OProduction of salinity tolerant Nile tilapia, *Oreochromis niloticus* through traditional and modern breeding methods: 1- Application of interspecific hybridization with blue tilapia, *Oreochromis aureus* as traditional method

Samy Y. El-Zaeem[1], Mohamed E. Salama[1], Hamad A. El-Maremie[2]

1- Animal and Fish Production Dept., Faculty of Agriculture, Saba-Bacha, Alexandria University, Alexandria, Egypt.

2- Animal Production Department, Faculty of Agriculture, Omar Almokhtar University, Al-Bayda, Libya.

Corresponding author's e-mail: selzaeem@yahoo.com,

ABSTRACT

This study was conducted to produce a salinity tolerant Nile tilapia, *Oreochromis niloticus* through interspecific hybridization with *Oreochromis aureus*. Growth performance, proximate body composition, feed utilization, body amino acid profile and some reproductive characteristics of the offspring produced under different salinity levels were evaluated. The results revealed that the productive performance traits of (♀ *O. niloticus* x ♂ *O. aureus*) and (♀ *O. aureus* x ♂ *O. niloticus*) had significant superiority (P≤0.05) in most of these traits at freshwater, 16 ppt and 32 ppt compared to either *O. niloticus* or *O. aureus*. Most of the productive performance traits of *O. niloticus*, (♀ *O. niloticus* x ♂ *O. aureus*) and (♀ *O. aureus* x *O. niloticus* ♂) had significantly decreased (P≤0.05) with increasing salinity levels. Moreover, *O. aureus* showed more salinity tolerance and significant superiority (P≤0.05) of feed utilization and survival rate at salinity level of 32 ppt compared with the other genotypes of fish at the same salinity level.

Keywords: Salinity tolerance, *Oreochromis niloticus*, interspecific hybridization, productive performance.

INTRODUCTION

Tilapias are popular culture species and will continue to be important particularly for the lesser-developed countries in tropics (FAO, 2001). Whilst the overall proportion of aquaculture production taking place in brackish water has decreased over the past decade, there has been a significant increase in the production of tilapia in brackish water reflecting a paucity of finfish species well suited to this environment (Kamal and Mair, 2005).

Interspecific hybrid fish have been produced for aquaculture and stocking programmes to increase growth rate, transfer desirable traits between species, combine desirable traits of two species into a single group of fish, reduce unwanted reproduction through production of sterile fish or mono-sex

offspring, take advantage of sexual dimorphism, increase harvestability, increase environmental tolerances, and to increase overall hardiness in culture conditions (Bartley *et al*., 2001).

Different tilapia species and strains are considered to be salinity tolerant. *Oreochromis aureus* (Payne and Collinson, 1983; Al-Amoudi, 1987), *Oreochromis mossambicus* (Foskett *et al*., 1981; Fortes, 1987) and *Oreochromis urolepis hornorum* (Payne, 1983; Stickney, 1986). The hybrids (♀: ♂) of *O. niloticus* x *O. aureus*, *O. mossambicus* x *O. u. hornorum* and *O. mossambicus* x *O. niloticus* (Watanabe *et al*., 1985, 1988; Al-Amoudi, 1987) are the most salinity-tolerant tilapia species. Many experiments were carried out to evaluate the salinity tolerance of hybrid *O. niloticus* x *O. aureus* (Hulata *et al*., 1988 and 1993; Wohlfarth *et al*., 1983; Majumdar and McAndrew, 1983; Labib, 1985; Al-Amodi, 1987; El-Etreby *et al.,* 1992; Haroun, 1999). Doudet, (1992) reported that, *O. aureus* and two hybrids, *O. niloticus* x *O. aureus* and *O. mossambicus* x *O. niloticus* can tolerate salinities up to 15 ppt with significantly higher survival rates. Balarin and Haller (1982) reported that, *O. aureus* can grow well at salinity from 36 to 44 ‰, while reproduction occurs at 19 ‰. With gradual acclimation, it can tolerate a salinity of up to 54 ‰.

Nile tilapia, *O. niloticus* is one of the most important freshwater finfish in aquaculture (Kamal and Mair, 2005). It grows fast, but it is less salinity tolerant than *O. aureus* (Avella *et al*., 1993; Hulata, 2001). The shortage in fresh water in many countries, together with the competition for it with agriculture and other urban activities has increased the pressure to develop aquaculture in brackish water and sea water (El-Sayed, 2006).

