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A Supplementary Feed Design for Mullet Pen Culture in Tongatapu Island, Kingdom of Tonga

II. Elementary study of feed composed of local products for mullet, *Liza macrolepis* and *Mugil Cephalus*

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Abstract

A series of mullet feeding experiments were carried out to determine supplementary feed for mullet extensive culture. Two series of feeding experiments were conducted under laboratory conditions, and one under penculture conditions.

An experimental feed composed of yam, copra meal and tuna meat was fed to *Liza macrolepis*. This feed had a protein content of 4.2%. The relationship between daily rate of feeding (f) and daily rate of growth (r) was presented by the formula r = 0.04251f - 0.002926 and the rate of feeding for maintenance of the body weight was m = 0.06883. The daily cost to feed this diet to maintain the body weight of mullets of 100g, was estimated at 0.34 seniti. The fish lost 0.29% of body weight each day under the condition of starvation during the experimental period.

A second diet composed of yam, copra meal and brown fishmeal, combined to give a protein content of 18.3%, was again fed to *Liza macrolepis*. The relationship between (f) and (r) equated to the formula r = 0.1021f - 0.002926 and the daily rate of feeding for maintenance of the body weight was found to be m = 0.0287 for this feed. The daily cost to feed this diet to maintain the body weight of mullets at 100 g was estimated at 0.195 seniti.

Further, Grey Mullet, *Mugil cephalus*, feeding experiments were carried out under small scale penculture conditions. The relationship between daily rate of feeding (f) and daily rate of growth (r) was presented by the

formula r = 0.1393f - 0.0042 and the daily rate of feeding for maintenance of the body weight was found to be m = 0.03015, when fed the same experimental feed as in the first experiment. The daily cost to maintain 100 g of mullet weight was estimated at 0.151 seniti. These results show that *M. cephalus* reared in a pen grew approximately three times faster than the mullet *Liza macrolepis* reared under laboratory conditions. With one daily satiation feeding of this diet, the grey mullet population could maintain their body weight under penculture condition suggesting a positive effect of pen conditions on the growth of grey mullet.

Profits from grey mullet, *Mugil cephalus*, penculture, in which the fish are fed daily the artificially composed feed with an amount calculated to maintain the required body weight/day, are estimated in this report. These potential gross profits are T$179, T$256.3, T$359.2 and T$462.2, when one kg of fingerlings with a mean weight of 0.66g are released into the pen and after one year reach 70g, 100g, 140g and 180g per individual respectively, depending on the productivity of the penculture site.

Introduction

This study was undertaken as the first step in determining supplementary feed for mullet extensive culture in Tonga using penculture . The site of these penculture trials was the coastal zone of Fanga'uta Lagoon. This is one of the projects of JICA fisheries in cooperation with the Ministry of Fisheries, the Kingdom of Tonga.

The supplementary feed refers to low cost feed, made predominately of low cost local products which are in constant supply. This feed should serve to maintain, at least, the body weight of the fish population in the pen by one daily feed of adequate quantities. This might be less than the satiation amount so the fish can also feed off the natural foods that they encounter in the interior of the pen (Ishiwata, 1969). Yam and coconut were selected as main components of the feed, which are abundant in this area and available all year round at a low price.

As a source of protein for the diet used in the first and third

experiments, local tuna flesh was used at a price of T$3/kg. Brown fishmeal, generally imported as feed for domestic animals or for agricultural fertilizer, can be obtained for a relatively low cost of one T$/kg[1]. This was used as the main animal protein source for the second mullet experiment and was combined with the local products; yam and copra meal.

A further experiment was conducted to compare the growth rate of *L. macrolepis* and grey mullet, *mugil cephalus*.

Materials and Methods

EXPERIMENT 1.

Feed

The local product yam and coconut (copra) meal were selected as the main components of the feed. Tuna meat was selected as the animal protein source and was rationed so that the estimated total crude protein rate of the diet was approximately 4%. The yam, copra meal and tuna meat were combined in proportions of 47.9%, 43.8% and 7.9% respectively. The price for 1 kg of the diet was about T$0.5. The price of each material obtained in the local market, the composition of the experimental feed and estimated protein level are presented in Table 1.

Yam was grated manually and the coconut embryo was squeezed by juicer eliminating the majority of the liquid content (approximately 29 % of the total wet weight of embryo), the copra meal was processed to an extremely fine meal using a domestic food processor, National MK-K 55.

The tuna meat was processed by food processor until converted to a paste. A small quantity of salt was added into it. All of the materials were then mixed in a rice cake making machine (National SD-M1860) for 10 minutes and steamed for 8 minutes.

1 T$1.00 = US$0.77 (100 seniti/T$)

Table 1. Local market price of each item in Nuku'alofa and composition and estimated protein level of the diet for Exp. 1.

Item	Price (seniti/g)	Weight (g)	Protein (%)[1] content/item	Price/Item (seniti)	Proportion of Feed (%)	Protein content (%)
Yam	0.042	47.4	2	1.9908	47.9	1.0
Copra meal	0.013	43.4	2.8[2]	0.5642	43.8	1.2
Tuna	0.3	7.8	25	2.34	7.9	2.0
Flour	0.125	0.2	12	0.025	0.2	0.02
Salt	0.317	0.2	0	0.073	0.2	0.00
Total	-	99.0	-	4.99	100.0	4.2
				Total Price		
				seniti/kg		50.42

1) South Pacific Commission, 1983 and Suehiro *et al.*, 1973.
2) Calculated with a loss of 29% occuring when coconut flesh was passed through the juicer.

The Fish

Liza macrolepis were used in this experiment and were captured ten days prior to the beginning of the feeding experiment. They were caught in the coastal zone near Sopu on Tongatapu Island using a tidal set net and transported to the fisheries laboratory in three containers each with 100 L capacity .

The fish were starved for five days and from the 6th day were conditioned to the experimental diet for 5 days. They were fed their diets from a 2 mm meshed net bag, crushed slightly by fingers and thrown into the tank.

