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Full Length Research Paper

The effect of feed made from fish processing waste silage on the growth of rainbow trout (*Oncorhynchus mykiss*)

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This study researched the degree to which the growth of rainbow trout (*Oncorhynchus mykiss*) was influenced by pellet feed made from silage produced from waste generated by the fish food processing industry. During the 90 day trial, a completely random parcel method was used with three repetitions. The average weight of the rainbow trout was 54.05±235 g, while their average length was 17.46±0.11 cm. One hundred (100) trout were stocked (25 kg/m^3) in each fiberglass fish feeding tank. Four different experimental groups were formed; feed without silage (control) and pellets with 25, 50 and 100% silage. Fish were fed twice per a day until they were satisfied (*ad libitum*). At the end of the study, the group that was fed with feed made from 50% silage increased the most in weight, followed by the control group and the groups fed with 25 and 100% silage, respectively. The average weight differences between the groups were found to be significant (P<0.05). In conclusion, it can be said that replacing the fish meal in food used to feed trout with 50% fish silage has a positive effect on growth, and that silage can be used in trout food at the aforementioned ratio.

Key words: Fish meal, fish silage, growth, feed efficiency, rainbow trout.

INTRODUCTION

The cost of feed represents the largest expense in farming fish. Fish meal is the most important of the basic ingredients used to make fish feed, and it is usually imported by fish feed manufacturers in Turkey. This increases the cost of fish feed and in turn the operating costs of the fish farming industry, which has a negative effect on the market price of fish.

For fish farming, 1.5 to 2 kg of feed is usually used to produce 1 kg of fish. In view of the fact that approximately 130.000 tons of fish are raised on fish farms in Turkey, this means that the fish farming industry consumes roughly 195.000 to 260.000 tons of fish feed per year (Korkut, 2008). A large number of studies have been carried out in recent years on alternative ingredients that can be used instead of fish meal, which the primary ingredient for fish is feed. Particular attention has been given to the use of waste products from the fish processing industry for both fish meal and fish silage. This is also considered to be an environmentally-friendly procedure because it consists of recycling organic material that is considered to be usable waste. The use of fish processing waste by making fish silage for the feed industry has the potential of reducing the cost of producing fish meal by approximately 15 to 20% (Yildirim et al., 1999; Gullu and Guzel, 2003; Turker and Buyukhatipoglu, 2006).

The first studies on fish silage were done in Sweden in 1930s. There are several advantages to making fish silage from fish processing waste and fish products of low economic value that are fished in large numbers. These include reduced cost of feed, elimination of storage costs for fresh fish feed, and production of feed that is not only easy for fish to digest but is also close in nutritional value to natural feed (Raa and Gildberg, 1982; Tatterson and Windsor, 1982; Raa et al., 1983).

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Fish silage can be made into semi-moist pellets (Oregon pellets) for feeding fish, or it can also be fed to the fish in the form of dry pellets (Michael, 1987; Lovell, 1978). When fish silage is made into dry pellets, they can be stored for longer periods of time because the feed has lower moisture content, and it also has a high level of pure protein.

The goal of this study is to make use of waste from the fish processing industry and to provide the fish feed industry with an ingredient for feed that is less expensive than fish meal. This will also make a contribution to protecting the environment by utilizing organic waste that can pollute the environment.

MATERIALS AND METHODS

Fish material and the design of the experiment

The rainbow trout were obtained from a private facility. The feeding trials were carried out at the Aquaculture Research and Application Department of Surgu Vocational School Division of Inonu University. Twelve rectangular fiberglass tanks (250 x 74 x 54 cm) and natural spring water (temperature: 11.2°C; pH: 7.4; dissolved oxygen: 8.5 mg/l) were used.

The trial used a "completely random parcel method" with three repetitions, resulting in a total of 12 groups (Duzgunes et al., 1987). The average weight of the fish in each group was 54.05±235 g, and 100 rainbow trout were placed in each tank (stock density: 25 kg/m^3, total 1200 trout). The fish were placed in the tanks for 15 days so they could adapt to the new environment, and the feeding study began at the end of that period. The trial groups were named as mentioned below:

(i) The group fed with feed made by replacing 25% of the fish meal with silage (25% silage);
(ii) The group fed with feed made by replacing 50% of the fish meal with silage (50% silage);
(iii) The group fed with feed made by replacing all (100%) of the fish meal with silage (100% silage);
(iv) The group feed with fish meal (0% silage) (Control).

