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Determination of Optimum Feeding Rate Expressed as Percent of Body Weight in Persian Sturgeon, *Acipenser persicus*

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Abstract: The present study was conducted to determine the best feeding rates expressed as percent of body weight in Persian sturgeon fingerlings at different body weights. Eighteen fiberglass tanks each holding 30 fingerlings with an average initial body weight of 19.45 ± 0.5 g were used in this experiment. Six different feeding trials (1, 2, 3, 4, 5 and 6 percent of body weight) were employed and each trial was run in three replicates through a period of 60 days (4 periods of 15 days).
The results were analyzed using Statgragh software and compared using Duncan test.
The optimum recommended feeding rate was 4 percent of body weight for an increase of body weight from 19.5 to 31g and 3 percent of body weight for an increase of body weight from 33 to 47g. For an increase in body weight from 47 to 90g the recommended feeding rate was 3 percent of body weight. The recommended doses are subject to alteration with variation in water temperature.

KEY WORDS : Persian sturgeon, *Acipenser persicus*, Feeding, Body Weight

Introduction

Sturgeons are the most important and lucrative fishes in the world that are found mainly in the Caspian Sea. More than 90 % of the caviar throughout the world is produced from this sea.

The sturgeons population has seriously declined in the recent years due to the lack of natural spawning place caused deterioration of ecosystem of Caspian Sea and rivers leading to it. This has greatly affected the crisis in the environmental conditions of the Caspian Sea and caused the loss of these valuable stocks. Being existed on the earth surface since the ancient times, they are known as living fossils. Due to the highly commercially valued caviar and obtained the produced meat from these fishes, researchers are working towards conserving and restoring

these valuable stocks in their natural habitats. Aquaculture techniques for sturgeons are developed throughout the world during the past decade, so that in some countries the annual production of meat has reached to 450 tons. Other countries have also succeeded in producing artificial caviar for trade in the world market. The enhanced use of suitable feeding is one of the important goals in the holding of sturgeons under artificial rearing conditions. In the future the increase in aquaculture production will entirely depend on formulation of diets, preparation of fish food, expenditure involved and feeding rates (Sattari & Motamed, 1997), so that lack of sufficient information will be considered a major drawback in sturgeon culture (Sillas *et al.*, 1987). It is evident that the absence of suitable and economic food not only result the decrease in growth and production, but will also lead to increase in the production cost and thus prove to be not cost effective (Sattari & Motamed, 1997).

It is evident from previous studies that the culture of various aquatic organisms depends on a large extent of understanding their physiological state and nutritive requirements. This will help us to determine a suitable and stable diet for them (Shevchenko, 1997). Therefore the present study was proposed to develop and understand the biotechnology of commercial sturgeon culture. The objectives of this study were reduction in food loss and maximum use of it, increase in growth of *A. persicus* fingerlings, decrease in production cost per kilogram of produced meat and thus determine the best feeding rates on the basis of live weight in this species.

Materials and Methods

This study was conducted on 1080 *A. persicus* fingerlings with an average weight of 19.45 ± 0.5g (produced from the breeding of one female and three male broodfish caught at the Sefidrud River) that were completely adapted to artificial food. The primary stocking density was 30 fingerlings in each fiberglass tanks (1×1×0.5 m). Selection of fingerlings was based on the external characteristics. Six feeding trials (1,2, 3, 4, 5, and 6 % of live body weight) were used in this study and 3 replicates were run for each trial. Biometric measurements were carried out at 15 day intervals on 15 fingerlings chosen randomly from each tank. The amount of food used for each tank was calculated on the basis of their biomass. The fingerlings were starved for 24 hours before and after each biometric measurements in order to decrease the stress inflicted on them (Moore, 1987). The artificial food was in the form of granules and consisted of 49-50% crude protein,

13–16% crude fat, 5-6% humidity made from fish meal, extruded soybean, wheat flour, yeast, edible oils, vitamins and mineral matter (Shevchenko, 1997). After diet formulating of each of the ingredients was weighed carefully using a digital balance (0.01g precision) and then mixed in a blender. The mixed food was then passed through a grinder where it was converted to cylindrical pellets. The diameter of the pellets was depends on the age and mouth size of fingerlings. The concentrated food was then placed on a mesh in a dryer at 50°C for a period of 24 hours. The prepared food was then cooled to the air temperature for an hour and then stored in plastic bags in the refrigerator. The fish in the tanks were fed at four definite hours of the day (at 7, 11, 16 and 20 hours) (Ronyai, 1997). Prior to the feeding water inlet of each tank was turned off for 110-20 minutes to make the food available to the fish.