When the fish were well accustomed to the diet bag as the feeding method, and began to attack it with strong activity, they were given 24 hours starvation, then they were lightly anaesthe zed by eugenol, 200 ppm, then weighed, measured and distributed into four experimental lots. The same process of measurement was used at the end of the experiment. The fish weight composition of each lot were controlled so as to be approximately equal by distributing them into each lot depending on the weight obtained in the measurement, making a density from 49 to 53 fish/lot.

Rearing method

The fish with initial mean weight 10.7, 10.5, 10.3 and 10.8g were distributed into four identical octagonal concrete tanks with 7 m^3 water capacity, corresponding to experimental Lot No.s 1, 2, 3 and 4 respectively, and reared for an experimental period of 14 days.

The fish were fed once daily. Experimental feed was: one satiation, 2/3 satiation, 1/3 satiation and nil in Lot No.s 1, 2, 3, and 4 respectively. The satiation amount is the amount consumed until the fish lose interest to feed at each feeding. This value was observed daily in Lot No. 1 and the amount for Lot No. 2 and No. 3 determined accordingly. An open circuit system with a daily water changing rate of 1.5 cycles was utilised for the rearing. Temperature and salinity of the sea water used fluctuated during the experimental period between 23.5°C to 25.2°C and 36.0‰ to 39.0‰ respectively.

Fish that died during the experimental period were weighed; the weight values and total number thereof were deducted from the initial total fish weight and initial total number respectively for each tank.

EXPERIMENT 2.

Feed

A diet composed of yam, copra meal and brown fishmeal in proportions of 38.2%, 19.1% and 33.5% respectively was prepared for this experiment. The fish meal was added to the feed to increase the total crude protein content to approximately 18 %. The cost of this feed was 68 seniti/kg. The price of each material, the composition of the experimental feed and estimated protein levels are presented in Table 2. The yam and coconut embryo were prepared as in Exp. 1.

Table 2. Local market price of each item in Nuku'alofa and composition and estimated protein level of the diet for Exp. 2.

Item	Price (seniti/g)	Weight (g)	Protein (%)*1) content/item	Price/Item (seniti)	Proportion of Feed (%)	Protein content (%)
Yam	0.042	84.2	2	3.5	38.2	0.8
Copra meal	0.013	42.1	2.8*2)	0.5	19.1	0.8
Fish meal	0.1	73.7	50	7.4	33.5	16.7
Binder	11	0.25	0	2.8	0.1	0.0
Vitamin	20	0.04	0	0.7	0.0	0
Water	0	20	0	0.0	9.1	0
Total	-	220.29	-	14.9	90.9	18.3
				Total Price seniti/kg		67.8

*1) South Pacific Commission, 1983 and Suehiro *et al.*, 1973.
*2) Calculated with a loss of 29% occuring when coconut flesh passed through the juicer.

The fish

One hundred and fifty-one mullets, *Liza macrolepis* (Smith) were used in this experiment which was started immediately after finishing Exp. 1, in which the same mullet population had been used. The results of the final measurement data of Exp. 1 served as the initial data for this experiment.

After measuring the fish, with initial mean weights: 10.3, 10.1 and 10.8 g, they were returned again into three tanks, forming Lot No.s 1, 2 and 3 respectively. These Lot No.s in Exp. 1 corresponded to the groups of 2/3 satiation, 1/3 satiation and starvation respectively, but were designated in this experiment as the groups fed with one daily satiation, 2/3 satiation and 1/3 satiation respectively during a 13 day period. The satiation amount was observed daily in lot No. 1 and the other two lots fed accordingly.

The fish weight composition of each lot were arranged to near equal by distributing them into the lots depending on the weight

values obtained in the measurement. The fish density varied from 49 to 51 fish/lot.

The fish were conditioned to the new diet in the experimental lots during the first days of the experiment. To feed, the food was crushed slightly by fingers resulting in small flat chips (1 cm^2 approximately), these were thrown into the tanks little by little until their feeding activity became lower, which was considered as the satiation point. Within a few days from the start the fish began to gather to attack and eat well.

One day before the start of the experiment and the day following the completion of the experiment, the fish were starved and then anaesthetized by eugenol (200 ppm). Their total length, standard length and folk length were measured, as well as their net body weight carefully avoiding the humidity from their body surface by semi-dry gauze.

Rearing method

The tanks and water exchange rate used in Experiment 1. was maintained. The temperature and salinity of the sea water used fluctuated during the experimental period between 23.6 °C and 27.5 °C and from 34.0‰ to 39.0‰ respectively.

Fish thad died during the experimental period were treated as in Exp. 1.

EXPERIMENT 3.

Feed

The local products; yam, coconut (copra) meal and tuna meat were prepared using the same methods and compositions as in Exp. 1, providing a diet with around 4.2% protein content and a price of approximately 50 seniti/kg. The price of each material,

the composition of the experimental feed, and estimated protein levels were presented previously in Table 1.

The Fish

Seventy-nine grey mullets, *Mugil cephalus*, captured by set net at the end of October, 1995 were used in this experiment. The mullet were caught just off the shore of Sopu, Tongatapu, Kingdom of Tonga. They were conditioned to the experimental diet for five days and were then starved for one day before being measured using the methods reported in Exp. 1. As soon as the measurements were finished the fish were transported to Fanga'uta Lagoon. The mullet were placed into four small scale pens, measuring 2m x 2 m x 1.7m, resulting in an initial density of 4.9 fish/m^2 and approximately 90 g in population weight/m^2. The four pens were identified as feeding experimental Lot No.s 1, 2, 3 and 4 and the fish in each pen were fed an amount of feed equal to one daily satiation, 2/3 satiation, 1/3 satiation and nil respectively.

The fish were fed daily except Sundays and were harvested on the 29th day after beginning the experiment. Before measurement, they were starved for one day. The diet was crushed slightly by fingers and little by little thrown into the pen to feed the mullet. The physical parameters, salinity and water temperature were not measured, however the data for the same season in 1994 was used as a reference and is as follows: salinity ranged from 22.6‰ to 32.4‰ and water temperature from 22.8°C to 27.9°C.

The number of fish reduced due to unknown causes in some lots, especially in Lot No. 2, where the final number of fish was half of the initial number. The experiment was abandoned for this lot and the data discarded, however, in the other lots, only three to four individuals disappeared and the total body weight of the lot was adjusted accordingly. This was done by estimating the missing individuals measurements such as total length, standard

length, folk length and body weight from those of the remaining fish and then deducting this weight value from the initial total body weight of the lot.