The present study aimed to produce a salinity tolerant Nile tilapia, *Oreochromis niloticus* through inter-specific hybridization with *Oreochromis aureus*. In addition, growth performance, proximate body composition, feed utilization, body amino acid profile and some reproductive characteristics of the offspring produced under different salinity levels were studied.

MATERIALS AND METHODS

The present study was carried out at the Experimental Fish Farm and the Laboratory of Breeding and Production of Fish, Animal and Fish Production Department, Faculty of Agriculture (Saba-Bacha), Alexandria University, Alexandria, Egypt.

Fish origin

The Nile tilapia and Blue tilapia was obtained from Middle East Fish Farm, Tolombat Halk El-Gamal, El-Behera Governorate, Egypt.

Experimental design

1- Interspecific hybridization

Ripe females and males with an average live weight of *Oreochromis niloticus* (65.50±2.10 and 92.50±1.80 g) and *Oreochromis aureus* (63.00±1.20 and 90.00±2.70 g), respectively were chosen. Strains of *O. niloticus* and *O.*

aureus and their diallel crosses were stocked for natural spawning in separated concrete ponds (3x1x1.2 m) at a rate of 4 breeders/ m^3. The sex ratio of the fish was 3 females: 1 male. Brood fish were fed twice daily on pellet diet contained 26 % protein at satiation for 6 days a week. Post-hatching fry of *O. niloticus* and *O. aureus* and their diallelic crosses were collected and transferred separately to laboratory experimental glass aquaria (100 liter volume). The fry acclimation to laboratory conditions were counted and weighed. Each aquaria was supplied with dechlorinated tap water and adequate continuous aeration systems, clean once daily by siphoning and was replaced one-half to two thirds of their water volume. Fry were fed three times daily on pellet diet containing 38% protein to satiation, six days a week for 90 days. Then all fish were fed on diet containing 32 % to satiation six days a week to another 45 days. Formulations of the different diets used in the present study were prepared according to (El-Zaeem, 2001). Fish were weighed biweekly for 135 days.

2- Base generation (F_0)

2.1- Culture conditions

Base generation (F_0) offspring produced from inter-specific cross-breeding were collected, counted and weighed. Then, fry transferred separately to glass aquaria (total area 100 x 34 x 50 cm) at a rate of 1 fish/10 liter, and divided randomly for subjected to different salinity treatments. The glass aquaria were supplied with fresh dechlorinated tap water and supplemental aeration. Water temperatures were maintained at 28.00±1.00°C.

2.2- Saline water acclimation

Two different salinity levels of (16 and 32 ppt) were made by mixing fresh water with crude natural salt (Likongwe, 2002) obtained from El-Nasr Company for Salt, Borg El-Arab, Alexandria, Egypt, beside a third group of fresh water as control. Fry obtained from *O. niloticus*, *O. aureus* and their diallelic crosses, were gradually acclimated to the respective treatment of salinities by raising the salinity at the rate of 4 ppt daily (Watanabe and Kuo, 1985). Then, water in each glass aquaria was partially changed once daily and totally every three days. Fry was fed three times daily on pellet diet containing 38 % protein, to satiation, six days a week for 90 days. Then all fish were fed on diet containing 32 % to satiation six days a week to the end of experiment. Fish were weighed biweekly for 135 days. The different salinities were maintained throughout the experimental period with salinity monitored daily using salinity refractometer (S/Mill-E, ATAGO Co., LTD).

Quantitative traits measurements

The following parameters were measured: initial and final body weight (g), average daily gain (g/day), specific growth rate (SGR %/day), total body length (cm), condition factor (K), feed intake, feed conversion ratio (FCR), protein efficiency ratio (PER), protein and energy retention percent (PR% and ER%). Gross energy contents of feed were calculated from MacDonald's tables (MacDonald *et al*., 1973). Gross energy of fish was calculated from their

chemical composition using the factor of 5.7 and 9.5 for protein and fat, respectively according to Viola *et al*. (1981). Initial and final body composition analyses were performed for moisture, crude protein and lipid contents according to the standard AOAC (1984) methods.

In addition, a new modification of Lowery *et al*. (1951) method was used for the determination of total protein content (Tsuyosh and James, 1978). The analysis and composition of total amino acids of fish muscular protein have been determined using 119 CL amino acid analyzer. All amino acids values are expressed as gram percent of protein on dry bases.

Moreover, by the end of experiment, gonads were carefully removed and weighed then fixed in 10% formal saline solution. Pieces of fixed ovary were examined under binuclear microscope to determine the oocyte diameters. The oocyte diameters were divided into several groups; the first groups (0.24 to less than 0.8 mm) are small and transparent, while the remaining ova ranging between 0.8 mm and 2.0 mm in diameter are yolky. Gonadosomatic index was calculated as follows: GSI=Gonad weight (100) /Body weight.

