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Growth of the Tilapia, *Oreochromis niloticus*, in the Closed Aquaculture System

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閉鎖式 飼育 裝置內에서 틸라피아 (*Oreochromis niloticus*)의 成長

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ABSTRACT

A series of rearing experiments were conducted to determine the growth rates and feed conversion efficiencies of tilapia in accordance with body size or age in nearly total closed system glass aquariums (270 ℓ each in water volume) and concrete tanks (4000 ℓ) from April 10 to October 16, 1987.

The fish used for the experiments was a Japanese strain of *Oreochromis niloticus*, and the size of the fish ranged from 7 g to more than 1,000 g in body weight. The starting stocking rates for each experimental lot were 10 to 20 ㎏ in the glass aquarium (3.7% to 7.4% of water volume) and 200 ㎏ in the concrete tank (5% of water volume). A single experimental rearing term was 14 days with slight variations on occasions.

Water temperature was designed to be kept at 26℃ but slight fluctuations were inevitable. Dissolved oxygen level was designed to be maintained at around 3 ㎎/ℓ, but it also showed some variations. The ammonia level in the glass aquarium section once reached up to 18 ㎎/ℓ, but generally remained at around 4 ㎎/ℓ, and in the concrete tank section it was maintained at around 1 ㎎/ℓ.

The feed was composed of mainly soybean meal with a small amount of fish meal as the protein source, and the crude protein content was about 32%.

Mean daily growth rate was 3.5% of body weight with 0.9 in food conversion ratio in the glass aquarium when the mean weight of fish was around 10 g with gradually reduced performances as the fish grew bigger. When the mean weight was 800 g, mean daily growth rate was 0.5% with about 1.5 in food coversion for fish in the glass aquarium, and 0.8% and 1.6 for fish in the concrete tank, respectively.

According to the mean growth rate obtained from this experiment, it was calculated that the fish reared in the concrete tank require 223 days from 50 g to reach 1,000 g which is the ideal size for market in Korea, at the conditions provided as above, and 302 days from 10 g fingerlings to 800 g fish in the glass aquarium conditions of the closed recirculating water system.

要 約

1987年 4月 10日부터 10月 16日까지 4,000 ℓ 콘크리트 탱크 및 270 ℓ 유리 水槽를 利用한 閉鎖循環濾過飼育裝置內에서 크기에 따른 一日成長率과 飼料係數를 測定하기 爲하여 다음과 같은 實驗을 實施하였다.

實驗에 사용된 魚體의 크기는 平均體重 7 g 에서 1,000 g 되는 日本系統 틸라피아 *Oreochromis niloticus* 였다. 每實驗마다 最初放養 무게는 콘크리트 탱크에서는 200 kg (水量의 5%), 유리 水槽에서는 10~20 kg (水量의 3.7%~7.4%)으로 調節하였다. 每實驗飼育期間은 14日 前後였다.

水溫은 26℃ 內外로 維持시키도록 했는데, 약간의 變化는 피할 수 없었다. 溶存酸素는 約 3 mg/ℓ 以內로 調節하였으며, 암모니아는 유리 水槽에서 一時 18 mg/ℓ 까지 上昇한 적도 있으나, 一般的으로 4 mg/ℓ 이었으며, 콘크리트 탱크에서는 約 1 mg/ℓ 로 維持되었다.

魚體重 約 10 g에서의 飼料係數는 0.9, 一日成長率은 3.5% 였으며, 魚體重 約 800 g 때의 콘크리트 탱크에서의 一日成長率은 0.8%, 유리 水槽에서의 一日成長率은 約 0.5%이었다.

實驗魚는 大豆粕을 主成分으로 한 32% 粗蛋白質을 含有한 飼料를 供給하였다.

이번 실험의 結果에 따라서 食用魚로 될 수 있는 틸라피아를 生產하는데 所要되는 期間은 計算上 다음과 같이 나타났다. 즉, 콘크리트 탱크($7m^2$)에서는 50 g 되는 치어를 방양하여 1,000 g 까지 기르는데 223日 걸리며, 유리 水槽에서는 10 g되는 치어를 방양 800 g 까지 기르는데 302日이 걸린다.