Results

EXPERIMENT 1.

The weight composition range, mean body weight, variance and standard deviation of each experimental lot are presented in the Table 3 and Figure 1.

The calculated values of daily rate of feeding (f), daily rate of growth (r), gross efficiency (r/f) and net efficiency (r/f - m) when fed the experimental diet are presented in Table 4. As the value of (f) increased from 0.001, 0.017, 0.035 and 0.053, the daily rate of growth increased to the order of -0.0029, -0.0022, -0.0014 and -0.00072 respectively.

The relationship between daily rate of feeding (f) and daily rate of growth (r) fits well to the linear regression with the formula (1) indicated below and shown in Figure 2.

$$r = 0.04251f - 0.002926 \text{ -------(1)}$$

The value of (f) obtained from the formula (1), substituting 0 for (r), became 0.06883, 6.883% of the body weight, which represents the amount of this diet needed to maintain the body weight. Therefore the cost of this diet to maintain the total mullet body weight of 100 g for a day can be calculated as follows:

$$100 \text{ (g)} \times 0.06883 \times 0.05(\text{seniti/g}) = 0.34 \text{ (seniti/day)---(2)}$$

The values of net efficiency in each experimental lot were calculated substituting this value for (m) in (r/f - m) in Table 4 obtaining the values 0.045673, 0.042056, 0.042231 and 0.042574 in

the composition of the experimental feed, and estimated protein levels were presented previously in Table 1.

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The fish were fed daily except Sundays and were harvested on the 29th day after beginning the experiment. Before measurement, they were starved for one day. The diet was crushed slightly by fingers and little by little thrown into the pen to feed the mullet. The physical parameters, salinity and water temperature were not measured, however the data for the same season in 1994 was used as a reference and is as follows: salinity ranged from 22.6‰ to 32.4‰ and water temperature from 22.8°C to 27.9°C.

The number of fish reduced due to unknown causes in some lots, especially in Lot No. 2, where the final number of fish was half of the initial number. The experiment was abandoned for this lot and the data discarded, however, in the other lots, only three to four individuals disappeared and the total body weight of the lot was adjusted accordingly. This was done by estimating the missing individuals measurements such as total length, standard

$$r = 1.4393 \times f^2 + 0.0652 f - 0.0042 \quad \text{-------} \quad (1)$$

As it is known that this relationship can be expressed by a linear function, the values obtained from Lot No.s 2 and 3 appear to be non-normal values obtained from a fish population which has a low efficiency to assimilate the feed.

The value of (r) obtained from Lot No. 1, the group of one daily satiation in this experiment was suggested to be the most reliable one amongst the three lots. The linear regression, using this value (f) = 0.047 and (r) = 0.0019, and the values (f) = 0.001 and (r) = -0.0029 obtained from the starvation group in Exp. 1, results in formula (2) below and is shown in Figure 5.

$$r = 0.1021 \times f - 0.002926 \quad \text{----------} \quad (2)$$

The daily rate of feeding for maintenance of body weight is calculated by substituting 0 for (r) resulting in the value (f) = 0.0287.

The value of net efficiency can be calculated substituting this value for (m) in the formula N = r/f - m of Table 6, resulting in the value N = 0.1038 for Lot No. 1.

The cost of this diet to maintain the population weight of 100g for a day under laboratory conditions can be calculated as follows:

$$100\ (g) \times 0.0287 \times 0.0678(\text{seniti/g}) = 0.195\ (\text{seniti/day})$$

EXPERIMENT 3.

The calculated values of daily rate of feeding (f), daily rate of growth (r), gross efficiency (r/f) and net efficiency N = (r/f - m) when fed the Experimental Diet are presented in Table 7.

As (f) increased in the order of 0, 0.012 and 0.0303, the daily rate

of growth increased to -0.0042, -0.0026 and 0.000047.

The relationship between daily rate of feeding (f) and daily rate of growth (r) fits well to the linear regression with the formula (1) indicated below and shown in Figure 6.

$$r = 0.1393 \times f - 0.0042 \text{ ----------(1)}$$

Substituting 0 for (r), the value of (f) in formula (1) becomes 0.03015 or 3.015% of the body weight, which represents the amount of this diet needed to maintain the body weight. Therefore the cost of this diet to maintain the total body weight of 100 g for a day can be calculated as follows:

$$100\ (g) \times 0.03015 \times 0.05(\text{seniti}/g) = 0.151(\text{seniti}/\text{day})\text{---(2)}$$

The values of net efficiency in each experimental lot were calculated substituting this value for (m) in (r/f - m) in Table 7, resulting in the values 0.188, 0.1433 and 0.1393 in Lot No.s 1, 3 and 4 respectively with the mean value being 0.1568. Formula (3) was obtained as follows by modifying formula (1).

$$r/f = 0.1393 - 0.0042/f\text{----------(3)}$$

In formula (3), as the value (f) becomes larger, the value r/f approximates its limit value of 0.1393, which should normally approximate the net efficiency values obtained in each lot. In this experiment however, the net efficiency value tended to increase as the daily rate of feeding (f) increased suggesting that the penculture conditions had a positive influence on the growth of the fish.

Discussion

Ogino *et al.* (1980) experimented using carps obtaining the result that to maintain the body weight of each 100 g of carp population,

it needed 0.106 g of good quality protein each day (measured using the diet with 10 % protein content, with BV value 80 and 98 % in digestibility). Ogino also mentioned that this value rises when proteins with lower BV values are used. In Exp. 1, the daily feeding rate of 6.883 % appeared to be the minimum amount for maintenance of body weight, with an estimated protein content of approximately 4.2 % in this feed (Table 1). For the maintenance of body weight of 100 g, around 0.289 g of protein would be required. Sato (1983) mentioned the lack of some amino acids in copra meal such as tryptophan, lysine, methionine and histidine, though it was used as poultry feed mixing 15~30% in with artificial feed.

