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Research Article

Estimation of the Nitrogen-Phosphorus Load Caused by Rainbow Trout (*Oncorhynchus mykiss* Walbaum, 1792) Cage-Culture Farms in Kesikköprü Dam Lake: A Comparison of Pelleted and Extruded Feed

Umut AŞIR, Serap PULATSÜ*
Department of Aquaculture and Fisheries, Faculty of Agriculture, Ankara University, 06110, Ankara - TURKEY

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Abstract: This research was conducted in order to estimate the nitrogen and phosphorus loads released into Kesikköprü Dam Lake between April and July 2006 from 2 different rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792) cage farms. Both farms had a capacity of about 20 t $year^{-1}$, and used pelleted and extruded feed. In Kesikköprü Dam Lake the nitrogen load was estimated to be between 56.00 and 62.92 kg t^{-1} of fish produced, and the phosphorus load was estimated to be between 10.66 and 12.17 kg t^{-1} of fish produced in cages in which pelleted feed was used, In cages in which extruded feed was used, the nitrogen load was estimated to be between 33.47 and 25.97 kg t^{-1} of fish produced, and the phosphorus load was estimated to be between 7.32 and 7.96 kg t^{-1} of fish produced. Based on the quantitative results of this study, it was concluded that for aquaculture to be sustainable in inland waters where rainbow trout is cultured, and to minimize its influence on eutrophication, it would be beneficial to use extruded feed.

Key Words: Rainbow trout, nitrogen and phosphorus loads, net cage culture, pelleted, extruded, fish feed, Kesikköprü Dam Lake

Kesikköprü Baraj Gölü'nde Ağ Kafeslerde Gökkuşağı Alabalığı (*Oncorhynchus mykiss* Walbaum, 1792) Yetiştiriciliğinden Kaynaklanan Azot-Fosfor Yükünün Tahmini: Pelet ve Ekstrude Yemin Karşılaştırılması

Özet: Bu araştırma, Kesikköprü Baraj Gölü'nde Nisan-Temmuz 2006 tarihleri arasında, yaklaşık 20'şer ton/yıl kapasiteli, pelet ve ekstrude yem kullanılarak gökkuşağı alabalığı (*Oncorhynchus mykiss* Walbaum,1792) yetiştiriciliği yapan iki farklı kafes işletmesinden göle bırakılan azot ve fosfor yükünün tahmini amacıyla yürütülmüştür. Kesikköprü Baraj Gölü'nde pelet yemin kullanıldığı kafeslerde, 1 ton balık üretiminde azot yükü 56,00 ve 62,92 kg, fosfor yükü 10,66 ve 12,17 kg; ekstrude yemin kullanıldığı kafeslerde ise 1 ton balık üretiminde azot yükü 33,47 ve 25,97 kg, fosfor yükü 7,32 ve 7,96 kg olarak tahmin edilmiştir. Araştırmada elde edilen kantitatif bulgular ışığında, kafeslerde gökkuşağı alabalığı yetiştiriciliğinin yapıldığı iç sularda yetiştiriciliğin sürdürülebilirliğini sağlamak ve yetiştiriciliğin ötrofikasyona etkisini minimuma indirmek açısından ekstrude yem kullanımının uygun olacağı belirlenmiştir.

Anahtar Sözcükler: Gökkuşağı alabalığı, azot ve fosfor yükü, ağ kafeslerde balık yetiştiriciliği, pres pelet, ekstrude, balık yemi, Kesikköprü Baraj Gölü

Introduction

Intensive aquacultural activity results in the release of organic waste and soluble inorganic nutrients, such as nitrogen and phosphorus, which can cause or accelerate eutrophication in natural aquatic systems. Nutrient release (principally nitrogen and phosphorus) consists of a dissolved and particulate fraction. Solid waste consists almost exclusively of uneaten feed pellets and fecal pellets. Some of these materials are eaten by wild fish and some are lost to the water column by dissolution. Excess absorption of these nutrients by cultured fish is excreted through the gills, together with the end-products of protein catabolism, in the form of dissolved ammonia and urea (1-3). In temperate waters, it is normally estimated that approximately 60% of the phosphorus and 30% of the nitrogen discharged from freshwater cages is in solid form (4).