Statistical analysis

Data were analyzed using the following model (CoStat, 1986):

$Y_{ijk}=\mu+T_i+S_j+(TS)_{ij}+B_k+e_{ijk}$

Where:

Y_{ijk}: Observation the ijkth parameter measured; μ: Overall mean; T_i; Effect of ith species; S_j: Effect of Jth salinity; $(TS)_{ij}$: Interaction species by salinity; B_k: Effect of Kth block; e_{ijk}: Random error.

For proximate body composition data at the beginning of experimental fish and gonadosomatic index, data were analyzed by fitting the following model (CoStat, 1986):

$Yij=\mu+Ti+e_{ij}$

Where:

Y_{ij}: Observation of the ijth parameter measured; μ: Overall mean; T_i: Effect of ith species;e_{ij}: Random error.

Significant differences ($P\leq0.05$) among means were tested by the method of Duncan (1955).

RESULTS AND DISCUSSION

The results showed that, there are no significant differences in initial body weight among different genotypes of fish. The highest values of final body weight (FBW) and the average daily gain (ADG) were recorded for the hybrid of (♀ *O. niloticus* x ♂ *O. aureus*). These values were significantly ($P\leq0.05$) higher than those of *O. niloticus, O. aureus* and hybrid (♀ *O. aureus* x *O. niloticus* ♂). SGR was significantly lower ($P\leq0.05$) for *O. aureus*, compared with the other genotypes. The highest significant values ($P\leq0.05$) of FBW, ADG and SGR were recorded for fish reared at fresh water compared to fish reared at salinity

levels of 16 and 32 ppt. The results of FBW and ADG of the hybrid (♀ *O. niloticus* x ♂ *O. aureus*) reared at fresh water had improved significantly (P≤0.05) compared with the other genotypes of fish reared at different levels of salinity. The highest means of SGR% /day were achieved by the hybrids of (♀ *O. niloticus* x ♂ *O. aureus*) and (♀ *O. aureus* x *O. niloticus* ♂) reared up to 16 ppt; and *O. niloticus* reared at freshwater and differed significantly (P≤0.05) from those of the other genotypes reared at different salinity levels (Table 1). Suresh and Lin (1992) indicated that a range of 10-20 ppt was optimal for tilapia growth. The results of the present work manifested that the hybrid obtained from interspecific hybridization (♀ *O. niloticus* x ♂ *O. aureus*) and (♀ *O. aureus* x *O. niloticus* ♂) had significant superiority of growth performance under different levels of salinity up to 32 ppt compared with *O. niloticus* and *O. aureus* at the same salinity levels. Pruginin *et al.* (1975); Wohlfarth *et al.* (1983); El-Ebiary and Zaki (1999); Haroun (1999) reported that the hybrid of (♀ *O. niloticus* x ♂ *O. aureus*) had higher growth performance than that of both parents and other tilapia hybrids. Fang and Chiou (1989) reported that *O. niloticus* raised in seawater grew almost 60% slower than that raised in freshwater. The same trend was observed in the present work.

The highest significant value (P≤0.05) of condition factor was observed for the hybrid (♀ *O. aureus* x ♂ *O. niloticus*). Insignificant differences were detected in condition factor of fish at different levels of salinity. The highest survival rate (89.99%) was achieved by *O. aureus*, which was significantly (P≤0.05) higher than those of the other genotypes. Fish reared at freshwater had significant (P≤0.05) increased survival rate (98.33 %) compared to the others reared at different salinity up to 32 ppt. Moreover, the lowest value of survival rate (46.66 %) was obtained by *O. niloticus* reared at 32 ppt, but did not differ significantly (P≤0.05) from that of the hybrids (♀ *O. aureus* x ♂ *O. niloticus*) and (♀*O. niloticus* x ♂ *O. aureus*) at the same level of salinity (Table 2). One major problem in culturing tilapia in high salinity water is the high incidence of diseases. Tilapias are more sensitive to handling stress in saline water and therefore are highly susceptible to secondary infection. Vine (1980) observed that *O. niloticus* lost it is appetite and developed lesions on the flanks after 2 months of rearing in the sea. Kamal and Mair (2005) reported that survival rate of *O. niloticus* was decreased at 22.5 and 30 ppt due to susceptibility of disease and possibly stress. The results reported by Wohlfarth and Hulata (1981); Al-Amoudi (1987); Doudet (1992) showed that mortality rate was increased with increasing salinity levels and *O. aureus* seems to be high salinity tolerance. Also Kirk (1972) found that *O. aureus* exhibited no mortality up to 25.2 ppt and only 20% mortality when transferred directly to 27 ppt. The results of the present study are consistent with these findings.