It is well known the lack of those amino acids in the feed can cause rodosis or stop of growth in fish. Therefore, the negative effect in the body protein assimilation of mullet can be assumed when they are reared under laboratory conditions using well mixed copra meal feed. In natural conditions like pen culture it can be expected that the products like coconuts or other vegetables, when fed to mullet, have the possibility of playing a secondary role to accelerate the growth of the benthic micro fauna and flora which would be used as natural food by mullet. The data obtained in this experiment is hoped to become the basis for feed comparisons for penculture in the near future.

The net efficiency obtained from the starvation lots in Experiment 1 and Exp. 3 were 0.04257 and 0.1393 respectively, with the latter value being 3.27 times larger than the former. As the same diets were used in both experiments, this overwhelming superiority in net efficiency of *M. cephalus* reared in a pen c(ı be due to both this fish's higher ability for protein assimilation when compared with *L. macrolepis* and the positive effect of pen culture conditions for fish rearing. It appears a feasible hypothesis that *M. cephalus* could grow approximately three times faster when reared in a pen than *Liza macrolepis* reared under laboratory conditions.

A consideration of the profitability of mullet penculture using an experimental feed composed principally of fish meal.

In summary, Experiments 1, 2 and 3 of this study yielded the following results:

1. The artificial diet of tuna meat, copra and yam as protein sources could not maintain the body weight of liza with one daily satiation feed (Exp. 1). This feed cost 50.4 seniti/kg. However, it could be suggested that the juveniles of grey mullet could grow three times faster when reared in a pen than liza reared under laboratory conditions, when fed the same diet with one daily satiation in small scale pens (Exp. 3).

2. The artificial diet composed principally of fish meal, costing 67.8 seniti/kg increased the weight of the experimental fish group of liza with one daily satiation under laboratory rearing conditions (Exp. 2)

The following is a discussion on the profitability of grey mullet culture in small scale pens utilising supplementary feed prepared in the laboratory of the Ministry of Fisheries in Tonga.

Nakamura (1949) noted that grey mullet fry would grow from of mean body weight of 0.32 g to 71-76 g in one year when fed only small quantities of feed, and to 187.5 g when reared with abundant quantities of pupa, rice bran, etc.. These were the average values of one years rearing obtained from nine private farms and in the Aichi prefectural experimental station respectively. Nakamura also discussed the annual growth of grey mullet reared in two ponds of 2,640m^2 and 3,960 m^2 with a density of 0.6 to 2 individuals/m^2. The fish were provided with a small quantity of rice bran and attained a final average mean body weight of 116.5 g for both ponds.

In these experiments (1-3) the authors estimated that grey mullet could grow approximately three times faster than liza when fed a

diet composed principally of fish meal. The cost to maintain one kg of body weight/day in fingerling of liza was calculated at 1.95 seniti. Therefore it can be deduced that the cost to maintain 1kg of body weight/day of grey mullet is approximately 0.65 seniti (1/3 of 1.95 seniti for liza).

From the above data, the mean body weight of grey mullet after one year rearing in penculture is expected to be between 70 g and 180 g, depending on feed quantities. The profitability of grey mullet culture in pens is calculated in Table 8. This calculation is based on one kg of seed or 1,515 individuals with mean body weight of 0.66 g as employed in the grey mullet feeding Experiment 4 (Kobayashi *et al.*, 1996). These fry would be released into the pen with a density of two individuals/m^2, with an estimated survival rate of 60 % up until harvest. The mean body weight would increase to between 70 and180 g after one year. The gross profit expected should vary from T$179 to T$462.2 as indicated in Table 8 depending on factors such as: the actual mean body weight at harvest time; the population weight maintained during the year; the cost of the artificial feed, and the amount of fish sold.

The total body weight (kg) to be maintained during a year was expressed here by the gross area between the lines a-b and c-d in Figure 7. The value obtained from this method is expected to be slightly lower than the actual one, as the growth curve would be more logarithmic than linear as assumed here. The total quantity of the diet consumed by the 40 % of the total population which were assumed to have died during the one year culturing period was not allowed for. The cost for construction and maintenance of the pen, wages, transportation etc. were not included in the gross profit indicated in Table 8.

The experimental conditions and results utilised for determining the amount of feed required to maintain one kg of body weight were slightly different to the conditions assumed for this profitability assessment. In the original experiments (Exp. 1 and

Exp. 2) the reliance of the fish on the natural food supply was minimal as a higher fish density was utilised (up to four fish/m^2) with a corresponding population weight of 90 g/m^2. To confirm or otherwise the broad assumptions and values utilised in this assessment it is expected that further experiments for grey mullet juveniles will be undertaken in the future.

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Table 3. The weight range, mean body weight, variance and standard deviation of the fish in each lot in Exp. 1.

Body Weight Range (g)	LOT NO. 1		LOT NO. 2		LOT NO. 3		LOT NO. 4	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
5.0-7.0	4	5	2	3	8	9	3	5
7.0-9.0	18	16	21	19	16	16	20	18
9.0-11.0	9	12	13	14	9	10	11	11
11.0-13.0	6	6	7	6	7	5	6	7
13.0-15.0	5	3	2	3	2	4	5	4
15.0-17.0	5	5	3	3	3	1	0	0
17.0-19.0	0	0	2	2	2	2	3	4
19.0-21.0	0	0	0	0	1	1	1	1
21.0-23.0	0	0	1	1	1	1	1	1
23.0-25.0	1	2	0	0	0	0	1	0
25.0-27.0	1	0	0	0	0	0	0	0
Total	49	49	51	51	49	49	51	51
Mean Body Weight(g)	10.7	10.6	10.5	10.3	10.3	10	10.8	10.4
VARIANCE	17.537	15.554	11.332	10.75	14.922	13.526	15.96	13.976
SD	4.188	3.944	3.366	3.279	3.863	3.678	3.995	3.738

