* 1996).

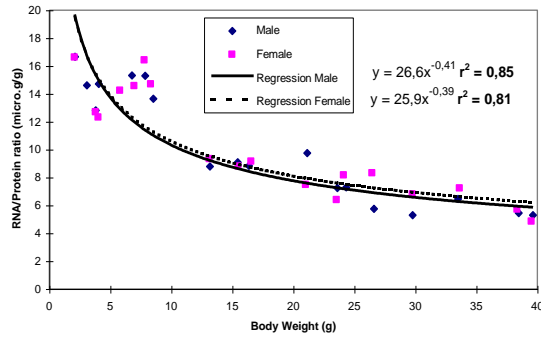


Figure 1 : RNA/protein ratio changes in white skeletal muscle during development of male and female tilapia *Oreochromis niloticus*

Figure 2 : RNA/protein ratio in white skeletal muscle of tilapia fed at two feeding rates since the first feeding stage and up to 50 g.

II 2 Uptake of $[U-^{14}C]$ -glycine in scales

Assessment of instantaneous growth rate sometimes required direct measurement of protein synthesis in muscle or in specific tissues such as scales used as an indirect index for growth (Fauconneau *et al.* 1989). Strong correlation between specific growth rate and uptake of glycine by scales has been observed in the different teleostean species studied (Ottaway, 1978, Ottaway et Simkiss, 1979; Adelman, 1980; Smith, 1986). Glycine is the main amino acid residue of collagene (1/3) and ichtylepedine which composed structural proteins of scale (Seshaiya *et al.*, 1963; Ottaway et Simkiss, 1977).

The scales were collected on live fish, immersed in a Ringer saline solution supplemented with 1g/l of glucose and containing $[U-^{14}C]$ -glycine. Preliminary trials have shown that total uptake of labelled glycine (per dry weight of scale or per protein content) gives better accurate results compared to incorporation of glycine into protein. We have demonstrated that glycine uptake by scale is significantly enhanced by increasing feeding rate (high feeding rate vs low feeding rate) (Fig. 3). Glycine uptake changed more rapidly than RNA/protein thus it could be applied to analyze early growth differences between male and female in tilapia. Furthermore, this method is easy to use and gives more rapid results than analysis of increased circuli on scales which is also correlated with growth rate in tilapia (Doyle *et al.* 1987).

II.3. Uptake of strontium in scales

We have developed a simple, non-stressing and non visual method of mass marking for the analysis of the effect of mixing cohorts of known sex ratio at early stages on social interaction and growth. The supplementation of diet with fluorescein starting at first feeding and during one month had not given any positive result on the labelling of scale (direct fluorescence or histoimmunology) and otoliths analysed at juveniles stages.

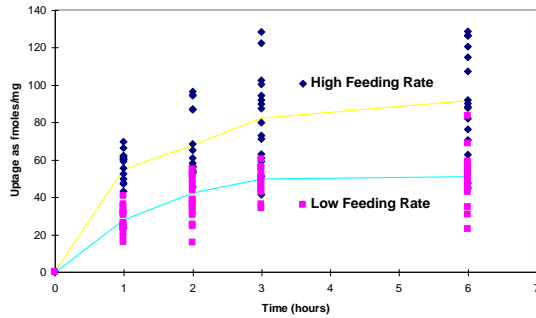


Figure 3 : *In vitro* uptake of [U-14C]-glycine by scales in tilapia fed at two feeding rates since the first feeding stage up to 50 g.

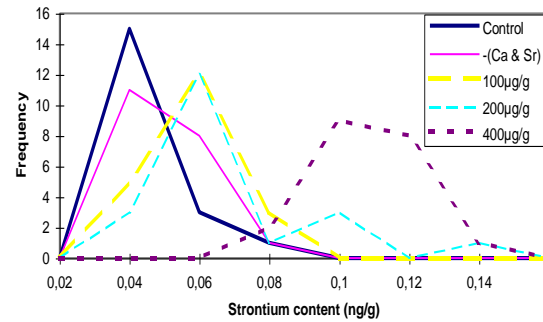


Figure 4 : Effect of strontium supplementation in the diet (as SrCl₂) during early stages (11 days post fertilization during 21 days) on distribution of Sr content in scales measured by atomic absorption spectrometry in juveniles (10 g mean body weight) of tilapia

The method developed was based on labelling of scale by substitution of a natural structural important component of scale, calcium, by a rare component, strontium supplied by the diet. Strontium (Sr) is present in very low amounts in fresh water environments and is easily incorporated in calcified structure: vertebrae, scale, otolith of fish. The method of labelling have already been used in other fish species (Yamada et Mulligan, 1982; Guillou et De la Noüe, 1987).