Table (1): Growth performance of *O. niloticus*, *O. aureus* and their diallelic crosses at different salinity levels.

Treatments	Initial body weight (g)	Final body weight (g)	Average Daily gain (g/day)	SGR%/ day
Genotype				
O. niloticus (N)	0.852±0.05	37.10±6.19^{c}	0.268±0.05^{c}	2.78±0.14^{a}
O. aureus (A)	0.772±0.08	28.51±0.85^{d}	0.205±0.01^{d}	2.67±0.07^{b}
♀ A x ♂ N	0.894±0.04	41.31±6.6^{b}	0.299±0.05^{b}	2.83±0.13^{a}
♀ N x ♂A	0.928±0.05	44.34±8.11^{a}	0.321±0.06^{a}	2.85±0.18^{a}
Salinity ppt				
Fresh water (FW)	0.848±0.07	41.84±9.28^{a}	0.303±0.07^{a}	2.86±0.13^{a}
16 ppt	0.854±0.09	40.95±7.50^{b}	0.293±0.05^{b}	2.85±0.11^{a}
32 ppt	0.883±0.08	31.11±2.72^{c}	0.223±0.02^{c}	2.63±0.02^{b}
Gen. X Sal.				
N-FW	0.835±0.09	41.22±1.13^{d}	0.299±0.01^{d}	2.88±0.10^{ab}
A-FW	0.766±0.03	28.16±0.62^{f}	0.202±0.01^{f}	2.670±0.01^{c}
♀ A x ♂ N-FW	0.891±0.07	46.77±0.50^{b}	0.339±0.01^{b}	2.93±0.10^{ab}
♀ N x ♂A-FW	0.901±0.04	51.22±1.32^{a}	0.372±0.01^{a}	2.990±0.01^{a}
N-16 ppt	0.865±0.05	40.90±0.87^{d}	0.296±0.01^{d}	2.850±0.02^{b}
A-16 ppt	0.772±0.18	29.22±1.33^{f}	0.210±0.01^{f}	2.70±0.15^{c}
♀ A x ♂ N-16 ppt	0.882±0.05	44.16±2.42^{c}	0.320±0.02^{c}	2.90±0.01^{ab}
♀ N x ♂ A- 16 ppt	0.898±0.03	47.70±0.45^{b}	0.346±0.01^{b}	2.94±0.04^{ab}
N-32 ppt	0.856±0.06	29.16±1.02^{f}	0.209±0.01^{f}	2.62±0.02^{c}
A-32 ppt	0.780±0.03	28.17±0.10^{f}	0.202±0.01^{f}	2.66±0.02^{c}
♀A x ♂ N- 32 ppt	0.910±0.01	33.17±0.87^{e}	0.237±0.02^{e}	2.66±0.01^{c}
♀ N x ♂ A-32 ppt	0.987±0.01	34.10±0.10^{e}	0.245±0.01^{e}	2.62±0.01^{c}

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05).
Initial and final body weight (IBW and FBW) = body weight at start and end of experiment.
Average daily gain (ADG) = (final weight - initial weight) / number of days.
Specific growth rate (SGR % /day) = (Ln final weight - Ln initial weight) / number of days (100).

The highest value of GSI (5.75) was recorded for *O. aureus* reared at freshwater and differed significantly (P≤0.05) from those of the other genotypes of fish reared at different levels of salinity (Table 2). Increasing salinity led to dropped (GSI) and percentage of yolky ova. This negative effect led to nonsuccess or decline of reproduction. Chervinski (1961) reported that GSI and percentage of yolky ova of *O. aureus* reared at 19 ppt were dropped. Chervinski and Yashouv (1971) noted that there was no reproduction and drop in GSI of *O. aureus* reared in sea water, may be due to a reabsorb of eggs. John (1979) reported that unable to reproduce of tilapia at high salinities, possibly due to the great osmotic stress on the eggs. Essa and Salama (1994) found that, spawning of *O. niloticus* was occurred at 5, 10 and 15 ppt of salinity.

Table (2): Condition factor, survival rate % and GSI of *O. niloticus*, *O. aureus* and their diallelic crosses at different salinity levels.