INTRODUCTION

Tilapia has recently become one of the most promissing aquacultured fishes around the world (German and Nobble, 1977 ; Chen, 1977 ; Stickney, 1979 ; Haller and Parker, 1981 ; Balarin, 1981, 1982 ; and Swift, 1985), and the species are widely cultured in Korea, with increasing production every year accompanied by a number of expected newly joining tilapia farmers.

Tilapia is generally cultured in ponds (Hepher and Pruginin, 1982) or in net cages (Coche, 1982) in tropical and subtropical areas, but it is not possible to grow this tropical fish species in the natural environment in Korea, because in the outdoor ponds the ambient natural water temperature in winter is very low and freezes.

The only solution to grow this species year-round in Korea is to employ the closed water system which must be able to keep culture medium at favourable temperature in the cool and cold seasons by heating and with insulated coverings (Kim and Kang, 1982). Therefore it is very important to grow the fish both as densely and as quick as possible in the costly closed system.

The aim of present study is to find out the growth rate and feed conversion at the each growing stage from the fingerling stage to marketable size, about 1,000 g in Korea, and to estimate the time and the amount of feed required for the growth in the high density closed rearing system.

METHODS

The rearing experiment was carried out at the Fish Culture Experiment Station of the National Fisheries University of Pusan, from April through October 1987. The rearing chambers were all installed in connection with the main closed system culture units with near-total recirculating filter

chambers.

Two series of experimental culture chambers were employed : six 4,000 ℓ concrete tanks measuring 3 m x 2.75 m x 0.6 m (water depth) with corners rounded-off, and ten 270 ℓ glass aquariums of 90 cm x 60 cm x 50 cm (water depth) in dimensions.

To maintain the water temperature at required level, the system was covered with vinyl sheet green house roof except for July and August. Water temperature was to be maintained at 26℃, but it was also fluctuated especially when the insulating covering vinyl sheet was ruptured by stormy winds in July.

Dissolved oxygen level was designed to maintain at 3 ㎎/ℓ, and the level in each rearing chamber was monitored every 2 hours, and readjusted when necessary by first regulating the flow rate into each tank and secondly with additional aeration by air bubbling as necessary, but some deviations were inevitable. The dissolved oxygen levels with other water parameters monitored during the experimental period are shown in Table 1.

Table 1-1. Water quality parameters monitored in the concrete tanks(㎎/ℓ)

Date	pH	Total NH_4-N	NO_2-N	NO_3-N	Alkalinity	Date	pH	Total NH_4-N	NO_2-N	NO_3-N	Alkalinity
Apr/04	6.59	1.34	0.20	42.63	41.2	Jul/10	6.86	0.77	0.18	45.40	
12	6.65	1.12	0.13	44.82		19	6.73	0.50	0.17	75.04	
25	6.76	0.82	0.13	32.71		25	6.88	1.22	0.16	52.88	
May/02	6.90	0.91	0.25	28.64		31	7.05	1.71	0.45	40.20	60.0
09	6.90	0.85	0.28	64.12	112.4	Aug/08	7.08	1.18	0.42	55.19	
15	6.78	1.27	0.29	58.27		14	7.03	0.79	0.21	28.98	
23	6.25	0.66	0.16	49.34		21	7.09	1.24	0.35	28.82	
29	6.25	0.69	0.20	53.60		27	6.79	1.90	0.32	35.67	
Jun/05	6.68	0.70	0.21	42.10		Sep/04	6.64	0.36	0.08	54.31	
19	6.30	0.87	0.26	15.51		13	6.62	0.64	0.13	52.29	20.0
26	6.45	0.67	0.29	40.53		25	6.92	1.08	0.35	49.90	
Jul/03	7.00	0.59	0.24	51.16		Oct/04	6.92	1.13	0.25	50.00	

Table 1-2. Water quality parameters monitored in the glass aquariums(㎎/ℓ)