The major ecological effect of cage farms is considered to be eutrophication of the water body, determined by the basic mass-balance of limiting nutrients such as phosphorus

* E-mail: spulatsu@agri.ankara.edu.tr

and nitrogen. The nutrient-budget balance, or mass balance model, is generally used to assess the relationships between feed nutrient input, nutrient retention in the cultured fish, and nutrient release into the environment, as related to a given production tonnage (2). Several authors have reported different mass balances for nitrogen and phosphorus for different fish species. There are differences not only between species, but also within species, depending upon the feeds employed, feeding regimes, culture systems, and environmental parameters of the local area (5,6).

The environmental impact of aquaculture is mainly a function of feed composition and feed conversion. In addition, rearing techniques, chemical use, site selection, size of the farm, and species of cultivated fish should also be considered important factors (5,7). The total discharge of nutrients from a cage is generally estimated to be in the order of 10-20 kg of phosphorus and 75-95 kg of nitrogen $year^{-1}$ t^{-1} of fish produced (8).

In Turkey, rainbow trout is the most common species cultured in both land-based raceways and cages, with an annual production of 56,026 t in 2006 (9). In 2004, there were 72 freshwater cage fish farms in reservoirs, with a total capacity of 4777 t, and these were primarily rainbow trout farms (10). In the present study, we aimed to estimate the quantitative nitrogen and phosphorus loads released from 2 different farms in Kesikköprü Dam Lake that used pelleted and extruded feed.

Materials and Methods

Study Site

Kesikköprü Dam Lake was created after the completion of the Kesikköprü Dam on the Kızılırmak River in 1996. It is located 110 km southeast of Ankara and 25 km downstream of the Hirfanlı Dam. The dam is located at lat 39°23′N, long 33°25′E, and is 785 m above sea level. It has an area of 6.5 km^2, a volume of 95×10^6 m^3, and a water-replenishment period of 0.04 years (11). Five rainbow trout cage farms, each with an annual capacity between 20 and 55 t, operate in Kesikköprü Dam Lake. This study was performed between the beginning of April and end of July 2006 at 2 different rainbow trout cage-culture farms (farms I and II) in Kesikköprü Dam Lake. Both farms had a capacity of about 20 t $year^{-1}$, and used pelleted and extruded feed. The stocking density was 60 fish m^{-3} (12,13). For each farm, the cages had a capacity of about 4 m^3 (1.8 × 2.2 × 1 m) and were constructed of 12-mm mesh. For this study, 2016 rainbow trout were obtained from a commercial enterprise and had an initial mean weight of 62.62 ± 0.26 g. Each cage farm received 50% of the fish, which were then placed into 2 feed subgroups (extruded feed subgroup and pelleted feed subgroup) (n = 504). Dead fish were removed and weighed daily. The amount of feed provided was adjusted according to temporal changes in the biomass and growth of the fish in the cages. The pelleted and extruded feeds used in the study were provided by a commercial feed company. The pelleted and extruded feeds contained, respectively, 48.8% and 50.6% crude protein, 16% and 22% crude fat, 12% and 10% crude ash, and 2.1% and 1.2% crude fiber. During this study 227 kg of pelleted feed and 216 kg of extruded feed were used.

Analytical Methods

Nitrogen and phosphorus content of the feeds and fish were determined according to a previous report (14). Kjeldahl and vanadomolybdophosphoric acid methods were used for nitrogen and phosphorus analysis, respectively.

Statistical Methods

The differences between the growth parameters of the groups were tested by repeated measures analysis of variance (ANOVA) and the differences between means were compared by Duncan's test (15).

Estimation of Nitrogen and Phosphorus Loads from the Cage Farms

Nitrogen and phosphorus loads from under the fish cultures were estimated according to Ackefors and Enell (1). The equations for nitrogen and phosphorus loads are given in (1) and (2).