Treatments	Condition factor (K)	Survival rate (%)	GSI
Genotype			
O. niloticus (N)	1.87±0.03^{c}	81.10±26.7^{bc}	-
O. aureus (A)	1.79±0.02^{d}	89.99±15.6^{a}	-
♀ A x ♂ N	2.00±0.04^{a}	82.21±22.8^{b}	-
♀ N x ♂A	1.94±0.04^{b}	79.44±22.9^{c}	-
Salinity ppt			
Fresh water (FW)	1.89±0.08	98.33±2.5^{a}	-
16 ppt	1.91±0.09	96.24±2.8^{b}	-
32 ppt	1.90±0.09	54.99±10.5^{c}	-
Gen. X Sal.			
N-FW	1.84±0.03	100.0±0.0^{a}	5.47±0.12^{b}
A-FW	1.80±0.01	100.0±0.0^{a}	5.75±0.06 ^{a}
♀ A x ♂ N-FW	1.98±0.01	98.33±2.4^{a}	4.95±0.04^{cd}
♀ N x ♂A-FW	1.93±0.10	94.99±2.4^{a}	4.18±0.07^{e}
N-16 ppt	1.87±0.03	96.66±0.0^{a}	4.79±0.13^{d}
A-16 ppt	1.79±0.03	100.0±0.0^{a}	5.05±0.21^{c}
♀ A x ♂ N-16 ppt	2.02±0.04	94.99±2.4^{a}	*
♀ N x ♂ A- 16 ppt	1.90±0.05	93.33±0.0^{a}	*
N-32 ppt	1.88±0.01	46.66±0.0^{c}	*
A-32 ppt	1.78±0.05	69.99±4.7^{b}	2.37±0.05^{f}
♀A x ♂ N- 32 ppt	2.00±0.03	53.33±9.4^{c}	2.11±0.01^{g}
♀ N x ♂ A-32 ppt	1.94±0.03	49.99±4.7^{c}	*

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05).

* Data unavailable duo to unavailable females for analysis.

Condition factor (K) = Body weight /Cubic total length (100).

GSI=Gonad weight / Body weight (100).

Considering the results of egg diameters, the highest percentage of yolky ova (98%) was recorded by *O. aureus* reared in fresh water (Table 3). This percentage decreased from 90% to 62% with increasing the level of salinity from 16 to 32 ppt, respectively. The negative effect on percentage of yolky ova as increasing salinity was showed by *O. niloticus* and reciprocal hybrids (Table 3). El-Sayed *et al.* (2003) showed the better spawning performance of *O. niloticus* in freshwater compared to salinity levels of 7 and 14 ppt. Fineman-Kalio (1988) indicated that spawning of *O. niloticus* was inhibited by high salinity, and the gonad development and spawning occurred at salinities of 17-19 ppt. With increasing water salinity from 25 to 30 ppt the onset of reproduction was delayed while reproduction stopped completely at salinity above 30 ppt.

Table (3): The percentage of yolky ova for *O. niloticus*, *O. aureus* and their diallelic crosses at different salinity levels.

Treatments	Ova diameters (mm)												Yolky ova %
	Transparence				Yolky								
	0.24	0.32	0.40	0.64	0.80	0.96	1.20	1.44	1.60	1.76	1.84	2.0	
N-FW	0	0	3	0	0	0	0	10	22	65	0	0	97.00
A-FW	2	0	0	0	0	0	13	22	25	0	28	10	98.00
♀ A x ♂ N-FW	0	0	4	0	27	0	21	18	24	6	0	0	96.00
♀ N x ♂A-FW	0	0	19	0	0	0	33	0	48	0	0	0	81.00
N-16 ppt	0	0	8	0	10	21	29	25	0	7	0	0	92.00
A-16 ppt	0	0	10	0	0	12	24	38	16	0	0	0	90.00
♀ A x ♂ N-16 ppt	*	*	*	*	*	*	*	*	*	*	*	*	*
♀ N x ♂ A- 16 ppt	*	*	*	*	*	*	*	*	*	*	*	*	*
N-32 ppt	*	*	*	*	*	*	*	*	*	*	*	*	*
A-32 ppt	0	0	38	0	0	0	28	0	22	12	0	0	62.00
♀A x ♂ N- 32 ppt	14	22	28	15	18	3	0	0	0	0	0	0	21.00
♀ N x ♂ A-32 ppt	*	*	*	*	*	*	*	*	*	*	*	*	*

***** Data unavailable duo to unavailable females for analysis.

No significant differences in moisture and lipid content were detected among *O. niloticus*, *O. aureus* and their reciprocal hybrids either in beginning or at the end of experiment. Body crude protein was significantly lower (P≤0.05) for *O. aureus*, while the highest significant (P≤0.05) value was obtained by either fish reared at 16 ppt or fish reared at freshwater. In respect to interaction, the lowest significant (P≤0.05) body moisture content value was obtained by either hybrid (♀ *O. aureus* x ♂ *O. niloticus*) or hybrid (♀*O. niloticus* x ♂ *O. aureus*) reared at fresh water, compared with *O. niloticus, O. aureus* and other hybrids reared at different levels of salinities (Table 4).