To prevent pollution, the outlet of each tank was opened to drain out faeces and uneaten food. The fish in each tank were weighted once in every 15 days and the following qualitative and quantitative factors were analysed statistically on the basis of randomized block pattern and using the Duncan test in order to compare the different treatments, interval between two biometric measurements and the interval between the first and last biometric measurements as follows:

1. Specific Growth Rate (SGR):

$$SGR == \frac{\text{Final weight - Intitial weight}}{\text{Duration in days}} \times 100$$

2. Food Conversion Rate (FCR):

$$FCR = \frac{\text{Mass of food consumed}}{\text{Increase in biomass}}$$

3. Biomass produced during the experiment period:
   Biomass produced = Final biomass - Initial biomass

Results

Morphometric measurements were conducted on the fingerlings that were reared under similar rearing conditions (temperature, light, water flow, dissolved oxygen concentration) at the end of the fourth 15 days rearing period. The results

of biometric measurements obtained from the entire rearing period are presented in table 1.

Table 1: Biometry results of the entire rearing period

S. No.	Tank No.	Block	Trial (% of feed)	Biomass Produced (g)	FCR	SGR
1	19	1	1 %	662.0	0.71	1.25
2	18	1	2 %	1580.2	0.79	2.15
3	21	1	3 %	2349.7	0.91	2.72
4	22	1	4 %	2692.0	1.24	2.86
5	24	1	5 %	2720.4	1.35	2.94
6	8	1	6 %	2357.3	1.91	2.64
7	26	2	1 %	683.5	0.66	1.13
8	20	2	2 %	1635.6	0.77	2.21
9	23	2	3 %	2238.8	1.05	2.61
10	29	2	4 %	2592.9	1.18	2.84
11	32	2	5 %	2743.2	1.49	2.96
12	15	2	6 %	2614.2	1.92	2.79
13	28	3	1 %	755.9	0.66	1.32
14	27	3	2 %	1590.2	0.75	2.24
15	30	3	3 %	2305.0	0.88	2.72
16	31	3	4 %	2672.0	1.21	2.90
17	36	3	5 %	2567.2	1.56	2.82
18	17	3	6 %	2522.9	1.95	2.74

First Biometric measurements (after 15 days):

Produced Biomass: On the basis of the obtained data the biomass produced in this stage showed significant difference at a confidence interval of 95 % ($df = 5$, $F = 28.21$, $P<0$), among some of the feeding rates used in this study. The biomass produced in trials using 4, 5 and 6 percent of the body weight feeding rates and also that using 2 and 3 percent of the body weight feeding rates showed no significant difference with each other whereas significant differences existed between the trial fed 1 percent of the body weight and the other trials.

During the 15 days period, the trial fed 5 percent of body weight produced the highest biomass with an average production of 518.9±25g in each tank and the trial fed 1 percent of body weight produced the lowest biomass with an average production of 194.3±29g in each tank (Fig. 1). At this stage the maximum daily biomass produced was 1.153 g $fish^{-1}$.