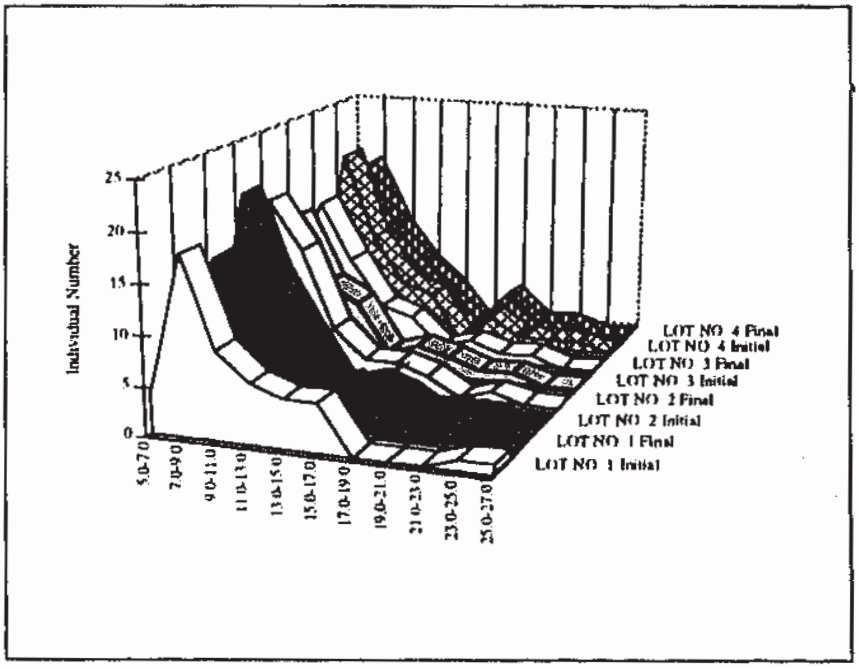

Figure 1. Weight composition of fish in each lot in Exp. 1.

Table 4. Calculated value of daily rate of feed (f), daily rate of growth (r), gross efficiency and net efficiency when fed Exp. Diet 1 (Lot No. 1-3) and starvation (Lot No. 4).

Lot No.	Initial body Weight(g) W0	Individual number N0	Mean body weight(g) W0/N0	Final body Weight(g) Wt	Individual number Nt	Mean body weight(g) Wt/Nt	Total food intake (g) F	Daily rate of feeding f*1	Daily rate of growth r*2	Gross efficiency r/f	Net efficiency r/f - m*3	Experimental period T (days)
1	525.1	49	10.7	519.8	49	10.6	387.4	0.053	-0.00072	-0.01368	0.04567262	14
2	535.1	51	10.5	524.4	51	10.3	256.1	0.035	-0.0014	-0.04179	0.04205626	14
3	506.8	49	10.3	491.6	49	10.0	121.1	0.017	-0.0022	-0.12550	0.04223123	14
4	551.2	51	10.8	529.3	51	10.4	6.2	0.001	-0.0029	-3.53226	0.04257423	14

*1: f=F/T(W0+Wt)/2. *2: r=(Wt-W0)/T(W0+Wt)/2. *3: m: Daily rate of feedning for weight maintenance.

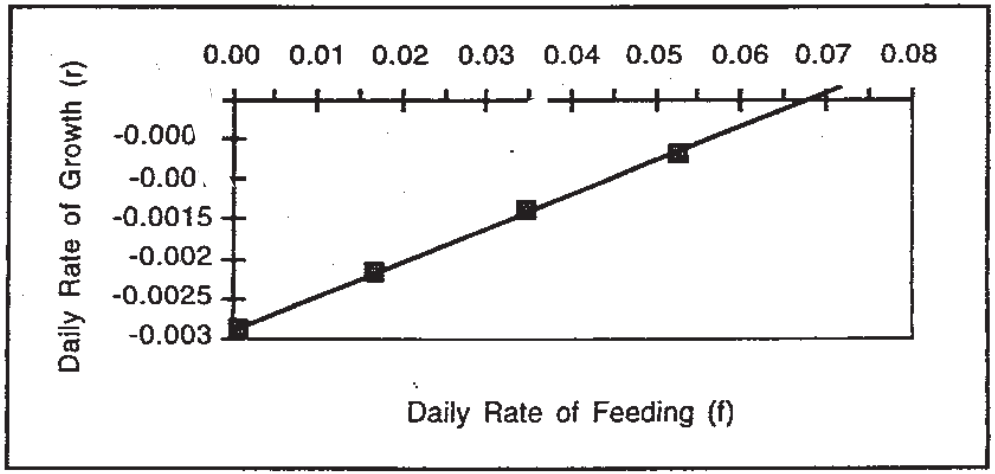

Figure 2. Relationship between daily rate of feeding (f) and daily rate of growth (r) in Exp. 1.

Table 5. The range of weights, mean body weight, variance and standard deviation of the fish in each lot in Exp. 2.

Body Weight Range (g)	LOT NO. 1		LOT NO. 2		LOT NO. 3	
	Initial	Final	Initial	Final	Initial	Final
5.0-7.0	3	1	9	9	5	5
7.0-9.0	19	19	16	15	18	17
9.0-11.0	14	12	10	9	11	11
11.0-13.0	6	9	5	5	7	6
13.0-15.0	3	3	4	4	4	4
15.0-17.0	3	3	1	1	0	1
17.0-19.0	2	2	2	3	4	2
19.0-21.0	0	0	1	0	1	2
21.0-23.0	1	1	1	1	1	1
Total	51	50	49	47	51	49
Mean Body Weight(g)	10.3	10.6	10.1	10	10.8	10.4
Variance	10.75	10.30	13.53	13.34	13.98	14.67
SD	3.2787	3.209	3.6783	3.6519	3.739	3.8296