Nitrogen load (kg of N): =

$$(\text{Feed} \times \text{Feed}_N) - (\text{Fish} \times \text{Fish}_N) \quad (1)$$

Phosphorus load (kg of P): =

$$(\text{Feed} \times \text{Feed}_P) - (\text{Fish} \times \text{Fish}_P) \quad (2)$$

where Feed = wet weight of pelleted or extruded feeds used per year,

Fish = wet weight of fish produced per year, Feed_N = nitrogen content and Feed_P = phosphorus content of the feeds, expressed as % of wet weight, and Fish_N = nitrogen content and Fish_P = phosphorus content of the fish, expressed as % of wet weight.

Results

The results of some growth parameters and chemical analyses from 2 different cage farms are presented in Table 1. Differences in the final mean weights of the pelleted feed and extruded feed subgroups were statistically significant between the 2 cage farms ($P < 0.05$). Mortality and FCR values were higher in the farm II pelleted feed subgroup. At both farms the nitrogen content of the extruded feed subgroups was at the maximum level (Table 1).

Monthly variations in some of the dam lake's water quality parameters are shown in Table 2. Although differences in pH values were significant only in April and June ($P < 0.05$), differences in water temperature and dissolved oxygen values were not statistically significant between the 2 cage farms ($P < 0.05$). During the study period, Secchi depth varied between 1.20 m (July, in cage farm II) and 3.47 m (April, in cage farm I).

Phosphorus content of the pelleted and extruded feeds was 1.24% and 0.96%, respectively, while the nitrogen content of the pelleted and extruded feeds was 8.1% and 7.8%, respectively.

The mass balance for nitrogen and phosphorus in cage farms I and II is given in Table 3. On the basis of nutrient elements, nitrogen load was estimated to be between 54.37% and 56.19% for pelleted feed, and between 26.61% and 34.35% for extruded feed, whereas phosphorus load was estimated to be between 70.00% and 73.64% for pelleted feed, and between 61.11% and 65.77% for extruded feed.

In the cages in which press pelleted feed with a nitrogen content of 8.1% and a phosphorus content of 1.24% was used, the following values were observed: feed conversion ratio (FCR): 1.27-1.38, nitrogen-retention level: 45.63%-43.81%; phosphorus-retention level: 30.00%-26.36%. In the cages in which extruded feed with a nitrogen content of 7.8% and a phosphorus content of 0.96% was used, the following values were observed: FCR: 1.25; nitrogen-retention: 65.65%-73.39%; phosphorus-retention level: 38.89%-34.23% (Table 3).

Table 1. Some growth parameters and results of chemical analyses at 2 different cage farms.

Cage farm	I		II	
Feed	Pelleted	Extruded	Pelleted	Extruded
Parameters				
Initial mean weight (g)	$62.46 \pm 0.33^{a*}$	62.59 ± 0.01^{a}	62.70 ± 0.22^{a}	62.76 ± 0.21^{a}
Final mean weight (g)	246.47 ± 5.65^{a}	265.24 ± 3.41^{b}	249.05 ± 2.82^{a}	269.82 ± 3.17^{b}
FCR	1.27 ± 0.08^{a}	1.25 ± 0.13^{b}	1.38 ± 0.15^{c}	1.25 ± 0.17^{b}
Mortality (%)	$5.95 \pm 0{,}56^{a}$	$8.93 \pm 0{,}84^{b}$	$12.70 \pm 4{,}49^{c}$	$9.33 \pm 0{,}84^{b}$
N content of fish (%)	4.70 ± 0.6^{a}	6.40 ± 0.3^{b}	$4.90 \pm 0{,}6^{c}$	7.20 ± 0.9^{d}
P content of fish (%)	0.46 ± 0.03^{a}	0.47 ± 0.03^{b}	0.44 ± 0.01^{c}	0.42 ± 0.01^{d}

* Differences between means with the same lower case letters in a row are not statistically significant ($P > 0.05$).