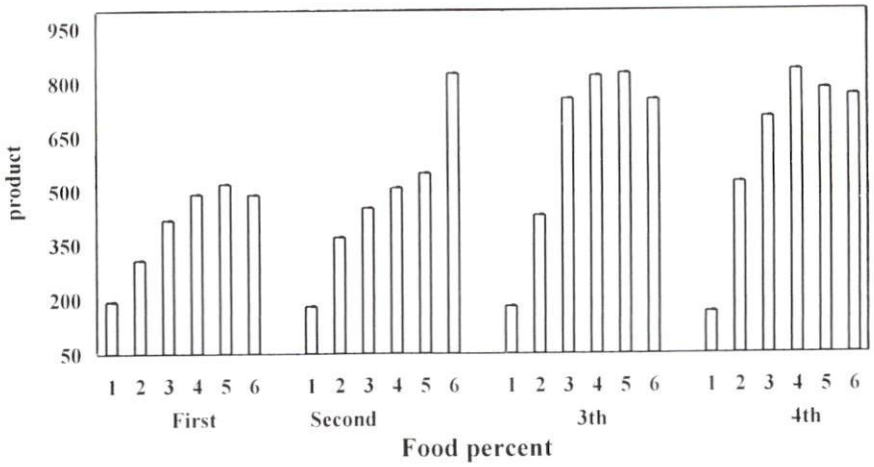

Fig. 1 : Biomass produced in rearing period.

Specific Growth Rate (SGR): The results from the analysis of variance of the daily growth rate at a confidence interval of 95% (df = 5, F = 61.66, P<0), showed no significant difference among the trials were fed 4, 5 and 6 percent of the body weight. Fish in these trials showed the highest daily growth rates. Trials that were fed 3, 2 and 1 percent of their body weight stood after trials fed 4, 5 and 6 percent of body weight regarding daily growth rates. The results from each of these trials showed significant difference with those of the other trials (Fig. 2). The highest and lowest daily growth rates 4.333 and 1.633 belonged to trials fed 5 and 1 percent of the body weight respectively.

Food Conversion Rate (FCR): The results obtained from the analysis of variance of FCR at 95 % confidence interval (df = 5, F = 31.39, P<0) showed significant difference among the various trials under study. The trial fed 1 percent of the body weight with the lowest FCR (0.536) was considered the most ideal trial and showed significant differences with the other trials. No significant

difference was observed by comparing FCRs of trails fed 2 percent body weight with those fed 3 percent body weight, trials fed 3 percent body weight with trials fed 2 and 4 percent body weight, trials fed 4 percent body weight with trials fed 3 and 5 percent body weight and trials fed 5 percent body weight with trials fed 4 and 6 percent body weight. The results from trials fed 6 percent body weight although showed no significant difference with those of trials fed 5 percent body weight but exhibited significant differences with the results obtained from other trials. The lowest FCR was obtained in trials fed 1 percent body weight and the highest FCR was obtained in trials fed 6 percent body weight with an average value of 0.536 and 1.123 respectively, per unit of produced biomass.

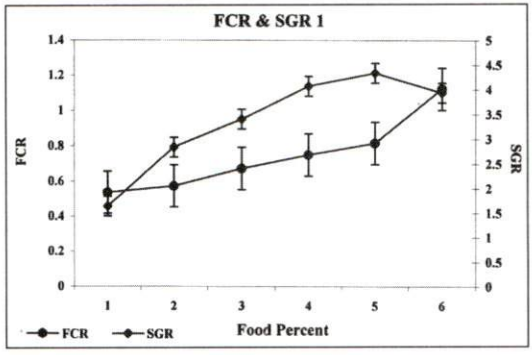

Fig. 2 : Specific growth rate and food conversion ratio in first rearing period

Second Biometric Measurements:

produced Biomass: The results from the analysis of variance of the produced biomass during the second period of rearing in the six under studied trials at a confidence interval of 95% (df = 5, F = 19.42, P = 0.000) are as follows:

The biomass produced in trials fed 6 percent of the body weight showed significant differences with those of other trials. No significant difference was observed in trials fed 5 percent of the body weight with trials fed 3 and 4 percent of the body weight and trails fed 2 percent of the body weight with trials fed 3 and 4 percent of the body weight. However trials fed 3 and 4 percent body weight showed significant difference with trials fed 1 and 6 percent of the body weight and trials fed 1 percent of the body weight showed significant differences with all other trials. The highest average produced biomass was 825.8±125g that belonged to trials fed 6 percent of the body weight and the lowest average produced biomass

was 181.2±28g belonged to trials fed 1 percent of the body weight. In this stage the highest produced biomass was 1.835 g fish $^{-1}$ day $^{-1}$.