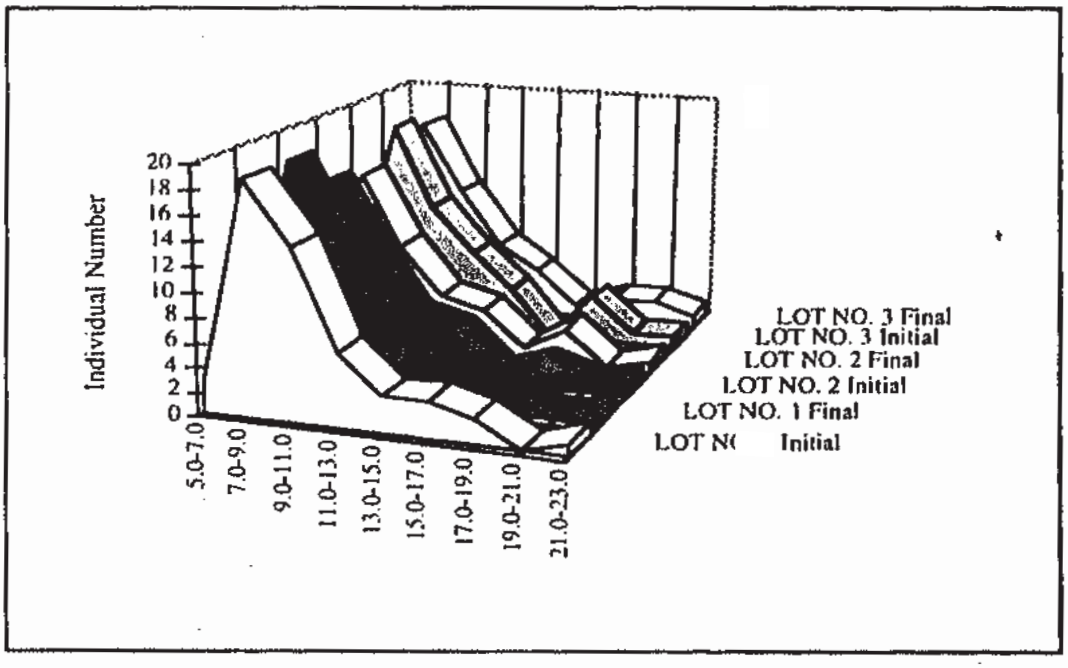

Figure 3. Weight composition of fish in each lot in Exp 2.

Table 4. Calculated value of daily rate of feed (f), daily rate of growth (r), gross efficiency and net efficiency when fed Exp. Diet 1 (Lot No. 1-3) and starvation (Lot No. 4).

Lot No.	Initial body Weight(g) W0	Individual number N0	Mean body weight(g) W0/N0	Final body Weight(g) Wt	Individual number Nt	Mean body weight(g) Wt/Nt	Total food intake (g) F	Daily rate of feeding f*1	Daily rate of growth r*2	Gross efficiency r/f	Net efficiency r/f - m*3	Experimental period T (days)
1	525.1	49	10.7	519.8	49	10.6	387.4	0.053	-0.00072	-0.01368	0.04567262	14
2	535.1	51	10.5	524.4	51	10.3	256.1	0.035	-0.0014	-0.04179	0.04205626	14
3	506.8	49	10.3	491.6	49	10.0	121.1	0.017	-0.0022	-0.12550	0.04223123	14
4	551.2	51	10.8	529.3	51	10.4	6.2	0.001	-0.0029	-3.53226	0.04257423	14

*1: f=F/T(W0+Wt)/2. *2: r=(Wt-W0)/T(W0+Wt)/2. *3: m: Daily rate of feedning for weight maintenance.

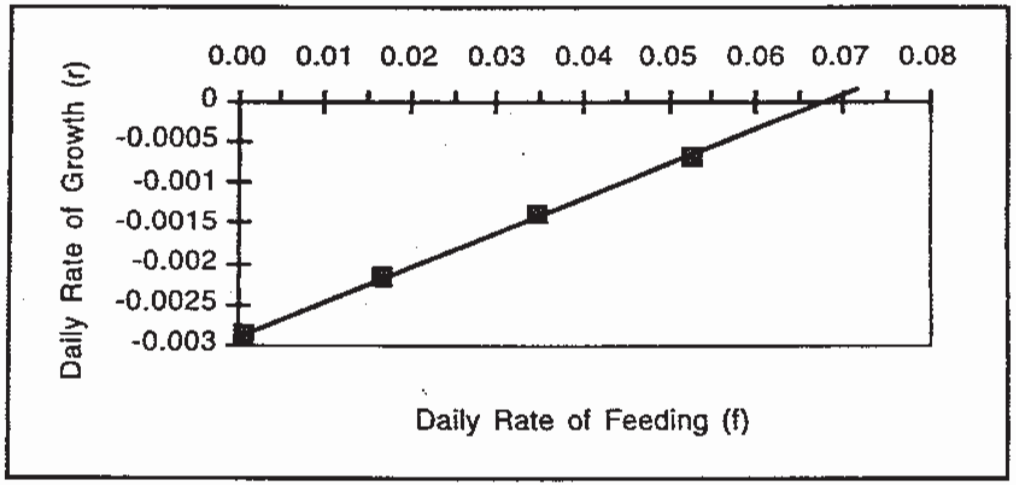

Figure 2. Relationship between daily rate of feeding (f) and daily rate of growth (r) in Exp. 1.

Table 5. The range of weights, mean body weight, variance and standard deviation of the fish in each lot in Exp. 2.

Body Weight Range (g)	LOT NO. 1		LOT NO. 2		LOT NO. 3	
	Initial	Final	Initial	Final	Initial	Final
5.0-7.0	3	1	9	9	5	5
7.0-9.0	19	19	16	15	18	17
9.0-11.0	14	12	10	9	11	11
11.0-13.0	6	9	5	5	7	6
13.0-15.0	3	3	4	4	4	4
15.0-17.0	3	3	1	1	0	1
17.0-19.0	2	2	2	3	4	2
19.0-21.0	0	0	1	0	1	2
21.0-23.0	1	1	1	1	1	1
Total	51	50	49	47	51	49
Mean Body Weight(g)	10.3	10.6	10.1	10	10.8	10.4
Variance	10.75	10.30	13.53	13.34	13.98	14.67
SD	3.2787	3.209	3.6783	3.6519	3.739	3.8296