Brolongan and Benitez (1992), found that insignificant differences in total lipids content in all organs of milk fish (*Chanos chanos*) reared at fresh water or sea water, while moisture content increased significantly with increasing salinity levels. Likongwe (2002) reported that, crude protein values of *Oreochromis shiranus shiranus* cultured at 0, 10 and 20 ppt of salinity were 49.18, 55.23 and 52.39%, respectively. The decreased body protein at high level of salinity (up to 20 ppt) may be due to increase the energy demand for osmoregulation and fish may utilize protein as source of energy at these levels of salinity. These findings are consistent with the results obtained during the present work.

The highest value of feed intake was recorded by the hybrid (♀*O. niloticus* x ♂ *O. aureus*), which was significantly (P≤0.05) higher than those of the other genotypes. The best value of FCR and highest PER were achieved by *O. aureus* and differed significantly (P≤0.05) from those of the other genotypes. Considering the different salinity levels, feed intake was significantly (P≤0.05) increased up to 16 ppt of salinity. The present results showed that the best and highest significant (P≤0.05) values of FCR, PER, PR and ER were achieved by

the fish reared at fresh water. In respect to interaction, the hybrid of (♀*O. niloticus* x ♂ *O. aureus*) reared at 16 ppt of salinity showed the highest significant (P≤0.05) feed intake value. The best FCR were recorded by *O. niloticus*, (♀*O. niloticus* x ♂ *O. aureus*) and (♀*O. aureus* x ♂*O. niloticus*), reared at freshwater, which were significantly (P≤0.05) lower than those of the other genotypes reared at different levels of salinities (Table 5). The same trends were reported by Watanabe *et al.* (1988); Clark *et al.* (1990) they found that, feed intake increased with increasing salinity. PER, PR and ER values were significantly (P≤0.05) increased for the hybrid of (♀*O. niloticus* x ♂ *O. aureus*) reared at freshwater, showing higher means compared with the other genotypes reared at different levels of salinities, but did not differ significantly from that of *O. niloticus* and the hybrid (♀*O. aureus* x ♂*O. niloticus*) reared at fresh water.

Table (4): Body composition of *O. niloticus*, *O. aureus* and their diallelic crosses at different salinity levels.

Treatments	Moisture	% on dry matter basis	
		Protein	Lipid
Genotype		At the start	
O. niloticus (N)	80.8±0.04	54.21±1.11	18.00±1.41
O. aureus (A)	79.9±0.78	53.92±0.25	18.22±0.03
♀ A x ♂ N	79.6±0.14	54.00±0.17	18.60±0.87
♀ N x ♂A	80.0±0.14	54.00±0.42	18.44±0.17
Genotype		At the end	
O. niloticus (N)	74.66±0.27	$57.04±0.16^{a}$	24.38±0.38
O. aureus (A)	74.51±0.27	$56.37±0.13^{b}$	24.54±0.57
♀ A x ♂ N	74.46±0.36	$57.04±0.16^{a}$	24.30±0.39
♀ N x ♂A	74.59±0.37	$56.87±0.29^{a}$	24.42±0.45
Salinity ppt			
Fresh water(FW)	$74.20±0.17^{b}$	$56.85±0.29^{ab}$	24.40±0.50
16 ppt	$74.80±0.18^{a}$	$56.95±0.37^{a}$	24.55±0.29
32 ppt	$74.66±0.180^{a}$	$56.68±0.32^{b}$	24.28±0.50
Gen. X Sal.			
N-FW	$74.40±0.03^{b}$	57.10±0.30	24.55±0.71
A-FW	$74.29±0.04^{b}$	56.43±0.04	24.60±0.05
♀ A x ♂ N-FW	$73.99±0.03^{c}$	57.02±0.03	24.10±0.31
♀ N x ♂A-FW	$74.12±0.03^{bc}$	56.86±0.02	24.30±1.00
N-16 ppt	$74.80±0.42^{a}$	57.14±0.01	24.44±0.10
A-16 ppt	$74.86±0.01^{a}$	56.38±025	24.81±0.27
♀ A x ♂N-16 ppt	$74.70±0.03^{a}$	57.10±0.17	24.5±0.46
♀ N x ♂ A- 16 ppt	$74.87±0.03^{a}$	57.20±0.06	24.4±0.31
N-32 ppt	$74.78±0.03^{a}$	56.88±0.11	24.16±0.28
A-32 ppt	$4.39±0.01^{b}$	56.30±0.07	24.22±1.10
♀A x ♂ N-32 ppt	$74.70±0.01^{a}$	57.0±0310	24.25±0.5
♀N x ♂ A-32 ppt	$74.80±0.03^{a}$	56.55±0.07	24.51±0.27

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05).