Date	pH	Total NH_4-N	NO_2-N	NO_3-N	Alkalinity	Date	pH	Total NH_4-N	NO_2-N	NO_3-N	Alkalinity
Apr/04	6.97	0.72	0.15	24.77	128.1	Jul/10	7.14	6.36	0.67	24.78	
12	7.05	1.96	0.21	22.41		19	6.95	4.48	0.18	40.64	
25	7.14	3.05	0.37	14.12		25	6.98	6.29	0.25	24.30	
May/02	7.19	1.96	0.45	30.55		31	7.05	1.71	0.45	40.20	61.0
09	7.31	6.92	0.55	35.08	206.8	Aug/08	7.08	1.18	0.42	55.19	
15	6.42	14.34	0.55	23.55		14	7.03	0.79	0.21	28.98	
23	7.42	18.04	0.57	16.85		21	7.09	1.24	0.35	20.82	
29	7.38	14.64	0.63	18.20		27	6.79	1.90	0.32	35.67	
Jun/05	7.45	10.23	0.63	14.60		Sep/04	6.64	0.36	0.08	54.31	
19	6.82	5.68	0.38	8.10		13	6.62	0.64	0.13	52.29	20.0
26	6.78	3.96	0.29	36.51		25	6.92	1.08	0.35	49.90	
Jul/03	7.23	4.21	0.51	68.02		Oct/04	6.92	1.13	0.25	50.00	

The fish used for the experiment was originated from a Japanese strain of *Oreochromis niloticus* and the specimens used for the experiment were fingerlings which were produced in September 1986, and overwintered in the tanks at relatively low temperatures.

The fish stocked in each chamber was 200 kg in the 4,000 ℓ concrete tanks at the beginning of every rearing terms, and 10 to 20 kg in the 270 ℓ glass aquariums. The stocking rates correspond to 5% of the water volume in the concreat tank and 3.7 to 7.4% in the glass aquarium.

The feed used for this experiment was specially prepared for this experiment with the aid from a local fish feed mill, Keum Sung Co. Ltd. The major ingredients are shown in Table 2, and they are solvent extracted soybean meal (46%), wheat flour, and white fish meal (12%) with other additives. The protein content was expected to be 32%, but practical values appeared at around 33%.

Table 2. Major ingredients of the feed used for the experiment*

Ingredient	%	Ingredient	%
Soybean meal, solvent extracted	46	Fish meal, white	12
Low grade flour	37	Table salt	0.5
Yeast, active	0.5	Others	4
Calculated protein content	32		

*The feed was exclusively provided by the courtesy of Kumsong Feed Co., Ltd. in Pusan.

One term of rearing experiment was set for 14 days but by situations for various reasons some variations arose. Feeding rates were set at near satiation at the beginning of each experimental term. The feeding was practiced by automatic time and amount regulated feeders which supplied preset amount of feed every 30 to 40 minutes from 7 : 00 hour in the morning until 24 : 00. The form of feed was either crumbles or pellets according to the size of fish under experiment.

Daily growth rate was calculated according to the following formula.

$$W_t = W_0\left(1+\frac{F}{C}\right)^t \quad \cdots\cdots 1$$

where
W_t = weight of fish on day t
W_0 = weight of fish on day 0
F = feeding rate percentage
C = food conversion ratio
whereas :

$$\frac{F}{C} = g(\text{daily growth rate})$$

then

$$W_t = W_0(1+g)^t \quad \cdots\cdots 2$$

$$(1+g)^t = \frac{W_t}{W_0}$$

$$1+g = \left(\frac{W_t}{W_0}\right)^{\frac{1}{t}}$$

thus,

$$g=\left(\frac{W_t}{W_0}\right)^{\frac{1}{t}}-1 \quad \cdots\cdots 3$$

The equation for the time required from W_0 to W_t is derived from the equation 2 as following :

$$t=\frac{\log W_t-\log W_0}{\log (1+g)} \quad \cdots\cdots 4$$

RESULTS

1. Growth of tilapia in 4,000 ℓ concrete tanks.

During this investigation, a sum of 66 feeding experiments were carried out in concreate tanks and the growth rates of each experimental lot are plotted in Fig. 1. Though the details of each experimental lot were not shown here, there were 3 groups of fish to start with according to initial sizes of the fish : small size group of 32 g in initial average size, middle size group of 63 g and 67 g, and large size group of 132 g to 143 g. The small size group (32 g in weight) required 164 days to reach 720 g in average size. The feed conversion ranged from 1.040 to 1.935 and average daily growth ranged 2.88% down to 0.518. But until they grew to 250 g size group the feed conversion values remained below 1.328.