Fish were fed at first feeding (11 days post-fertilization) during 21 days with different diets containing either 0,55, 110 and 220 mg Sr /g diet. Sr was detected in scale, opercule and otoliths using an atomic absorption spectrometer demonstrating the possibility to labelled very early fish fry (Fig. 4). However only the higher dose 220 mg Sr/g diet allowed to discriminate controlled and treated fish. Higher dose and longer dietary supplementation would improve this method.

These works demonstrate also the efficiency of incorporation of dietary Sr in scales. Thus measurement of Sr in scale could be used as an index of individual feeding rate in fish especially in early stages and in non controlled feeding conditions.

II 4 Endocrine indices

Two hormonal systems contribute to the control of somatic growth: somatotropic and thyreotropic axis. Growth hormone (GH) and thyroid hormones (T₄, T₃) could be used as indices of growth if their level in plasma reflect their synthesis. We have analysed during development changes in pituitary content and plasma level of growth hormone (Fig. 5).

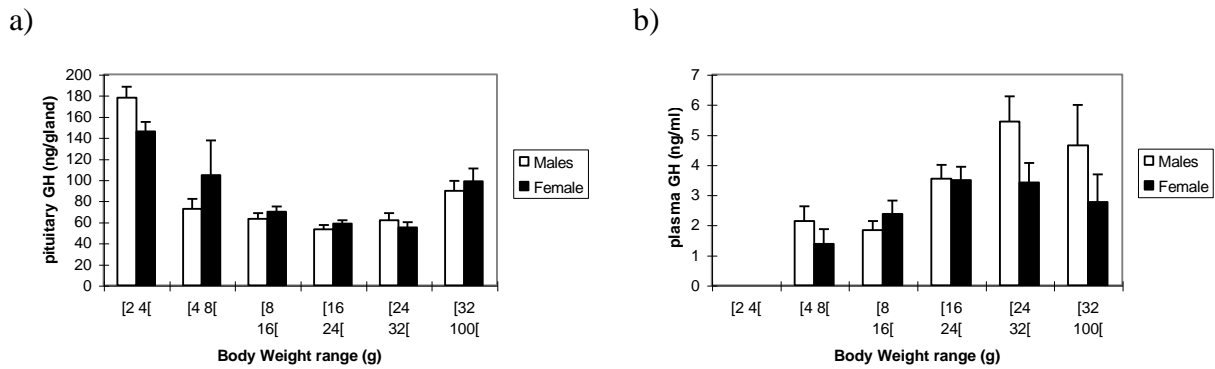


Figure 5: Changes during development of a) pituitary GH content (ng / fish) and b) plasma GH (ng/ml) in tilapia.

Pituitary GH content decreased during development with size of tilapia in agreement with the decrease in specific growth rate with aging. However such a decrease was only observed in early stages up to 20 g and above this size GH content in pituitary gland increased. Plasma level of GH increase during development and thus is not directly related to growth rate changes. Growth hormone status was also analysed in tilapia fed since first feeding at two feeding rate. No differences in pituitary content of GH was observed between the two groups ((Fig. 6a), and GH plasma level was higher at high feeding rate than at low feeding rate (Fig. 6b).

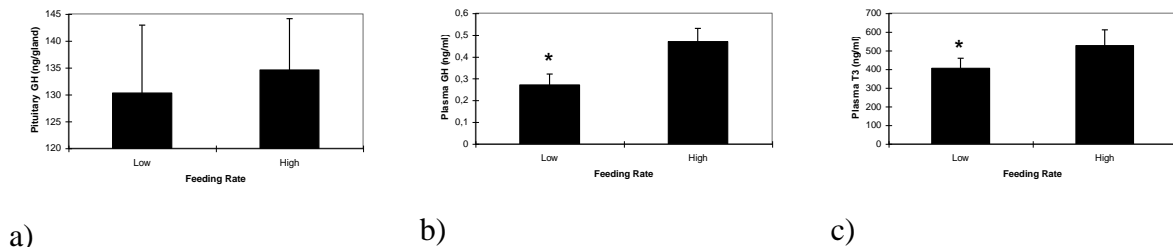


Figure 6: Effect of two feeding rates applied since first feeding and up to 45 g body weight on a) pituitary GH content (ng / fish), b) plasma GH (ng/ml) and c) and plasma tri-iodo thyronine (T3) (ng/ml) in tilapia.