The results of the present study showed that, *O. aureus* seems to be more salinity tolerant and significant ($P \leq 0.05$) superiority for feed utilization at 32 ppt of salinity level compared with *O. niloticus* and their reciprocal hybrids with *O. aureus* (Table 5). Haroun (1999) reported that the maximum feed utilization was obtained by the hybrid of (♀*O. niloticus* x ♂ *O. aureus*) compared with pure fish reared at freshwater. Likongwe *et al.* (1996) reported that FCR of *O. niloticus* was improved at 8 ppt compared with 16 ppt. Kamal and Mair (2005) found that, FCR of *O. niloticus* reared at different levels of salinity of 0, 7.5, 15, 22.5 and 30 ppt were 0.76, 0.73, 0.76, 0.80 and 0.96, respectively.

Generally, the highest value of body amino acid content was recorded for glutamate, while the lowest value was observed for cystine. Referring to the effects of salinity on the body amino acid content, the results showed that *O. niloticus*, *O. aureus* and their reciprocal hybrids reared at 16 ppt of salinity had superiority of amino acid content compared with the fish reared at freshwater. While amino acid content of these fish decreased with increasing salinity from 16 to 32 ppt (Table 6). Likongwe (2002) reported that, whole body protein of *O. shiranus* and *O. karonge* decreased with increasing salinity to 20 and 10 ppt, respectively, may be due to the fish utilized protein as source of energy at these levels of salinity. Amino acids are involved in the energetic balance in higher organisms. The cellular machinery employs the amino acids for gluconogenisis and for the oxidation to CO_2 through the cycle of tricarboxylic acids, it is highly probable that the decreased content of amino acid with increasing salinity from 16 to 32 ppt reflected a higher consumption of energy by fish for osmoregulation at high salinity level. The differences between these findings and the present study may be due to the differences in fish species.

Table (5): Feed utilization of *O. niloticus* , *O. aureus* and their diallelic crosses at different salinity levels.

Treatments	Feed intake (g)	FCR	PR%	PER	ER%
Genotype					
***O. niloticus* (N)**	73.26±7.4^{c}	2.05±0.23^{a}	20.69±2.60	1.42±0.16^{b}	15.46±1.85
***O. aureus* (A)**	54.67±1.9^{d}	1.97±0.06^{b}	21.3±0.83	1.47±0.05^{a}	15.72±0.85
♀ A x ♂ N	82.98±3.5^{b}	2.09±0.30^{a}	20.19±2.76	1.40±0.20^{b}	15.34±2.25
♀ N x ♂A	89.14±5.2^{a}	2.10±0.32^{a}	20.36±3.36	1.39±0.21^{b}	15.21±2.41
Salinity ppt					
Fresh water(FW)	74.90±15^{b}	1.83±0.10^{c}	23.03±1.13^{a}	1.58±0.06^{a}	17.39±0.67^{a}
16 ppt	79.67±15^{a}	2.0±0.040^{b}	20.84±0.39^{b}	1.44±0.03^{b}	15.40±0.37^{b}
32 ppt	70.74±12^{c}	2.31±0.21^{a}	18.03±1.89^{c}	1.24±0.13^{c}	13.52±1.31^{c}
Gen. X Sal.					
N-FW	72.70±0.6^{f}	1.80±0.03^{d}	23.65±0.40^{ab}	1.61±0.02^{a}	17.57±0.33^{a}
A-FW	52.90±2.1^{i}	1.93±0.12^{c}	22.0±1.40^{bc}	1.51±0.10^{b}	16.57±1.03^{b}
♀ A x ♂ N-FW	83.50±0.1^{d}	1.82±0.01^{d}	22.65±2.00^{ab}	1.60±0.01^{a}	17.66±0.32^{a}
♀ N x ♂A-FW	90.62±0.8^{b}	1.80±0.03^{d}	23.86±0.46^{a}	1.62±0.02^{a}	17.76±0.27^{a}
N-16 ppt	81.70±2.0^{d}	2.04±0.01^{c}	20.55±0.33^{c}	1.42±0.01^{c}	15.33±0.29^{c}
A-16 ppt	56.33±1.6^{h}	1.98±0.02^{c}	20.95±0.32^{c}	1.47±0.10^{bc}	15.08±0.40^{c}
♀ A x ♂N-16 ppt	86.55±1.1^{c}	2.00±0.10^{c}	21.10±0.73^{c}	1.45±0.10^{bc}	15.69±0.47^{c}
♀ N x ♂A-16 ppt	94.10±0.4^{a}	2.00±0.03^{c}	20.83±0.24^{c}	1.44±0.02^{bc}	15.50±0.28^{c}
N-32 ppt	65.38±0.9^{g}	2.31±0.04^{b}	17.88±0.3^{d}	1.24±0.03^{d}	13.48±0.31^{d}
A-32 ppt	54.80±0.3^{hi}	2.0±0.01^{c}	20.95±0.22^{c}	1.45±0.01^{bc}	15.52±0.23^{c}
♀A x ♂ N-32 ppt	78.90±1.4^{e}	2.46±0.02^{a}	16.87±0.10^{d}	1.16±0.01^{e}	12.69±0.21^{de}
♀N x ♂ A-32 ppt	82.80±0.8^{d}	2.50±0.01^{a}	16.41±0.10^{d}	1.14±0.01^{e}	12.39±0.10^{e}