The middle size groups (63 g and 67 g in average weight) reached 712 g and 676 g and the third group, large size group, 135~143 g in initial weight, reached 915~1,035 g in average weight for the same period. Throughout the period of this experiment total mortalities were 0.94% in the glass aquariums and 0.66% in the concrete tanks without any disease outbreaks. No drugs and chemicals were administerd.

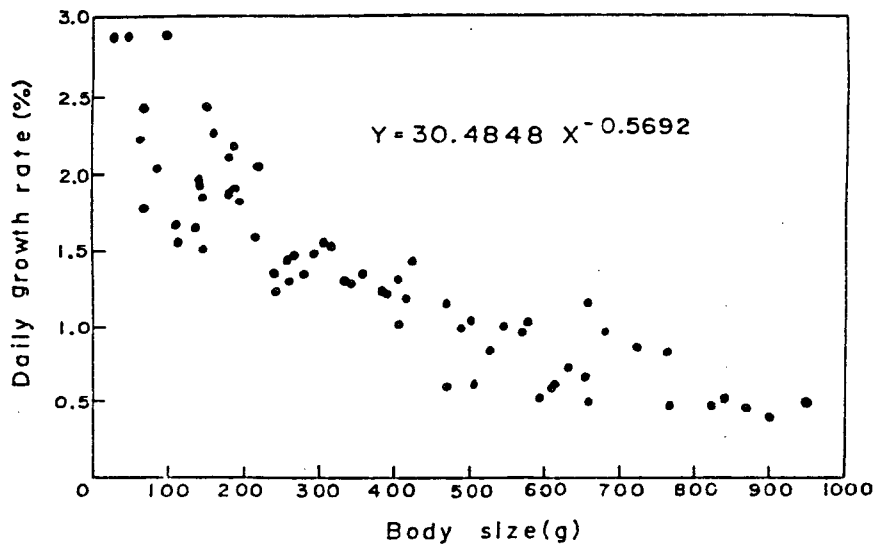

Fig. 1. Growth rates of *Oreochromis niloticus* by the initial mean size of each experimental lot grown in concrete tanks.

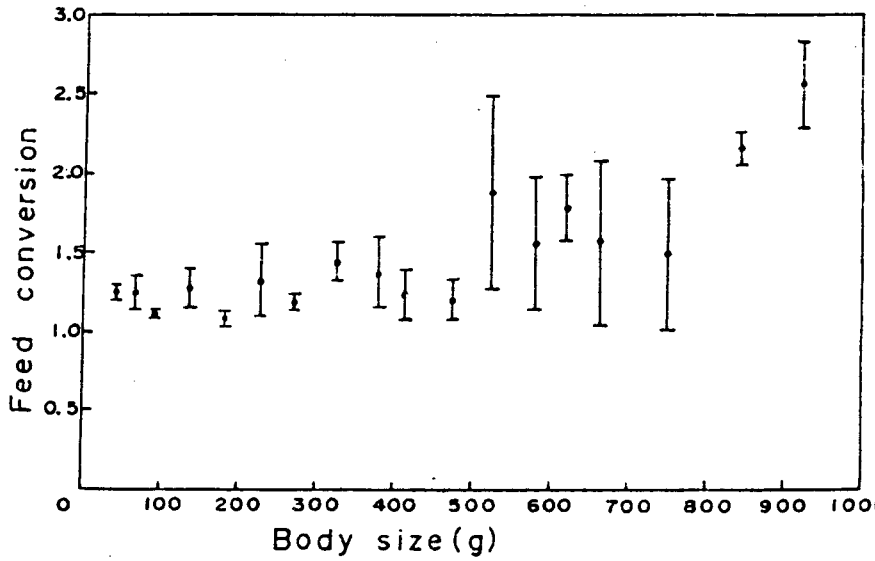

Fig. 2. Summarized results for the feed conversion of *O. niloticus* grown in concrete tanks.