The relationship between GH plasma levels and somatic growth rate is dependent on pulsatility of GH secretion which induce large variation in plasma levels along the nycthemere (Le Bail *et al.*, 1991). Furthermore, GH is not involved directly in the control of somatic growth but indirectly through the synthesis of IGF-1 (Insulin-like Growth Factor-1, somatomédine) which control development a tissue level (Peter et Marchant, 1995). There is a strong negative feed back of IGFs on the synthesis and secretion of GH by pituitary gland and consequently GH levels in plasma in well growing fish are very low. We have observed in tilapia fed at different feeding rate for short period of time that circulating levels of growth hormone are dependent on two antagonistic processes: in fasted fish plasma level of GH are high but it decreases as nutritional status of fish is improved, above a given threshold close to

ad libitum, the plasma levels of GH increase and it is related only in this case with increase in growth rate (Toguyéni et al. 1996). The relationship between pituitary content of GH and growth rate observed in early stages suggest that it could be used as an indice of growth.

Thyroid hormone levels in plasma are dependent on their secretion rate but also on their metabolism. The plasma level of active hormone tri-iodo-thyronin (T3) was related to growth rate differences induced by long term treatment at two feeding rates (Fig. 6c), however if changes in growth rate were induced by short term treatment at different feeding rates no differences in thyroid status are observed (Toguyéni et al. 1996). In this case however, high T4 and low T3 plasma levels are observed in fasted fish in concordance to what is observed in poultry (Darras *et al.*, 1995).

III. Component of somatic growth

III.1. Growth allometry of different body traits

We have analysed external morphology of male and female tilapia which is complementary to the classical analysis of meristic characters. External landmarks (fin basis, head profile) were measured on numeric image of fish and morphology was studied either by analysis of whole set of landmarks coordinate according to Bookstein et Rohlf analysis or by analysis of morphology traits calculated as distances between landmarks or area enclosed by landmarks. The results of the first analysis showed that external morphology was relatively homogeneous within a group of fish once size effect have been corrected (Fig. 7) and the main variability was observed for ventral profile. External morphology of male and female were also very similar, except for the relative size of the head and relative heights measured along the vertebral axis which were respectively lower in female than in male.

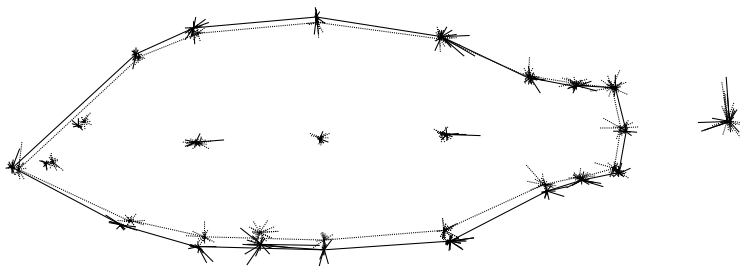


Figure 7 : Morphology of tilapia (*Oreochromis niloticus*) analysed from a set of landmarks measured on fish. Straight lines represent male and dotted lines females. The morphology differences between individuals at one point are drawn as a vector line.

Allometry relationship between morphometric traits and standard length of fish are given in Table 1. There was a relative growth in height associated with a relative development of dorsal muscle but also of visceral area at the stages studied (40-60g). The growth of the caudal part of tilapia was either isometric or lower than body length. Allometry coefficient for body heights and head traits were higher in male than in female. The opposite was found for allometry coefficient for body length. Thus differential growth between male and female is associated with differential development of different part of fish.

Standardized morphometric traits calculated with specific male and female allometry coefficient did not show any difference in head traits (Table 1) except for head height which was higher in male than in female. The difference in mouth traits observed by Brzeski and Doyle (1988) were not confirmed in our experiment for mouth length. The length of the posterior part of fish (starting from first dorsal fin radius) was different between male and female and also the height of caudal peduncle which was higher in male than in female however such difference was not significant ($P > 0.05$). It has been observed in a recent study that the length and the width of the caudal peduncle was different between male and female (Oliveira *et al*, 1995) and this could be related to difference in activity and locomotion of male and female. Finally the standardized height of male was higher than those of female especially in the anterior part of the fish between the head and the middle of dorsal fin. This was in agreement with the global analysis of morphology and with a higher condition factor in male 2.19 than in female 1.94 ($P < 0.001$). These differences resulted more of a higher height in male of the ventral part of the fish (viscera) than of the dorsal (muscle) part.