The feeding trial continued 90 days. The fish were fed *ad libitum* twice a day. Measuring and weighing the fish were carried out periodically every month by randomly selecting 50 fish and sedated them with 2-Phenoxyethanol (0.30 ml^{-1}). Measurement of mid-caudal length was carried out with a measuring board accurate to 0.1 cm, while the weight was measured with an electronic scale accurate to 0.1 g (Anderson and Gutreuter, 1989; Stickney, 1989). The trial involved recording the parameters of weight (W) and length (L), condition factor (C), specific growth rate (SGR), feed conversion rate (FCR) and survival rate. The formulas reported by Halver (1989) and Hepher (1990) were used for the calculations.

Feed material

The feed material used in this study was the feed that was produced in another research study entitled "An evaluation of the utilization of fish processing waste to produce silage and a study of the possibilities for using the resulting product in the feed manufacturing industry." Although, four different kinds of feed (including the control group feed) were used as material, the only difference between the types of feed was the amount of silage that was used in place of fish meal. The other raw materials and ingredient ratios for the feed was the same. The ingredients and their content ratio for the feed used in the study as well as the chemical analysis of the feed have been given in Table 1. The following formula was used to calculate the cost of the feed:

Cost of feed needed for the group to gain one kg of live weight = Unit cost of the feed used in the group (TL/Kg) X Feed conversion rate for the Group. Results were calculated separately for each type of feed.

Pellet feed and chemical analysis of fish meat

Prevalent methods were used to identify the chemical composition of the pellet feed and the trout meat. These analyses were the crude protein and crude ash (AOAC 1984); crude fat (Blig and Dyer, 1959) and moisture (Ludorf and Meyer, 1973). A sample of eight fish was taken from each trial for the chemical analysis of fish meat. The filets of the fish selected for analysis was removed, placed in bags and then stored in a deep freeze (at -18°C) until they were analyzed.

Statistical analysis

Recorded data were analyzed statistically using analysis of variance technique (ANOVA) and means were compared by Duncan's multiple range test.

RESULTS

Natural spring water was used in this study where the water temperature varied between 11 and 12°C, with an average of 11.2±0.4°C. The average amount of dissolved oxygen in the water was found to be 8.5±0.05 mg/L and the pH level was found to be 7.4±0.05. The average weight (W±SE), length (L±SE), condition factor (C±SE) and feed conversion rate (FCR) for the study have been given in Table 2.

A comparison of the average weight gains in the groups for specific periods revealed that the lowest weight gain was in the 100% silage group. The control group and the group fed with feed made from 50% silage exhibited similar weight gain. The difference in weight gain between 25 and 100% silage groups was found to be statistically significant ($P<0.05$), but the difference in weight gain between the control and the 50% silage groups was found to be insignificant ($P>0.05$) (Table 2). At the end of the trial, the differences in average length between the groups were found to be statistically insignificant ($P>0.05$) (Table 2). A graph of the weight gain of the groups over specific time periods has been given in Figure 1.

The differences between the trial groups with regard to overall average condition measurements were found to be statistically insignificant ($P>0.05$) (Table 2). A comparison of the average FCR measurements for the trial groups at the end of the study revealed that the lowest value (that is, the best food utilization) was in the 50% silage group, while the highest FCR value was in the 100% silage group. The FCR values for the 50% silage group and the control group were found to be close to each other (Table 2).

Table 1. Ingredients used in the experiment, the results of chemical analysis of feed with participation rates and costs.

Ingredient (%)	Experimental group			
	Control	25% Silage	50% Silage	100% Silage
Fish meal	38.00	28.50	19.00	-
Fish silage	-	9.50	19.00	38.00
Soybean meal	27.00	27.00	27.00	27.00
Fish oil	14.22	14.22	14.22	14.22
Feed flour	11.46	11.46	11.46	11.46
Corn gluten	4.46	4.46	4.46	4.46
Sunflower seed meal	3.00	3.00	3.00	3.00
Wheat gluten	1.00	1.00	1.00	1.00
Vitamin premix	0.40	0.40	0.40	0.40
Biomas	0.15	0.15	0.15	0.15
Mineral premix	0.10	0.10	0.10	0.10
Selplex + Bioplex Zn	0.08	0.08	0.08	0.08
MYCO AD A – Z	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Chemical composition (%)				
Moisture	8.16	5.75	6.66	7.72
Crude protein	46.68	46.34	44.03	44.41
Ether extract	17.97	19.25	22.99	24.96
Ash	6.32	6.76	6.53	5.82
Crude fiber	5.59	5.42	5.57	5.00
N-free extract	15.28	16.48	14.22	12.09
Digestible energy (kcal/kg)	3930.2	3949.6	4160.4	4361.0
Pellet feed costs (TL)	1.81	1.61	1.41	1.00

The cost of gaining 1 kg of live fish weight was calculated as follows: 2.17 TL (1.40 $) in the control group, 2.06 TL (1.33 $) in the 25% silage group, 1.62 TL (1.04 $) in the 50% silage group and 1.50 TL (0.97 $) in the 100% silage group. The cost of fish feed in the 25% silage group, 50% silage group and 100% silage group were found to be 5.07, 25.35 and 30.88% cheaper than the control group respectively. During the study, no differences were found in the behavior of the fish in the trial groups with regard to the feed they were given. Furthermore, none of the fish in the groups died during the study. Table 3 shows the results of the chemical analysis performed on the meat of fish randomly selected from the groups at the end of the trial.