Specific Growth Rate (SGR): The results from the analysis of variance of the daily growth rate at a confidence interval of 95 % (df = 5, F = 9.13, P = 0.0017) indicate that no significant difference exits among the trials fed 3, 4, 5 and 6 percent body weight and also trials fed 2, 3, 4 and 6 percent of the body weight. However significant differences were observed between trials fed 5 percent of the body weight and trials fed 2 percent of the body weight. Also trials fed 1 percent of the body weight showed significant difference with all other trials.

The highest daily growth rate (4.067gr/day) and the lowest daily growth rate (2.167gr/day) were exhibited in trials fed 5 and 1 percent of the body weight respectively.

Food Conversion Ratio (FCR): The analysis of variance of FCRs at confidence interval of 95% (df = 5, F = 11.67, P = 0.0006) show significant differences among the various under studied trials. Significant differences were observed in trials fed 1 and 2 percent of the body weight and trials fed 4, 5 and 6 percent body weight; trials fed 5 percent of the body weight and trials fed 1, 2 and 6 percent of the body weight; trials fed 3 percent of the body weight and trials fed 6 percent of the body weight; and trials fed 6 percent of the body weight and all other trials (Fig. 3). The food conversion ratios of trials fed 1 percent of the body weight were the lowest and those of trials fed 6 percent of the body weight were the highest with an average value of 0.4437 and 1.253 respectively.

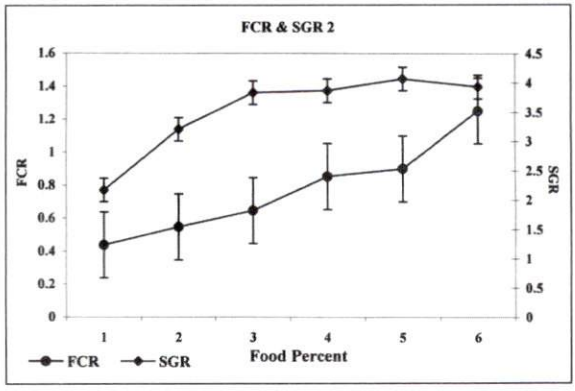

Fig. 3 : Specific growth rate and food conversion ratio in second rearing period

Third Biometric Measurements:

Biomass Produced: On the basis of the results obtained, significant differences were exhibited in the biomass produced in this period among some of the trials at a confidence interval of 95 % (df = 5, F = 35.6, P = 0).The biomass produced in trials fed 3, 4, 5 and 6 percent of the body weight showed no significant difference with trials fed 1 and 2 percent of the body weight, whereas trials fed 1 and 2 percent of the body weight showed significant differences with all other trials.

The highest biomass was produced in trials fed 5 percent of the body weight and lowest biomass produced was in trials fed 1 percent of the body weight, with an average value of 826.1 g and 181.2 g tank $^{-1}$ respectively (Graph 2). In this stage the maximum increase in biomass was 1.836 g fish $^{-1}$ day $^{-1}$.

Specific Growth Rate (SGR): The analysis of variance of specific growth rate at a confidence interval of 95 % (P = 0.0001, F = 19.17, df = 5) showed that no significant difference exists among trials fed 3, 4, 5 and 6 percent of the body weight. However trials fed 1 and 2 percent of the body weight showed significant differences with all other trials. The trials mentioned also showed low specific growth rates, the latter being lower.

The highest SGR value 2.67 belonged to trials fed 3 percent of the body weight and the lowest SGR value 1.103 belonged to trials fed 1 percent of the body weight (Fig. 4).