Table 2. Monthly variations in mean water temperature, dissolved oxygen, and pH at 2 different cage farms.

Parameter	Water temperature (°C)		Dissolved oxygen (mg l^{-1})		pH	
Cage farm	I	II	I	II	I	II
Months						
April	$12.25 \pm 1.75^{aA*}$	12.65 ± 1.85^{aA}	7.30 ± 0.50^{aA}	7.05 ± 0.45^{aA}	8.05 ± 0.01^{aA}	7.96 ± 0.01^{aB}
May	16.75 ± 0.25^{bA}	16.90 ± 0.30^{bA}	6.70 ± 0.00^{aA}	6.45 ± 0.05^{aA}	8.17 ± 0.01^{bA}	8.19 ± 0.01^{bA}
June	20.50 ± 0.50^{cA}	20.95 ± 0.55^{cA}	6.60 ± 0.00^{aA}	6.33 ± 0.03^{aA}	8.05 ± 0.01^{aA}	7.89 ± 0.01^{cB}
July	22.00 ± 0.00^{cA}	22.10 ± 0.10^{cA}	6.55 ± 0.0^{aA}	6.43 ± 0.03^{aA}	8.16 ± 0.01^{cA}	8.15 ± 0.01^{dA}

* Differences between means with the same lower case letters in a column and differences between means with the same upper case letters in a row for each parameter are not statistically significant ($P > 0.05$).

Table 3. Mass balance for nitrogen (N) and phosphorus (P) at 2 different cage farms.

Cage farm	Feed	N from feed (kg)	N retained in fish (kg)	N load (kg)	P from feed (kg)	P retained in fish (kg)	P load (kg)	N and P retained in fish (%)	N and P load (%)
I	Pelleted	8.79	4.01	4.78	1.30	0.39	0.91	45.63 N	54.37 N
								30.00 P	70.00 P
	Extruded	8.79	5.77	3.02	1.08	0.42	0.66	65.65 N	34.35 N
								38.89 P	61.11 P
II	Pelleted	8.72	3.82	4.90	1.29	0.34	0.95	43.81 N	56.19 N
								26.36 P	73.64 P
	Extruded	8.98	6.59	2.39	1.11	0.38	0.73	73.39 N	26.61 N
								34.23 P	65.77 P

Table 4. Nitrogen and phosphorus loads from the production of 1 t of fish in Kesikköprü Dam Lake.

Cage farm	Feed	Nitrogen (kg)	Phosphorus (kg)
I	Pelleted	56.00	10.66
	Extruded	33.47	7.32
II	Pelleted	62.92	12.17
	Extruded	25.97	7.96

Table 5. Nitrogen and phosphorus loads from 1 t of feed consumption released into Kesikköprü Dam Lake.

Cage farm	Feed	Nitrogen (kg)	Phosphorus (kg)
I	Pelleted	44.00	8.38
	Extruded	26.77	5.85
II	Pelleted	45.56	8.82
	Extruded	20.66	6.34

The estimated nitrogen and phosphorus loads from the production of 1 t of fish and from 1 t of feed consumption are presented in Tables 4 and 5, respectively.

Discussion

In 2 other studies performed on cultured rainbow trout fed dry feed in cage systems (16), nitrogen load was between 87 and 104 kg t^{-1} of fish produced, and phosphorus load was between 27 and 13.5 kg t^{-1} of fish produced. In this study, both nitrogen (25.97-62.92 kg) and phosphorus (7.32-12.17 kg) loads arising from rainbow trout cage-farms using press pelleted and extruded feed were found to be lower than had been determined by O'Connor et al. (16).

It has been established that in general, for cultured trout, FCR is 1.5-2.0:1 and that the amount of phosphorus released into the environment is 17-32 kg t^{-1} of fish produced (17). In the present study, FCR varied between 1.25 and 1.38, and average values of phosphorus released into the dam lake were determined to be lower (7.32-12.17 kg t^{-1} of fish produced) than reported by Atay (17). It was reported that the main effect of fish culturing in cages on a lake or reservoir is the increase in phosphorus load; an average of 18.8 kg of phosphorus is loaded per t of trout produced (18,19). In the present study, despite the fact that the phosphorus load was estimated to be an average of 9.53 kg, without considering differences between the farms and types of feed, it is clear that the phosphorus load that resulted from using extruded feed (7.32-7.96 kg) was lower than the phosphorus load that resulted from the use of pelleted feed (10.66-12.17 kg) (Table 4).