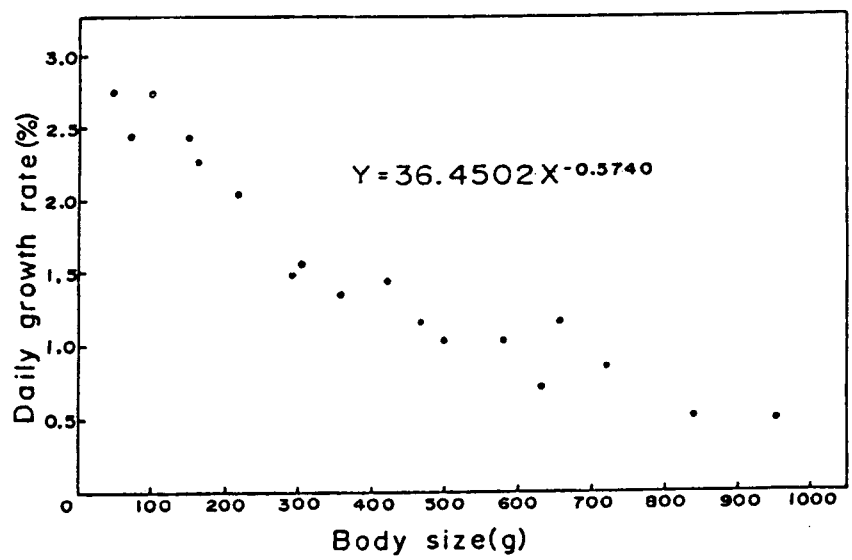

Fig. 3. Growth rates of the 18 best grown lots among all the 66 experimental lots in concrete tanks.

2. Growth of tilapia in 270 ℓ glass aquariums.

During this investigation, sum of 109 feeding experiments were carried our in glass aquariums and the growth rates of each experimental lot are plotted in Fig. 4. There were 3 groups of fish to start with according to the size of the fish : small size group of 7~8 g in initial average size, middle size

group of 49~50 g, and large size group of 87~109 g.

The small size group (7~8 g in weight) was graded into further smaller and larger sub-groups

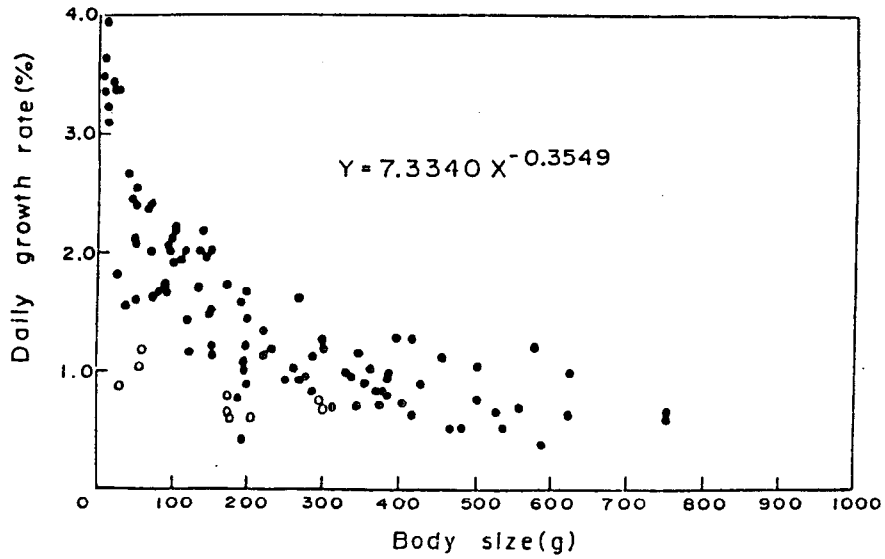

Fig. 4. Growth rates of *Oreochromis niloticus* by the initial mean size of each experimental lot grown in glass aquariums.

● : normal temperature period (Apr. 10~Jung 4, June 22~Oct. 16)

○ : abnormal temperature period caused by the rupture of vinyl house (June 5~21).