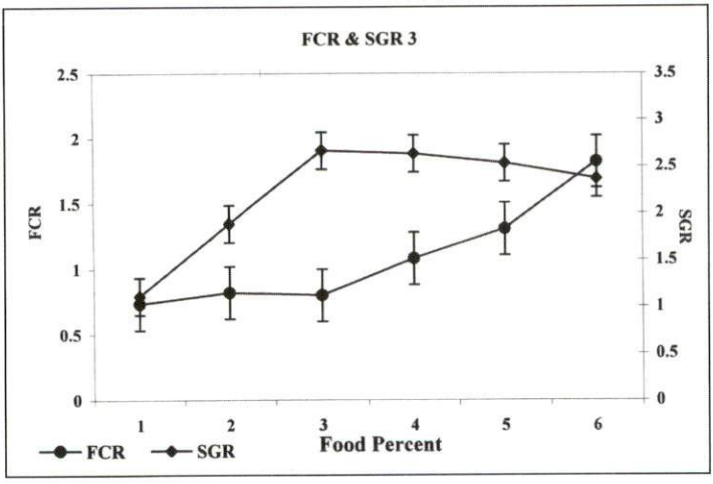

Fig. 4 : Specific growth rate and food conversion ratio in third rearing period

Food Conversion Ratio (FCR): The analysis of variance of food conversion ratios at 95% confidence interval of (P = 0, F = 46.95, df = 5) indicates that trials fed 1, 2 and 3 percent of the body weight showed significant differences with each other as well as with trials fed 4, 5 and 6 percent of the body weight. No significant difference was observed among trials fed 4, 5 and 6 percent of the body weight. The lowest food conversion ratios were obtained in trials fed 1 percent of the body weight with an average value of 0.734 and the highest ratios were obtained in trials fed 6 percent body weight with an average value of 1.82 per unit of increase in biomass.

Forth Biometric Measurements:

Produced Biomass: The analysis of variance at a confidence interval of 95% (P = 0.0009, F = 10.76, df = 5) showed significant differences in the biomass produced in this period among trials fed 3, 4, 5 and 6 percent of the body weight. Trials fed 2 percent of the body weight showed significant differences with trials fed 1, 4 and 5 percent of the body weight while with trials fed 1 percent of the body weight significant differences were exhibited with all other trials. During this period, the highest biomass was obtained in trials fed 4 percent of the body weight with an average production of 834.3 g tank $^{-1}$, whereas the lowest biomass was obtained in trials fed 1 percent of the body weight with an average production of 164.8 g tank $^{-1}$. The maximum increase in biomass during this period was 1.854 g fish^{-1} day^{-1}.

Specific Growth Rate (SGR): The analysis of variance of the specific growth rates at a confidence interval of 95% (P = 0.0008, F = 11.122, df = 5) showed that no significant difference exists among trials fed 3, 4, 5 and 6 percent of the body weight although these trials showed significant differences with trials fed 1 and 2 percent of the body weight. Significant differences were also observed between trials fed 1 and 2 percent of the body weight.

The highest SGR value obtained was 3.91 and belonged to trials fed 5 percent body weight and the lowest SGR value 1.934 belonged to trials fed 1 percent body weight (Fig. 5).

Food Conversion Ratio (FCR): The analysis of variance of food conversion ratios at confidence interval of 95 % (P = 0.0022, F = 8.532, df = 5) are indicative of the fact that no significant differences exist between trials fed 1 and 2 percent body weight and trials fed 1 and 3 percent of the body weight. Trials fed 3, 4, 5 and 6 percent of the body weight were not significantly different from each other,

however these trials showed significant differences with trials fed 1 and 2 percent of the body weight. The lowest food conversion ratios were obtained in trials fed 2 percent of the body weight with an average value of 1.02 and the highest ratios were obtained in trials fed 6 percent of the body weight with an average value of 3.253 per unit of biomass increase.

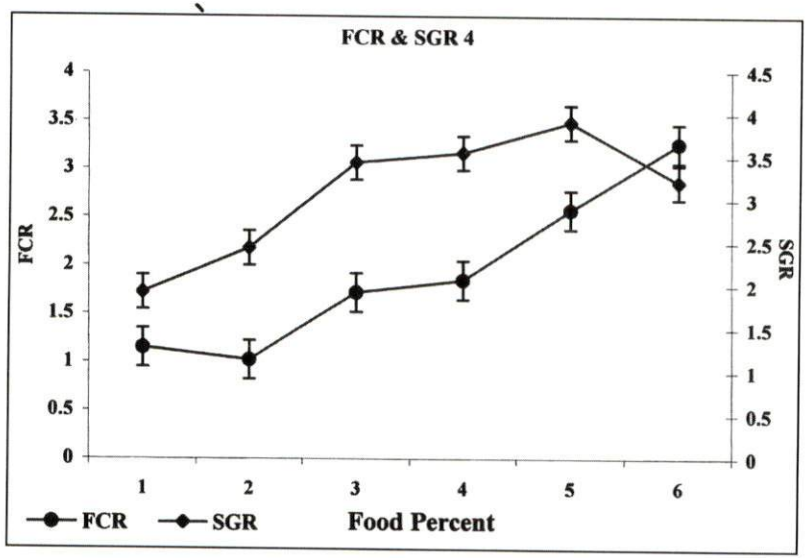

Fig. 5 : Specific growth rate and food conversion ratio in forth rearing period

The Entire Rearing Period (after 60 days of maintenance):