The observed levels of nitrogen and phosphorus retained by the rainbow trout in the present study were higher than the values reported by Ackefors and Enell

(27.7% N and 29.8% P) (1). Nitrogen-phosphorus mass balance has been studied in salmon species other than trout in intensive cage-culturing (6,20). The levels of nitrogen and phosphorus retained by the fish in the present study were higher than those reported by Folke and Kautsky (6) (25% N and 23% P). The nitrogen and phosphorus load values observed in the present study were also higher than the values reported by Boyd and Queiroz (67.8% N and 43.8% P) (20) for salmon stock-farmed in cages (FCR: 1.1; feed content: 7.04% N; 1.3% P). As for the nitrogen and phosphorus budget-data of cage systems, according to a study of 3 fish species (*Siniperca chuatsi*, *Megalobrama amblycephala*, and *Ictalurus punctatus*) cultured in Niushanhu Lake between March and December 2000, the nitrogen load was 160 kg and the phosphorus load was at about 35 kg for each t of fish produced (21). Nitrogen- and phosphorus-load values in the present study of rainbow trout cage-farms were lower than those reported by Guo and Li (21). In 3 reservoirs in Indonesia in which carp (*Cyprinus carpio* L.) and tilapia (*Oreochromis niloticus* L.) were cultured, the nutrient element load-values for the years of maximum production were estimated to be 3.1-15.2 t of nitrogen year^{-1} and 128-636 t of phosphorus year^{-1} by Abery et al. (22). In the Saguling reservoirs in Indonesia, for cage systems in which *Cyprinus carpio* L. and *Oreochromis niloticus* were cultured (FCR: 8.4), nitrogen and phosphorus loads for 1997 were 1970 t and 263 t, respectively (23). The nitrogen- and phosphorus-load values determined in the present study of rainbow trout cultured in cages in Kesikköprü Dam Lake were lower than the values determined by Abery et al. (22) and Hart et al. (23).

The phosphorus needs of different fish species vary, and for rainbow trout the value is 0.7% (23). Dominguez et al. (5) stated that the nutrient element level in fish feed is generally 6%-9% N and 1.1%-1.6% P. Mires (7) stated that the phosphorus content of fish feed varies between 0.5% and 1.5%. Phosphorus level of the pelleted and extruded feed used in the present study varied between 0.96% and 1.24%, lower than the values reported by Yıldırım and Korkut (24), but similar to the values reported by other researchers. The measured nitrogen content of the pelleted and extruded feeds used in the present study is in agreement with Mires (7.8%-8.1%) (7).

In the scope of this study, FCR in the pelleted feed subgroups varied between 1.27% and 1.38%, and the phosphorus level was 1.24%. In the extruded feed subgroups FCR was 1.25 and the phosphorus level was 0.96% (Table 1). The phosphorus levels of the feeds that were used and FCRs in the farms directly affected phosphorus loads; for each t of pelleted feed used, mean phosphorus load (kg) released into the dam lake was 8.60, while with extruded feed, this value was 6.09.

In conclusion, quantitative data were obtained concerning nitrogen and phosphorus loads arising from rainbow trout culturing in cages in Kesikköprü Dam Lake. On the basis of these data, in order to ensure the sustainability of aquaculture in cages, which is becoming more widespread in Turkey's inland waters, and to reduce the effects of cage-culturing on eutrophication to a minimum, decreasing nitrogen and phosphorus loads released into the environment from cage farms must be considered necessary for the implementation of an environmentally friendly cage culture-environment interaction. Accordingly, the main feature of such implementation should be an increase in the use of extruded feed.

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