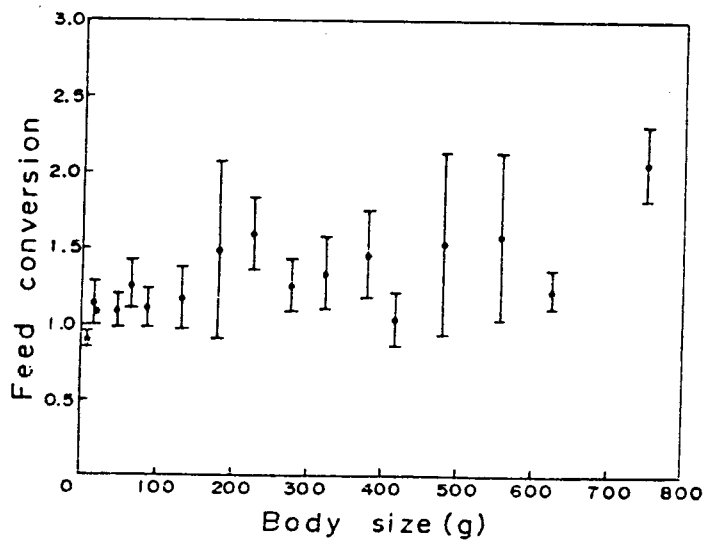

Fig. 5. Summarized results for the feed conversion of *O. niloticus* grown in glass aquariums.

after three consecutive feeding experiments and the larger sub-group reached 414~444 g at the end of total feeding experiments for 179 days, but the smaller sub-group reached only 248 gragms in average weight for the same period.

The feed conversion for the whole groups ranged from 2.312 down to 0.905 (Fig. 5) and average daily growth ranged from 3.95% down to 0.758% (Fig. 4).

From the original data, it showed that the middle size group (49 g and 50 g in average weight) reached 506~579 g in average weight, with feed conversion from 2.296 down to 0.943 but mostly below 1.5 or so. Daily growth rate ranged from 2.524% down to 0.514%. The third group, large size group, 87~109 g in initial average weight was further graded according to their sizes after 4 consecutive feeding experiments, and the larger size sub-group reached over 800 g in average weight and the smaller sub-group reached only 540 g in average weight at the end of 179 day experiments.

DISCUSSION

The results of this experiment in the nearly total closed system conditions show that the feed conversions and growth rates seem to be comparable with other conventional practices in the open water system for any other species. The outcomes are better than the author's previous data on the hybrid between Israeli and Korean strains of common carp (Kim, 1980) in which feed conversion and daily rate growth were 1.61 and 1.086% respectively. Another results for common carp (Kim and Lee, 1981), in which the feed conversion and daily growth rate were 1.31 and 1.03% respectively, were also inferior to the results of present experiment with the same size group.

Viola and Arieli (1987) showed the feed conversion 2.0 and daily growth rate 1.0% with tilapia of 250g in body size. Present results with same size fish were 1.303 in feed conversion and 1.534% on daily growth rate with the tilapia in concrete tanks, being much better performance than those of Viola and Arieli(1987). These big differences may have been partly coused by the differences in feeding regime. Viola and Arieli fed twice a day and 6 days a week only, but in the present experiment the fish were fed more than 20 times every day. Thus the fish were fed even at night under the lamp illumination, and this could have led to much better performance. This practice was also effective to prevent oxygen concentration increase in the early morning. This was seemed to have effectively controlled the outbreak of columnaris disease which is of highly aerobic, thus readily leading to heavy outbreak of gill and fin rot diseases under chronic high concentration of dissolved oxygen in fish ponds.

In the glass aquarium section, the performance both in feed conversion and growth rate suffered considerably from June 5 to 21. This was caused by the decrease of water temperature resulting from the sudden rupture of vinyl film cover of the green house by stormy weather. Therefore the water temperature was suddenly lowered from the previous period. This temperature is not really low for tilapia growth, if it was under the condition of increasing temperature in the spring season. Nevertheless both the growth rate and feed conversion suffered when the temperature was decreasing. The same experiences have been encountered in autumn seasons in the past years.

Mean growth rates by the size of fish and time required to reach next step size were calculated (Table 5) from the equations in Fig. 1 and Fig. 4 of the mean growth rates for the fish grown in the concrete tanks and glass aquariums. From this table the time required to reach 1 kg size from 50 g seeds was 223 days in the concrete tanks. In the glass aquariums, it was 302 days from 10 g seeds to 800 g fish.