DISCUSSION

The average temperature, dissolved oxygen and pH values measured in the study were within acceptable limits for the growth of rainbow trout (Baur and Rapp, 1988; Edwards, 1994). There were no differences detected between the groups about weight after 30 days, but differences became evident at 60 and 90 days. These differences were only found to be statistically significant between 25 and 100% silage groups ($P<0.05$). The differences between the control and 50% silage groups were determined to be statistically insignificant ($P>0.05$) (Table 2). The group that used 50% silage exhibited similar growth to the control. This provides important information about the percentage of silage that can be used in fish feed instead of fish meal.

Various researchers have reported that when feeding carnivorous fish, fish feed can be substituted with other protein sources (fresh fish, frozen fish, and silage made from fish and fish waste), and that this produces different results with regard to the growth of the fish, the feed conversion rate and the cost of feed (Kanidyev et al., 1975; Lie et al., 1988; Dabrowski et al., 1989; Goncalves et al., 1989; Stone et al., 1989; Heras et al., 1994; Aral et al., 1999; Yildirim et al., 1999; Gullu and Guzel, 2003; Gullu et al., 2003; Turker and Buyukhatipoglu, 2006). In a study carried out by Lie et al. (1988) on dry pellet feed and silage with or without the fat removed, the authors reported that the best growth was in the group fed with commercial feed and 50% silage. Goncalves et al. (1989) fed young eels with fish silage obtained from sardines, and reported that the best growth was in the group fed

Table 2. Growth parameters of experimental groups; average weight (W±SE), length (L±SE),condition factor (C±SE) and feed conversion rate (FCR), (n=50).

Period (Day)	Parameter	Experimental group			
		Control	25% Silage	50% Silage	100% Silage
0	W±SE	54.60±0.48[a]	51.60±0.37[a]	53.60±0.41[a]	56.40±0.27[a]
	L±SE	17.44±0.15	17.02±0.10	17.15±0.12	17.87±0.11
	C±SE	1.33±0.01	1.32±0.01	1.34±0.01	1.38±0.01
30	W±SE	90.97±1.68[a]	85.09±0.14[a]	89.38±4.10[a]	85.01±2.68[a]
	L±SE	19.58±0.19	18.70±0.18	19.04±0.18	18.99±0.14
	C±SE	1.34±0.01	1.34±0.01	1.36±0.01	1.33±0.01
60	W±SE	133.07±3.12[a]	124.82±1.99[ab]	132.61±6.56[a]	115.43±2.73[b]
	L±SE	21.08±0.19	20.74±0.21	21.14±0.16	20.3±0.18
	C±SE	1.35±0.01	1.35±0.01	1.37±0.01	1.35±0.01
90	W±SE	178.73±5.43[a]	165.00±1.83[ab]	178.67±7.99[a]	153.33±1.73[b]
	L±SE	23.37±0.24	22.65±0.25	23.49±0.26	22.41±0.20
	C±SE	1.33±0.01	1.33±0.01	1.33±0.01	1.37±0.01
Overall	C±SE	1.34±0.01[a]	1.33±0.01[a]	1.35±0.01[a]	1.34±0.01[a]
	YDK	1.20	1.28	1.15	1.50

Different letters refer to significant differences ($p<0.05$).

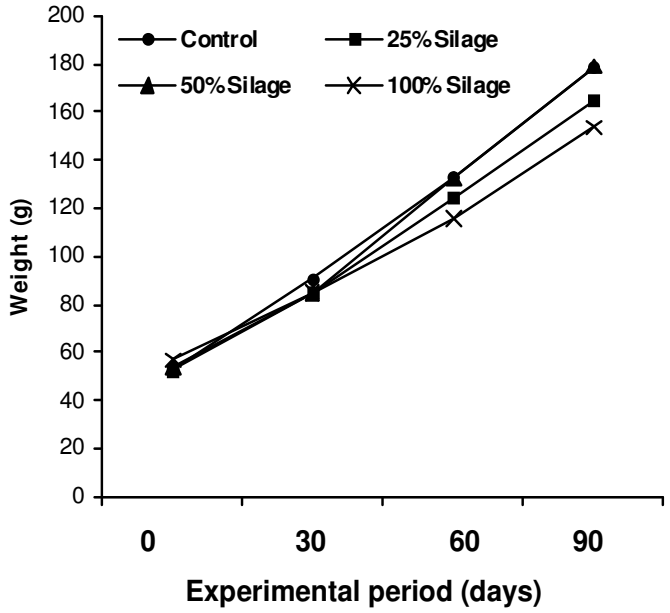

Figure 1. Mean weights of experimental fish during the period.