Table 1: Allometry coefficient with body standard length of different morphometric traits and standardized morphometric traits at a mean length of 13.5 cm in male and female tilapia *Oreochromis niloticus* (Bouaké strain).

		ALLOMETRY COEFFICIENT			STANDARDIZED TRAITS			
		Total	Male	Female	Sign.	Male	Female	Sign
WEIGHT (g)	Body weight	3,10	3,61	2,39	*	51,1	46,3	*
	Head	2,08	2,45	1,86	**	5,5	5,3	
AREA (cm ²)	Muscle	2,06	2,27	2,00	*	19,4	19,3	
	Viscera	2,49	2,33	2,21		11,3	10,4	**
	Head	1,10	1,12	0,99	*	3,3	3,2	*
HEIGHT (cm)	Maximum height	1,21	1,28	1,02	**	4,4	4,3	**
	Caudal Peduncle	0,94	1,00	0,91		1,9	1,8	
	Head	1,02	1,32	0,90	**	3,4	3,4	
LENGTH (cm)	Anterior Length	1,00	0,54	1,20	**	2,4	2,3	
	Posterior Length	0,82	0,73	0,89	*	5,7	5,6	*

Sign.: ANOVA analysis for allometry coefficient and Student t-test for standardized traits: * $P < 0.05$, ** $P < 0.01$

Such morphology changes between male and female of tilapia has never been described in previous studies as they were more concerned by sexing of tilapia and thus based on meristic traits. It has been found a sexual dimorphism in urogenital papilla (2 slits in female and only one in male Huet, 1972; Balarin, 1979), pelvic fin (reaching the anus in male and not in female), dorsal and anal fin (rounded in female and pointed in male) (Chervinski, 1965; 1983; Oliveira *et al*, 1995) and mouth (Brzeski and Doyle 1988, Oliveira *et al*,. 1995). The only difference of morphology concerned differences in width which is higher in male than in female (Oliveira *et al*, 1995). Our study demonstrated that there is a significant difference in visceral profile of male associated with a lengthening of the tail in male as compared to female.

A discriminant analysis between male and female realized on all the morphometric traits allowed to dissociate more than 90 % of individuals. Thus it could be possible starting from the global analysis to describe a specific morphotype for each sex. A discriminant analysis based on only the more variable morphometric traits (n=5) was less efficient also it dissociated 70 % of individual between the two sex.

III.2. Muscle Growth

Whole body growth result in tilapia as in other species of growth of different tissues and mainly of skeletal muscle tissues. Growth of muscle have been characterized in most of farmed fish species but never in tilapia except for few studies on red muscle ultrastructure (Kisia and Hughes 1992). In this part we aimed to characterized fibre size distribution in red and white muscle and myofibrillar protein composition in white muscle.

Post natal growth of fish muscle is very original as both increase in the number of fibre (hyperplasia) and increase in the size of fibre (hypertrophy) contribute to increase in muscle mass (Stickland 1983). The hyperplasic process seems to be predominant in juvenile growth. Furthermore, an increase in the rate of growth is associated in most of the cases studied rather with an increase in recruitment of new fibres than with an increase in the size of fibres (Fauconneau *et al*. 1997). We have thus analyzed more specifically the population of small diameters fibres which result of the process of recruitment of new fibres.

We have observed that there were no anatomical separations between peripheral muscle fibre and deep fibre. Such a characteristic has never been described in a teleost fish except in flat fish. It could be related to locomotion of tilapia. The specificity of peripheral fibres (red muscle) and deep fibres (white muscle) has thus to be confirmed by analysis of metabolic and contractile characteristics of fibres by histochemical and histoimmunological methods. Ultrastructural analysis of these fibres and analysis of contractile protein have however demonstrated that these fibres correspond to slow oxydative and fast-twitch glycolytic fibres respectively (Kisia *et* Hughes 1992, Crockford *et al*. 1995). The differences

of mean size of fibres that were observed between superficial fibres and deep fibres (Fig. 8 and 9) were in concordance with such a classification.