Table 3. Growth and feed conversion effciency of the 18 best grown lots of *Oreochromis niloticus* among all the 66 experimental lots in the all 3 size groups in the concrete tanks

Group* and time sequence	Initial		Final		Days fed	Water temp.	Mortality kg(No.)	Feed conver-sion	Daily growth rate
	Total (kg)	Mean (g)	Total (kg)	Mean (g)		℃			(%)
A2	200	49	289.5	71	13	26.6	1.92(42)	1.040	2.880
A3	200	69	273.3	96	13	25.4	1.92(34)	1.260	2.431
A4	200	99	297.3	148	14	26.9	1.68(19)	1.085	2.872
A5	200	149	280.3	210	14	27.3	1.86(11)	1.328	2.440
C2a	200	161	267.5	217	13	26.5	1.14(9)	1.017	2.262
A6	200	218	288.2	316	18	26.9	1.15(5)	1.099	2.050
C4d	200	292	245.5	365	14	26.9	3.47(9)	1.184	1.475
B7a	200	305	248.4	382	14	26.6	1.83(5)	1.364	1.560
C5b	200	357	241.2	436	14	27.3	2.93(7)	1.354	1.347
C6c	200	423	258.5	549	18	26.9	1.20(2)	1.048	1.436
C6d	200	468	245.6	588	18	26.9	4.78(9)	1.270	1.148
A9	200	501	236.0	594	16	24.7	1.91(2)	1.117	1.040
C8a	200	581	233.2	680	15	26.4	0.65(1)	1.104	1.029
C8b	200	633	222.7	707	15	26.4	0.80(1)	1.526	0.719
C8c	200	658	237.7	782	15	26.4	0.	1.223	1.158
C9b	200	722	229.0	830	16	24.7	0.76(1)	1.164	0.850
C11a	200	840	215.9	915	15	28.5	1.85(2)	2.227	0.511
C11c	200	952	215.3	1035	15	28.5	2.40(2)	2.363	0.493

* A, B and C designate the small, middle and large size groups, respectively when feeding experiment was first started in April 1987, and the numericals mean time sequenses thereafter until October 1987. Small letters a, b and c designate each lot in a given time period. For the smallest intial size group (A), only one lot of experiment was conducted throughout the experimental periods.

Summarized results for the best grown lots were prepared (Tables 3 and 4 and Figs. 2 and 5) to see the differences of performances between for all groups and for best grown groups. Actually some farmers select only well growing groups for the ongrowing purpose and discard the other poor growing ones.

It was calculated that the best grown groups required only 192 days (Table 6) instead of 223 days for whole (Table 5) from 50 g to 1,000 g in concnete tanks, and 227 days (Table 6) instead of 302 days (Table 6) from 10 g to 800 g in the glass aquariums. Therefore It will be much more economical if selected bigger ones are reared from the early stage of tilapia growth provided that tilapia seeds are readily available in quantity. Actually a couple of millions of tilapia fry can be produced annually in about 600 m^2 area if proper water system is prepared based on the experiences gained here. Nevertheless it is clear that even if the all specimens of any siblings belonging to this strain are grown in the present water system, it seems to be feasible in the present econimic situation in Korea.

Table 4. Growth and feed conversion efficiency of the 17 best grown lots of *Oreochromis niloticus* among all the 109 experimental lots in all size groups in the glass aquariums

Group* and time sequence	Initial		Final		Days fed	Water temp.	Mortality kg(No.)	Feed conversion	Daily growth rate
	Total (kg)	Mean (g)	Total (kg)	Mean (g)		℃			(%)
A1b	15.0	8	25.6	13	15	26.0	0.03(4)	0.858	3.628
A2a	15.0	12	25.8	20	14	26.3	0.06(4)	0.992	3.950
A3c	15.0	21	23.1	33	13	26.4	0.22(11)	1.081	3.377
A4b	15.0	42	20.0	57	11	25.8	0.22(6)	1.084	2.362
B2b	15.0	67	20.8	94	14	26.3	0.09(2)	1.164	2.362
B2a	15.0	71	20.9	99	14	26.3	0.06(1)	1.142	2.398
A7b	10.0	102	14.4	148	17	25.2	0.11(1)	1.006	2.168
C3a	15.0	170	18.7	213	13	26.4	0	1.078	1.710
B7a	10.0	222	12.5	284	17	25.2	0.09(1)	1.142	1.321
A11b	15.0	268	20.0	357	18	25.1	0	0.964	1.611
B8a	10.0	303	11.8	358	14	26.2	0	1.072	1.189
B11c	15.0	395	19.0	500	18	25.1	0	0.965	1.276
C7b	10.0	417	12.4	517	17	25.2	0	1.192	1.273
C8a	10.0	455	11.7	532	14	26.2	0	1.059	1.128
C11a	15.0	577	18.6	715	18	25.1	0	0.929	1.202
C11b	15.0	625	17.8	746	18	25.1	0	1.134	0.987
C12a	15.0	750	16.4	820	15	28.5	0	2.136	0.597

*Remarks are the same as in Table 3.