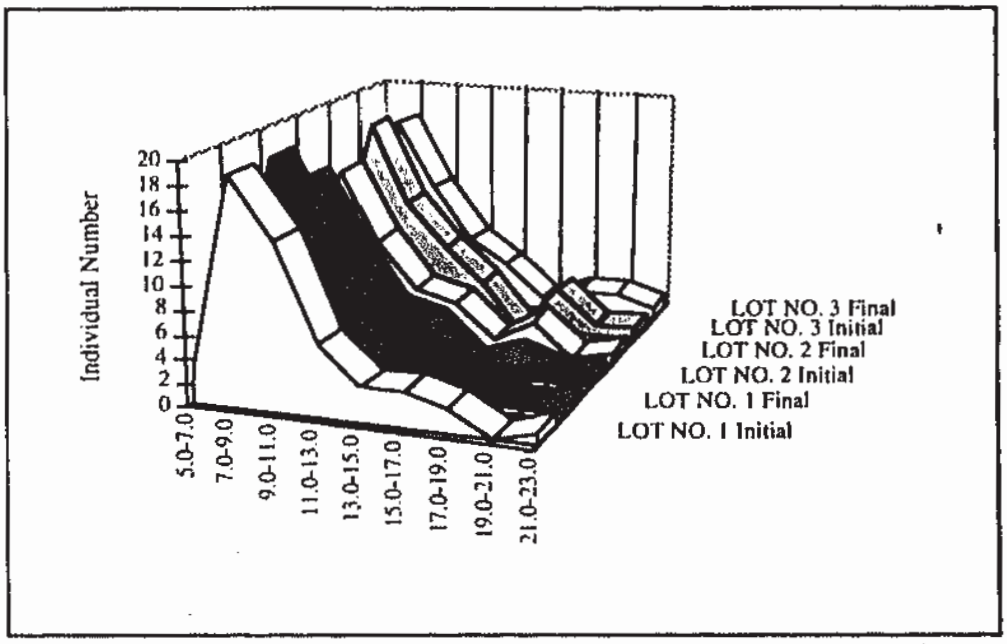

Figure 3. Weight composition of fish in each lot in Exp 2.

Table 6. Calculated value of daily rate of feed (f), daily rate of growth (r), gross efficiency and net efficiency when fed Exp. Diet 2 (Lot No. 1-3).

Lot No.	Initial body Weight(g) W0	Individual number N0	Mean body weight(g) W0/N0	Final body Weight(g) Wt	Individual number Nt	Mean body weight(g) Wt/Nt	Total food intake (g) F	Daily rate of feeding f*1	Daily rate of growth r*2	Gross efficiency r/f	Net efficiency r/f - m*3	Experiment period T (days)
1	516.5	50	10.3	529.5	50	10.6	316.2	0.047	0.0019	0.04111	0.1038	13
2	474.9	47	10.1	469.5	47	10.0	188.3	0.031	-0.0009	-0.02868	-	13
3	529.3	49	10.8	510.3	49	10.4	108.8	0.016	-0.0028	-0.17463	-	13

*1: f=F/T(W0+Wt)/2. *2: r=(Wt-W0)/T(W0+Wt)/2. *3: m: Daily rate of feeding for weight maintenance.

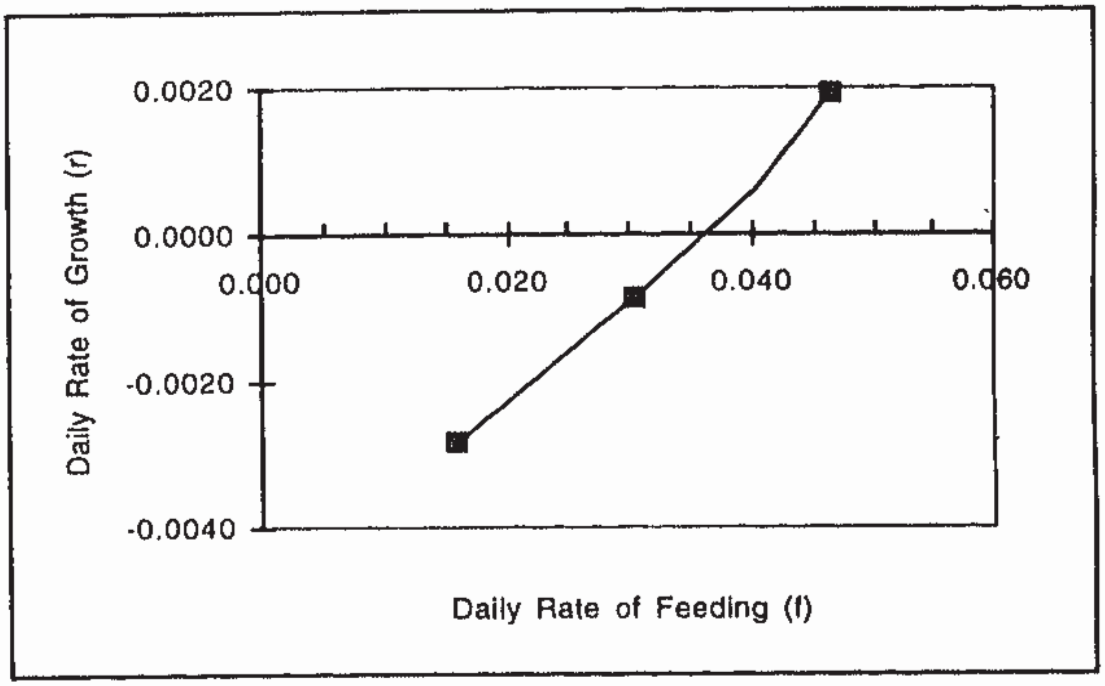

Figure 4. Relationship between daily rate of feeding (f) and daily rate of growth (r) in Exp. 2.