Analysis of fibre size distribution of red muscle was not different between male and female. However the relative frequency of mean size fibres (15 μm diameter) seemed to be higher in female than in male (Fig. 8). In white muscle the relative frequency of small diameter fibre is high both in female and in male (Fig. 9). This demonstrate indirectly that hyperplastic process contribute to white muscle growth as it is in most of the fish species studied especially in juvenile (Weatherley *et al.*, 1980a, Stickland 1983). There were no great differences in the size of white muscle fibres between male and female. However the percentage of small diameter fibres was higher in male than in female and consequently the distribution of fibres size was significantly different between male and female (test X2, $P < 0.001$). Such a difference suggested that hyperplastic growth of white muscle was stimulated in male as compared to female.

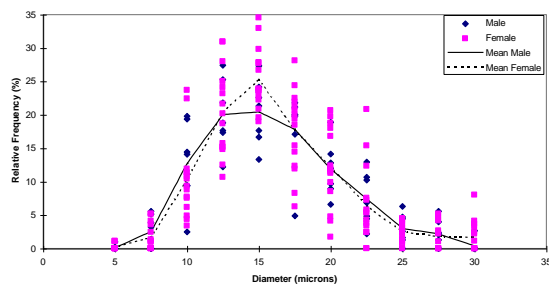


Figure 8 : Relative size (diameter in micrometer) distribution of red muscle fibres in male and female tilapia at 25 g mean body weight. The distribution is the mean of 25 measurements.

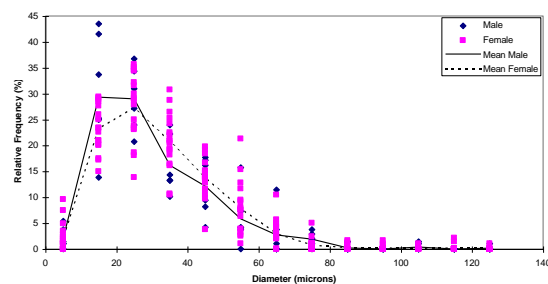


Figure 9 : Relative size (diameter in micrometer) distribution of white muscle fibres in male and female tilapia at 25 g mean body weight. The distribution is the mean of 25 measurements.

III.3. Muscle differentiation

Differentiation status of muscle was characterised by the analysis of electrophoretic pattern of myosin light chains. Myosin, the most important contractile protein of muscle, is an hexameric molecule composed of two heavy chains (HC) and two pairs of light chains (LC) specific of each muscle types. In white muscle, 3 different LC have been identified (LC1f, LC2f et LC3f) and only two in red muscle (LC1s and LC2s) (Martinez *et al.* 1990, Ochai *et al.* 1990). The relative composition of myosin LC changes with the differentiation state of muscle and this is associated in white muscle with an increase in LC3f/LC1f ratio during development.

SDS PAGE electrophoretic analysis of white muscle myofibrillar protein (Fig. 10) showed that myosin of tilapia have the same three light chains as those observed in other teleostean fish (Martinez *et al.*, 1990). As generally observed in fish the relative content of

LC3f is higher than that of LC1f in tilapia when the opposite was found in mammals and birds. (Huriaux et Focant, 1985). Such a characteristic is generally associated to fish locomotion (Watabe *et al.*, 1982).

Figure 10. SDS PAGE electrophoretic pattern of myofibrillar protein in white skeletal muscle of tilapia (mean body weight 35 g).

It is interesting to note that in some individual two LC1f or two LC3f were observed. Such a polymorphism in light chain has been observed in other species (Martinez *et al.*, 1989; Ochiai *et al.*, 1990) but also in tilapia (Crockford *et al.*, 1995). It could be related to the maintenance in the expression of early isoforms of myosin light chains in connection with the persistence of small diameter fibres. However, Crockford *et al.* (1995) have shown that in *Oreochromis andersonii* this polymorphism is associated to the expression of allelic variants of light chains and that there is a mendelian inheritance of this light chain composition.

III.4 Conclusion

Our results demonstrated some specificities in the growth of tilapia especially for relative development of some parts of fish and for muscle growth. A polymorphism in light chain composition related to genetic origin was also observed.

IV. Feeding and Growth

IV-1 Feeding behavior

We have characterized feeding behavior of tilapia using a self feeders system. (Boujard *et al.*, 1992). The experiment was realized on 4 months age fish (10 g mean body weight) dispatched in replicates of 22 fish. Tilapia needs only few days to be adapted to the self feeders. The feeding behavior was analysed by continuous recording of feeding demand during 31 days.