Produce Biomass: The results obtained from the analysis of variance of the biomass produced during the period of 60 days at a confidence interval of 95 % (P = 0, F = 265.26, df = 5) are as follows: No significant difference was observed between the biomass produced in trials fed 4 and 5 percent of the body weight although the results obtained from these trials showed significant differences with those of other trials. It should be noted that the highest biomass was produced in these trials. Lowest biomass was produced in trials fed 1, 2, 3 and 6 percent of the body weight which showed significant differences one with another.

During this period of 60 days, the highest biomass was obtained in trials fed 5 percent of the body weight with an average production of 2677 g tank $^{-1}$, whereas the lowest biomass was obtained in trials fed 1 percent of the body weight with an average production of 701 g tank $^{-1}$. The maximum increase in biomass during this period was 1.487 g fish^{-1} day^{-1}.

Specific Growth Rate (SGR): The analysis of variance of the specific growth rates at a confidence interval of 95% (P = 0.0009, F = 2..072, df = 5) revealed significant differences among the under studied trials. Trials fed 3, 4, 5 and 6 percent of the body weight and trials fed 1, 2, 3 and 6 percent of body weight showed no significant differences with each other. Trials fed 4 and 5 percent of the body weight. The highest SGR value was 2.907 and belonged to trials fed 5 percent of the body weight and the lowest SGR value 1.9 belonged to trials fed 1 percent of the body weight.

Food Conversion Ratio (FCR): The analysis of variance of food conversion ratios at a confidence interval of 95% (P = 0, F = 158.24, df = 5) are indicative of the fact that although no significant differences exist between trials fed 1 and 2 percent of the body weight, these trials showed significant differences with other trials. The trials fed 3, 4, 5 and 6 percent of the body weight, revealed the highest food conversion ratios and each of the mentioned trials showed significant differences with other trials. The lowest food conversion ratios were obtained in trials fed 1 percent of the body weight with an average value of 0.677 and the highest ratios were obtained in trials fed 6 percent the body weight with an average value of 1.927 per unit of biomass increase.

Discussion:

According to the results from the analysis of variance and comparisons of the specific growth rates, food conversion ratios and biomass produced per tank in the various trials and also as indicated in Fig. 1 and 2, trials fed 1, 2, 3 and 6 percent of the body weight cannot be considered ideal feeding rates for the following reasons:

In trials fed 1 percent of the body weight, the biomass produced was low with a high mean deviation. Also the curves for SGR and FCR intersect one another which indicates unsuitable conditions for growth. In trials fed 2 and 3 percent of the body weight, although the produced biomass was high and the mean deviation for the produced biomass was low, the difference between the SGR and FCR (vertical distance between points on the linear curves) was low. Therefore these feeding rates are not suitable for growth.

According to the Fig. 1 and 2 for trials fed 6 percent of the body weight, it is evident that the mean deviation for the produced biomass in this trial is high and the curves for SGR and FCR intersect each other at this range, thus the indicative of adverse conditions of growth. However in trials fed 4 and 5 percent of body

weight we observed that the biomass produced was higher than that in other trials with low mean deviations. Apart, the difference in the SGR and FCR (vertical distance between points on the linear curves) in these two trials was large. Considering that the trials fed 4 and 5 percent of the body weight showed no significant difference with each other regarding their SGR, FCR and produced biomass we can conclude that during the first period of rearing i.e from an average body weight of 19.45 g to 31.3 g, 4 percent of the body weight is an ideal feeding rate. Using this feeding rate we can produce the highest biomass at the lowest cost.