with feed containing 15 to 20% silage. Stone et al. (1989) fed rainbow trout with pellets made from fresh fish, frozen fish and silage obtained from fish waste. They observed the best growth and feed utilization occurred with frozen fish, fresh fish and feed with silage made from fish waste, respectively. Yildirim et al. (1999) reported that trout can feed with waste from fish processing plants and this can reduce the fish feed price. Gullu et al. (2003) reported that one part commercial pellet feed to one part pellet feed made from pearl mullet *(Chalcalburnus tarichi)* silage can be used for trout feed, and so, the cost of feed may be reduced to 14.5%. Turker and Buyukhatipoglu (2006) stated that anchovy derivative semi-moist feed , trout internal organs and bonito internal organs can be used for feeding rainbow trout and this can reduce the cost of feed. The mentioned studies results are similar to our study, which concludes that feeding trout with feed that has 50% of the fish meal replaced with fish waste silage had a positive effect on growth and reduced the cost of feed by 25.35%.

A comparison of FCR values indicates the control group and 50% silage group utilized the feed better than the other groups (Table 2). Overall, the FCR values for the groups varied between 1.15 and 1.50. Some other studies reported that FCR values varied from 1.4 to 8.7 (Lie et al., 1988; Goncalves et al., 1989; Stone et al., 1989; Gullu et al., 2003). It is possible that the large range of differences in the studies is due to the variety of silage materials used, the ingredients of the feed, the ratios of feed ingredients, the differences between the species of fish that were fed, the test environment and the quality of water. The 50% silage group was found close to the control group. The variation of condition factors from 1.33 to 1.35 between the groups was not significant ($P>0.05$).

With regard to the cost of the feed necessary to obtain 1 kg of fish, it was determined that depending on the amount of silage (25, 50 and 100%) added to the feed, the cost of feed was 5.07, 25.35 and 30.88% cheaper in

Table 3. The end of the experiment the chemical composition of fish meat (n=8).

Parameter (%)	Experimental group			
	Control	25% Silage	50% Silage	100% Silage
Moisture	73.41	74.27	74.19	72.70
Crude protein	22.95[a]	21.64[a]	22.97[a]	23.17[a]
Ether extract	9.92	11.20	10.96	11.94
Ash	0.99[a]	0.99[a]	0.99[a]	0.98[a]

Different letters refer to significant differences ($p<0.05$).

those groups, respectively, than the control group. However, when the growth performances of the trial groups were evaluated together with the cost of feed, it was clear that the 50% silage group was seen more advantageous than the other groups. For example, even though the cost of feed in the 100% silage group was 30.88% lower than the control group, it does not perform as well. For this reason, it appears that completely (100%) replacing fish meal with silage from fish processing waste for trout feed rations is not a good solution. Various researchers have reported feed made from fish silage can reduce the cost of feed (Aral et al., 1999; Yildirim et al., 1999; Gullu and Guzel, 2003; Gullu et al., 2003; Turker and Buyukhatipoglu, 2006).

The fat content increased in proportion to the percentage of silage used (25, 50 and 100%) (Table 2). The percentage of fat was higher in the meat of fish fed with feed that had high fat content (Table 3). Various studies have reported similar results with fat content; however, they state that the crude protein and ash percentages did not change (Lie et al., 1988; Goncalves et al., 1989).

In conclusion, if we consider that the cost of feed represents 60 to 65% of operating expenses in fish farming, it is clear that using feed made from 50% silage instead of fish meal is significant. Saving 25.35% in feed costs could be a noticeable advantage for fish farms. Furthermore, utilizing waste from processing fish will make significant contributions to the country's economy and to protecting the environment. Fish meal is an essential ingredient in making fish feed, but excessive demand and insufficient resources make this raw material expensive. The feed industry in Turkey imports fish meal. By replacing some of the fish meal used to making fish feed with fish silage made from fish processing waste, this study provides a partial solution to the difficulty and high cost of procuring fish meal. In conclusion, it can be said that replacing the fish meal in food used to feed trout with 50% fish silage has a positive effect on growth, and that silage can comfortably be used in trout food pellets.

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