We have demonstrated that feeding activity is essentially during the light period (Toguyéni *et al.* 1997). A peak of activity was observed at the beginning of the light period probably associated with the abolition of social hierarchy. A peak of feeding activity at the

end of the light period was probably a compensatory feeding activity related to the interindividual interactions observed during the day.

Some groups after 30 days of experiment expressed few by significant feeding activities during the dark period, and this was the case for groups which have strong social interactions such as whole male groups and also normal male and female group as compared to whole female groups (Toguyéni et al. 1997). These activities observed during the night were associated with feeding and they demonstrated that in some condition feeding activity of tilapia although observed typically during the day could be turned to the night.

Using such conditions of voluntary feeding, we observed good growth performances: specific growth rate: 3.5 à 4.0 %/j, Feed conversion ratio: 1.0 à 1.2. In these conditions associated with a low rearing density, difference between male and female was observed very early (15 g chez les femelles et 25 g chez les mâles).

IV.2. Short term effect of feeding rate

Different feeding rates of 0, 1, 2 and 3 % of biomass per day were distributed to 80g body weight fish individually labelled with Floy-tags (two replicates of 25 fish were used for each treatment). Growth performances were directly related to feeding rate (Fig. 11). The same effect was observed in male and female however the effect of fasting was more important in female than in male and the effect of high feeding rate was more important in male than in female. These differences on the effect of feeding rates were significantly different (two ways analysis of variance) between male and female. These results demonstrated the interest of using individual labelling for the analysis of short term changes in growth rate.

IV.2. Long term effect of feeding rate.

Two feeding rates were distributed to tilapia starting at first feeding and up to a body size of 100 g. The low feeding rate was close to ad libitum: starting at 30%.d-1 at 11 days post-fertilization up to 4% at 45 g). The high feeding rate was twice the low level. The fish were reared in aquarium then net cages and whatever the feeding rate, the growth performances of fish were good. The fish fed on the high feeding rate have a significantly higher growth rate than those fed on the low feeding rate and this was observed as early as 60 days PF. Mean body weight at 142 jours PF of low feeding rate groups were similar to those observed at 120 days PF in high feeding rate groups. (Fig. 12).

In these conditions, significant differential growth between male and female was observed first in fish fed at high feeding rate (120 days PF) at a mean body weight of 35 g for female and 50 g for males then later in fish fed at low feeding rate (142 days PF) and for similar body weights (Fig. 13).

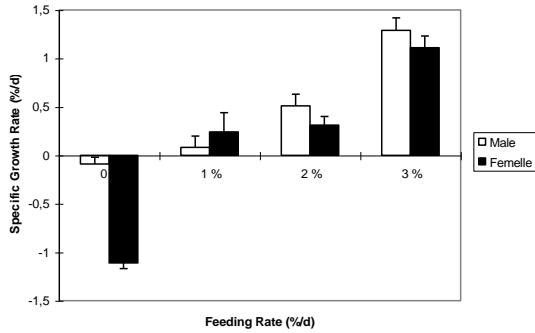


Figure 11 Effect of different feeding rates (0, 1, 2 et 3 $\% \cdot d^{-1}$) distributed during 15 days on individual specific growth rate ($\% \cdot d^{-1}$) of male and female tilapia at 60 g mean body weight. Open bar correspond to male and closed bar to female (mean and standard deviation)

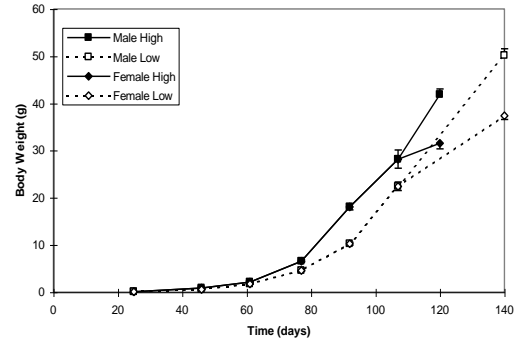


Figure 12: Effect of two different feeding rates distributed since first feeding on growth and sexual differential growth in tilapia.

The results observed in this two experiments demonstrated that factors involved in the control of growth and more specifically in differential growth between male and female are dependent on feeding conditions. At low feeding rate or low rearing density, strong feeding competition are favoured and energy provided is affected to reproduction. At high feeding rate energy in excess is affected both for growth and reproduction and in some extreme condition differential growth between male and female could be observed late associated or not with a strategy of late sexual maturation (Roff, 1982).