Table 5. Time required for the growth of tilapia calculated from the equations in Figs. 1 and 4 which were plotted from the original data.

Initial Fish size (g)	Concrete tanks		Glass aquariums	
	Daily growth rate (%)	Time required to reach next size (day)	Daily growth rate (%)	Time required to reach next size (day)
10	–	–	3.2392	21.7
20	–	–	2.5328	36.6
50	3.2887	21.4	1.8297	38.2
100	2.2166	18.5	1.4307	28.5
150	1.7597	16.5	1.2389	23.4
200	1.4939	27.3	1.1189	36.4
300	1.1860	24.4	0.9687	29.8
400	1.0069	22.3	0.8747	25.6
500	0.8868	20.7	0.8081	22.7
600	0.7993	19.4	0.7575	20.4
700	0.7322	18.3	0.7172	18.7
800	0.6786	17.4	–	–
900	0.6346	16.7	–	–
1,000				
Total time (days)		222.9		302.0

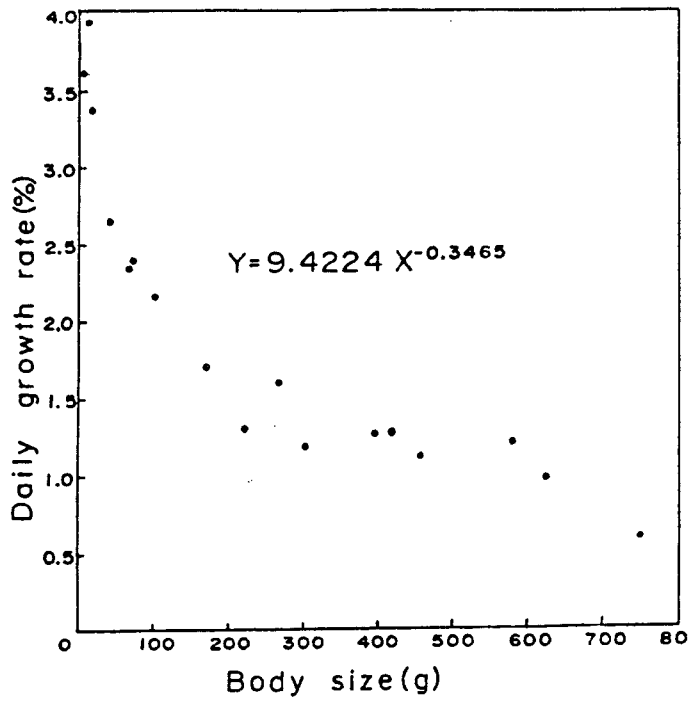

Fig. 6. Growth rates of the 17 best grown lots among all the 109 experimental lots in glass aquariums.

Table 6. Time required for the growth of tilapia calculated from the equations of the best grown groups in Figs. 3 and 6.

Initial Fish size (g)	Concrete tanks		Glass aquariums	
	Daily growth rate (%)	Time required to reach next size (day)	Daily growth rate (%)	Time required to reach next size (day)
10	–	–	4.2428	16.7
20	–	–	3.3369	27.9
50	3.8591	18.3	2.4292	28.9
100	2.5923	15.8	1.9105	21.4
150	2.0541	14.1	1.6601	17.5
200	1.7414	23.5	1.5026	27.2
300	1.3798	21.0	1.3056	22.2
400	1.1698	19.2	1.1818	19.0
500	1.0291	17.8	1.0938	16.8
600	0.9269	16.7	1.0269	15.1
700	0.8484	15.8	0.9734	13.8
800	0.7858	15.0	–	–
900	0.7343	14.4	–	–
1,000				
Total time (days)		191.6		226.5

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