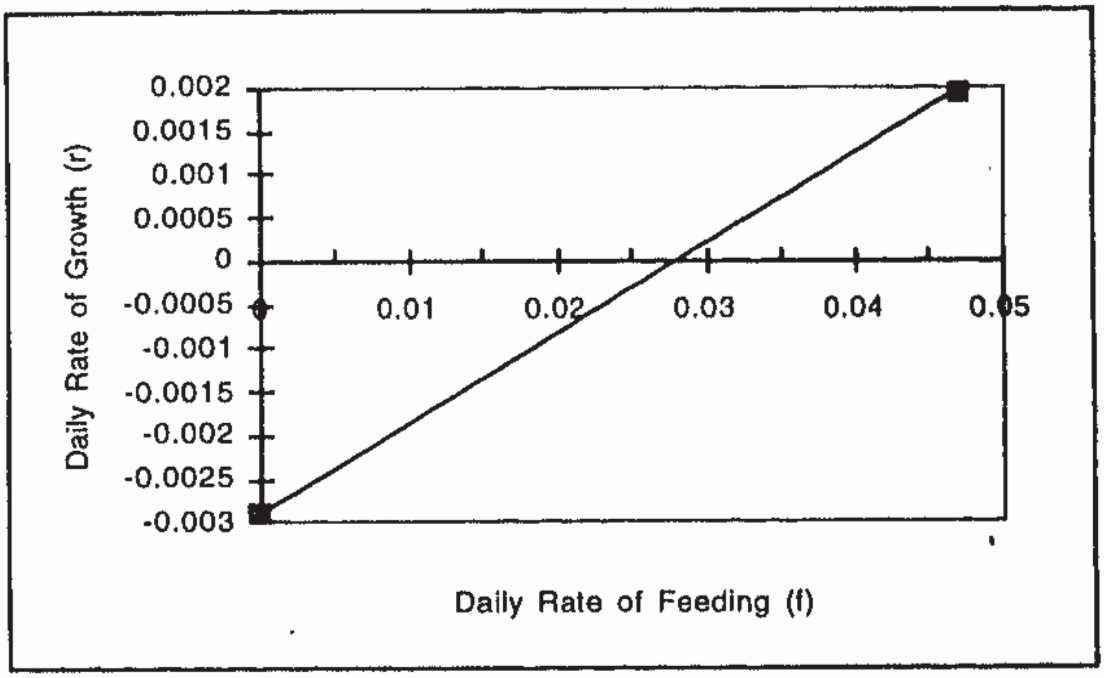

Figure 5. Relationship between daily rate of feeding (g) and daily rate of growth (r), when -0.0029 was used as the value of daily growth rate in starvation and 0.0019 as its value in satiation in Exp 2.

Table 7. Calculated value of daily rate of feed (f), daily rate of growth (r), gross efficiency and net efficiency when fed Exp. Diet 3 (Lot No. 1, 3 and 4).

Lot No.	Initial body Weight(g) W0	Individual number N0	Mean body weight(g) W0/N0	Final body Weight(g) Wt	Individual number Nt	Mean body weight(g) Wt/Nt	Total food intake (g) F	Daily rate of feeding f*1	Daily rate of growth r*2	Gross efficiency r/f	Net efficiency r/f - m*3	Experimental period T (days)
1	377	19	19.8	377.5	19	19.9	320.9	0.0304	0.000047	0.00156	0.1880	28
3	337.3	15	22.5	314	15	20.9	109.1	0.0120	-0.0026	-0.21357	0.1433	28
4	365.4	14	26.1	325	14	23.2	0	0.0000	-0.0042	-	0.1393	28

*1: f=F/T(W0+Wt)/2. *2: r=(Wt-W0)/T(W0+Wt)/2. *3: m: Daily rate of feeding for weight maintenance.

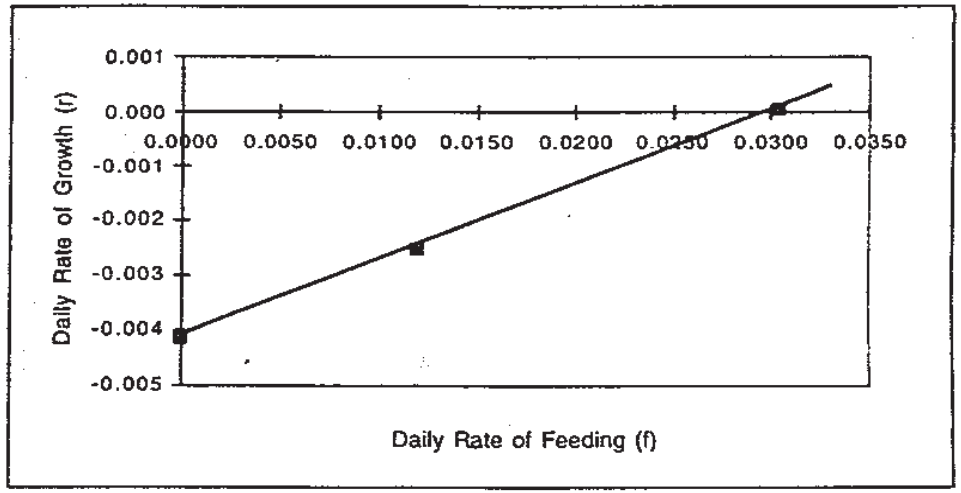

Figure 6. Relationship between daily rate of feeding (f) and daily rate of growth (r) when fed experimental supplementary feed composed of local products, under penculture conditions, in Exp 3.

Table 8. Expected profits on grey mullet pen culture

(1)	Fish number to release(Indiv.)	1,515 (1 kg)			
(2)	Density (Indiv./m2)	0.6-2.0/m2			
(3)	year(%)	60%			
(4)	Fish number to be harvested	909			
(5)	Final body weight (g)/indiv.	70	100	140	180
(6)	Harvested quantity (kg)	63.63	90.9	127.26	163.62
(7)	Population weight to be maintained during a year (kg)	11,795.0	16,771.8	23,407.5	30,043.2
(8)	Cost to maintain 1kg of population weight per day (seniti)	0.64	0.64	0.64	0.64
(9)	Cost of the diet to maintain the population weight during one year (T$)	75.5	107.3	149.8	192.3
(10)	Mullet price(T$) in Nuku'alofa	4	4	4	4
(11)	The amount sold (T$)	254.52	363.6	509.04	654.48
(12)	The gross profit expected (T$)	179.0	256.3	359.2	462.2

(4) :(1) x (3)/100
(5) :Depending on the productivity of the culture site
(6) :(5) x (4)/1,000
(7) : S=[(6)+1(kg)] x 365/2
(8) :1.95 seniti/ 3
(9) :(8) x (7)
(10) :Reported by Fale et al, 1995
(11) :(10) x (6)
(12) :(11)-(9)

Figure 7. Sum total of the body weight (kg) to be maitained during the year expressed by the gross area between the lines a-b and c-d, and b indicates the quantity harvested at the end of one year rearing.