IV.4 Conclusion

Our result demonstrated the interest of the tilapia model for the study of feeding behaviour and short term growth changes. Long term effects of different feeding pattern on differential growth between male and female was also demonstrated.

V. Social interaction and growth

The aim of this work was to analysed the effect of social behavior on growth in *Oreochromis niloticus*. Two experiments based on different sex ratio composition were built.

V.1 Social interaction within population

An experiment was built on 4 months age fish (10 g mean body weight) dispatched in 3 groups : male (100% male = F0), female (F100) and a mixed group (50% male / 50% female = F50). Male and female were identified by early determination of sex on the characteristic of genital papilla and the three groups constituted in triplicates. Feeding and growth of groups were analysed in voluntary feeding conditions.

The growth differences observed between male and female groups were very clear although the two groups were fed the same amount of food. The mixed group have the higher feed intake and the lower growth as compared to F0 and F100 groups. Consequently the feed condition ratio and other feed efficiency ratio (protein, lipid, energy) were lower in the mixed group than in the monosex groups (Table 2). Furthermore fish of mixed group tend to have a feeding activity during the night especially at the end of the experiment.

Social interaction between male (territorial behavior) and between male and female (sexual behavior) would explain a higher activity and a higher energy consumption in the mixed group F50 compared to other group. This was only partially compensated by a feeding activity during the night and a lower growth of fish of this group was observed. The effects of social interaction on growth of male and female has been observed in other fish (Magnuson, 1962; Saclauso, 1985). It has been demonstrated in natural environment that dominant fish have a large influence on feeding of dominated fish which have not access to feeding area (Yamagishi *et al.*, 1974). However these social interactions could be modified by changes in feeding rate (Jobling, 1983).

Table 2 : Growth parameters and feed utilization ratio of monosex male and female and mixed group fed on self feeders during a 31 days period in tilapia.

Groups	Monosex male	Monosex female	Mixed	
			male	female
Growth				
Initial Weight (g)	12,8 ± 0,7	9,4 ± 1,0	12,2 ± 0,4	9,8 ± 0,8
Final Weight	70,1 ± 2,1	42,8 ± 1,2	58,4 ± 2,0	40,1 ± 1,0
Voluntary Feeding (%)	3,6 ± 0,1	3,9 ± 0,1	4,1 ± 0,1	
Feed Conversion Ratio	0,98 ± 0,04	1,13 ± 0,03	1,22 ± 0,03	
Protein Efficiency Ratio	2,4 ± 0,1	1,9 ± 0,0	1,93 ± 0,4	
Net Protein Utilization (%)	38,7 ± 1,2	31,2 ± 0,9	30,2 ± 1,1	
Net Lipid Utilization (%)	80,5 ± 1,5	62,8 ± 1,5	65,1 ± 3,0	
Net Energy Utilization (%)	48,6 ± 0,9	38,5 ± 0,6	38,8 ± 1,4	

PER: Body Weight Growth (g) / Protein ingested (g), Net Nutrient Utilization (Nutrient deposited / Nutrient Fed %)

VI.2. Social interaction between populations

Three groups of fish have been constituted at 11 days post-fertilization: a normal mixed group (50% male / 50% female or F50) from one cohorte, a 100% female group (F100) from another cohort and a third group (F75) obtained by mixing the two cohorts. The different groups F50, F100 et F75 were realized in replicate and were fed at two level of feeding starting at first feeding up to 100 g.

Figure 13: Effect of mixing of two different cohorts (monosex female F100 et normal F50) since first feeding stage on growth of tilapia. Open bars correspond to male and closed bars to female. (mean and standard deviation).

The growth performances of these groups (Fig. 13) showed that a higher growth was observed for male and female of the F50 group compared to the F75 group whatever the feeding level. This differences could be related to differences in the sex ratio of the group as suggested by Volpato *et al.* (1989). However the changes observed were not directly related to the sex ratio and it could be suggested that the growth differences resulted of the mixing of two different cohorts which would induce stronger social interactions in F75 group than in F50 and F100 groups.

V.4 Conclusions

Our results suggest for the first time that mixing of fish of different sex or different cohort in tilapia could alter growth performances of a group through changes in social interactions and feeding competition. Further studies are required to analyze the genetic and physiological meaning of such results.

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