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05).
Feed conversion ratio (FCR) = dry feed intake / gain.
Protein efficiency ratio (PER) = gain / protein intake.
Protein retention (PR%) = protein increment / protein intake (100).
Energy retention (ER %) = energy increment / energy intake (100).

Table (6): Amino acids (g /100 protein) of *O. niloticus* (N), *O. aureus* (A) and their diallelic crosses (♀A x ♂N, ♀N x ♂A) reared at different salinity levels.

Treatments / Amino acid	N-FW *	A-FW	♀A x ♂N-FW	♀N x ♂A-FW	N-16 ppt	A-16 ppt	♀A x ♂N-16 ppt	♀N x ♂A-16 ppt	N- 32 ppt	A- 32 ppt	♀A x ♂ N-32 ppt	♀N x ♂ A-32 ppt
Aspartate	9.10	10.18	7.12	8.72	9.14	10.7	7.15	8.68	9.05	10.16	7.04	8.69
Threonine	4.98	4.56	4.62	4.68	5.01	4.55	4.65	4.67	4.92	4.49	4.59	4.66
Serine	3.92	4.21	4.08	4.10	4.00	4.22	4.18	4.12	3.98	4.20	4.04	4.08
Glutamate	13.92	15.01	14.63	14.27	13.85	13.88	15.2	14.77	13.88	14.93	14.41	14.25
Proline	5.18	4.88	4.77	4.49	5.17	4.96	4.79	4.48	5.14	4.90	4.62	4.53
Glycine	4.41	4.92	5.41	4.48	4.39	4.80	5.39	4.50	4.39	4.86	5.32	4.44
Alanine	6.15	7.12	7.51	6.32	6.21	7.10	7.44	6.33	6.10	7.00	7.35	6.27
Cystine	0.44	0.77	0.54	0.30	0.48	0.78	0.58	0.28	0.47	0.74	0.51	0.26
Valine	5.25	5.25	5.30	5.07	5.33	5.28	5.33	5.10	5.18	5.20	5.28	5.08
Methionine	2.69	2.88	2.77	2.31	2.71	2.90	2.69	2.33	2.58	2.70	2.25	2.21
Isoleucine	7.55	8.00	6.86	5.88	7.48	8.20	6.79	5.91	7.49	7.83	6.87	5.82
Leucine	7.23	8.10	6.98	6.27	7.17	7.53	6.80	6.34	7.17	8.00	6.90	6.19
Tyrosine	3.36	4.01	3.22	3.29	3.45	4.11	3.28	3.33	3.38	3.92	3.26	3.19
Phenylalanine	3.72	4..05	3.84	3.66	3.74	4.20	3.90	3.72	3.64	4.00	3.82	3.54
Histidine	2.38	2.78	1.81	2.55	2.40	2.74	1.83	2.62	2.31	2.66	1.77	2.49
Lysine	7.32	7.12	6.80	6.90	7.30	7.11	6.91	7.22	7.26	7.00	6.72	6.83
Arginine	4.51	5.33	4.48	3.60	4.54	5.28	4.52	3.66	4.53	5.35	4.51	3.61

*FW: Freshwater

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