Second Biometric Measurements: As indicated in graphs 3 and 4, the results of the analysis of variance and comparison of SGR, FCR and the produced biomass the various trials used during the second 15 days of rearing it is evident that fishes in trials fed 1 and 2 percent of body weight were under suitable conditions of growth comparing to those in trials fed 3, 4 and 5 percent of the body weight. The produced biomass in trials fed 1 and 2 percent of the body weight was much lower comparing to that of other trials and the difference between SGR and FCR (vertical difference between the points on the linear curves) was less than that observed in trials fed 3 percent of the body weight. In trials fed 6 percent of the body weight the curves for SGR and FCR intersect each other, which indicates adverse conditions of growth. Apart, although the produced biomass in this trial was high, but due to the high mean deviation in the produced biomass this index cannot be treated as a good index for growth. Trials fed 3, 4 and 5 percent of the body weight produced suitable SGRs, FCRs and biomass and showed no significant difference with each other. Therefore 3 percent of body weight can be considered an ideal feeding rate for fishes with an average the body weight of 31.2 g to 47 g. This feeding rate produced the highest biomass at the lowest cost.

Third Biometric Measurements: The results of the analysis of variance and comparison of SGR, FCR and produced biomass in the various trials are clearly indicative of unsuitable conditions of growth in trials fed 1, 2, 5 and 6 percent of the body weight when compared with those in trials fed 3 and 4 percent of the body weight.

The produced biomass in trials fed 1 and 2 percent of the body weight was very low as comparing to that produced in other the trials. And the difference between SGR and FCR in the mentioned trails were also less than that in trials fed 3 and 4 percent of the body weight.

In trials fed 5 and 6 percent of the body weight, the curves for SGR and FCR intersect each other and thus indicate adverse conditions of growth in the trials. Moreover, although the produced biomass in these trials was high, but due to their high mean deviations they cannot be regarded ideal for growth. On the other hand good SGRs, FCRs and biomass were produced in trials fed 3 and 4 percent of the body weight and also no significant difference was observed between these trials. Therefore 3 percent of the body weight can be considered an ideal feeding rate for fishes with an average of the body weight of 47g to 68.6 g because this feeding rate produces the highest biomass at the lowest cost.

Fourth Biometric Measurements: The results of the analysis of variance and comparison of SGR, FCR and produced biomass in the various trials are clearly indicative of unsuitable conditions of growth in trials fed 1 and 2 percent of the body weight when compared with those in trials fed 3, 4, 5 and 6 percent of the body weight. The produced biomass in trials fed 1 and 2 percent of the body weight was much lower than that produced in other trials and the difference between SGR and FCR (vertical distance between the points on the linear curves) in the mentioned trials was less than those in trials fed 3 and 4 percent of the body weight. In trials fed 5 and 6 percent of the body weight the curves for SGR and FCR intersect each other and thus indicate adverse conditions of growth in these trials. Also, although the produced biomass in these trials was relatively high but due to their high mean deviation they cannot be regarded as good indices.

Trials fed 3 and 4 percent of the body weight produced good SGRs, FCRs and biomass and also showed no significant difference with each other. Therefore for fishes with an average body weight of 68.6g to 90g, 3 percent of the body weight can be considered an ideal feeding rate because this feeding rate produces the highest biomass at the lowest cost.

Complete Rearing Period: The results of the analysis of variance and comparison of SGR, FCR and produced biomass in the various trials during the 60 days period of rearing are clearly indicative of unsuitable conditions of growth in trials fed 1, 5 and 6 percent of the body weight when compared with those in trials fed 2, 3 and 4 percent of the body weight.

The produced biomass in trials fed 1 and 2 percent of the body weight was much lower than that produced in other trials and the difference in the SGR and FCR (vertical distance between the points on the linear curves) in these trials was low, when comparing to that in trials fed 3 and 4 percent of the body weight. The

curves for SGR and FCR in trials fed 5 and 6 percent of the body weight were close to each other which indicates the unsuitable conditions of growth in these trials.

Trials fed 3 and 4 percent of the body weight were considered suitable on the basis of SGR, FCR and produced biomass and also showed no significant difference with each other. Therefore for rearing fishes from an average weight of 19.5 g to 90 g, 3 and 4 percent of the body weight can be recommended as ideal feeding rates although allowances should be made for variations in water temperature.

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