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Comparison of Nutritıonal Composition, Mineral and Heavy Metal Content of Rainbow Trout from Different Aquaculture Systems

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Abstract: In this study, proximate compositions, meat yields, mineral matter (Na, Mg, Ca, K), and heavy metal (As, Fe, Zn, Se, Mn, Co, Cu, Pb, Ni) contents of rainbow trout (*Oncorhynchus mykiss*) obtained from concrete pond systems and dam lake net cage were examined. Mineral and heavy metal contents were measured by ICP-OES instrumental analyser. According to the results of rainbow trout meat yield and nutritional composition analysis varied between; meat yield were 57.43-66.40%, crude protein were 16.99-19.93%, crude fat were 3.07-4.18%, crude ash were 0.98-1.58%, and moisture contents were 75.10-77.65%. Mineral contents of Ca 2.66-30.58 $mg.kg^{-1}$, Na 19.53-36.04 $mg.kg^{-1}$, K 252.79-310.05 $mg.kg^{-1}$, and Mg 120.75-137.44 $mg.kg^{-1}$ were detected in the presented ranges. Detected heavy metals were As 0.42-0.56 $mg.kg^{-1}$, Fe 2.16-3.69 $mg.kg^{-1}$, Zn 2.67-4.69 $mg.kg^{-1}$, and Se 0.17-0.77 $mg.kg^{-1}$. On the other hand, Mn, Co, Cu, Pb, and Ni were not detected. As a result of the study, it was found that the proximate composition, meat yield, mineral matter, and heavy metal contents of rainbow trout vary depending on the location and size of the fish ($p<0.05$). However, the heavy metal levels detected in muscle tissue did not exceed the consumption limits.

Keywords: Aquaculture systems, proximate composition, *Oncorhynchus mykiss*, mineral, heavy metal accumulation.

Farklı Akuakültür Sistemlerinde Yetiştirilen Gökkuşağı Alabalıklarının Besin Kompozisyonu Mineral Madde ve Ağır Metal İçeriklerinin Tespiti

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Öz: Bu çalışmada, farklı akuakültür işletmelerinden farklı büyüklüklerde temin edilen Gökkuşağı alabalıklarının (*Oncorhynchus mykiss*) besin kompozisyonları, et verimleri, mineral madde (Na, C, K, Mg) ve ağır metal (As, Fe, Zn, Se, Mn, Co, Cu, Pb, Ni) birikimleri incelenmiştir. Mineral madde tespiti için yaş yakma yöntemi uygulanmış ve ICP-OES enstrümental analiz cihazı ile ölçülmüştür. Gökkuşağı alabalığının et verimi ve besin kompozisyonlarından ham protein, ham kül, ham yağ, su analiz sonuçları sırasıyla; %57,43-66,40; %16,99-19,93; %0,98-1,58; %3,07-4,18; % 75,10-77,65 aralığında tespit edilmiştir. Mineral madde içeriklerine bakıldığında Ca 2,66-30,58 mg/kg, Na 19,53-36,04 mg/kg, K 252,79-310,05 mg/kg ve Mg 120,75-137,44 mg/kg, olarak bulunmuştur. Tespit edilen ağır metaller ise As 0,42-0,56 mg/kg, Fe 2,16-3,69 mg/kg, Zn 2,67-4,69 mg/kg, ve Se 0,17-0,77 mg/kg olarak bulunmuştur. Diğer yandan Mn, Co, Cu, Pb ve Ni tespit edilememiştir. Araştırma sonunda farklı işletmelerden alınan gökkuşağı alabalıklarının besin kompozisyonu, et verimi, mineral madde içeriği ve ağır metal birikimi balıkların büyüklükleri ve avlandığı yere göre değişim göstermiştir ($p<0,05$). Ayrıca kas dokudan yapılan ağır metal analizleri sonuçlarına göre ağır metal birikimlerinin limitlerin altında olduğu tespit edilmiştir.

Anahtar kelimeler: Yetiştiricilik sistemleri, besin kompozisyonu, *Oncorhynchus mykiss*, mineral madde, ağır metal birikimi.

INTRODUCTION

Rainbow trout (*Oncorhynchus mykiss*), a member of the Salmonidae family, is a widely farmed species in the world and Türkiye. *O. mykiss* has been globally cultivated for about 120-130 years, and its farm production emerged in the US. Since then, it has been farmed in nearly all regions. The practice was initiated both for the need for fresh fish and fish stocking in cold streams, rivers, and lakes (Tekelioğlu, 2005). Although rainbow trout are traditionally cultured in ponds, farming in inland waters, dam lakes, and net cages has developed rapidly. Rainbow trout production in the world is 960 thousand tonnes in inland and coastal fisheries, while in Türkiye, it ranks second, following sea bass with 152 thousand tonnes (FAO, 2020; TurkStat, 2021).

While many trout farms practice breeding through their own hatchery during the natural spawning period, some farms continue their production out of season, either by purchasing eggs from abroad or via photoperiod. Thus, they continue production in summer and utilize their operating capacity and resources most efficiently. Depending on the water temperature, it takes 10-12 months to reach the portion size of 250-300 g live weight. Approximately 90-95% of trout production in inland waters is based on portion-sized production. Some farms produce bigger trouts (at least 1 kilogram). However, the literature suggests that growing trout to bigger sizes is not profitable for all farms (Çelik, 2013).

Rainbow trout farms are generally established on land; most operate in concrete ponds, and very few operate in earthen ponds. In addition, there are net cage farms operating in dam lakes (Tekelioglu, 2005; Çelik, 2013). Using net cages has paved the way for aquaculture development and new technologies (Emre et al., 2011). It is essential to consider factors such as land, water quantity, and climate when choosing pond types that vary depending on fish species in trout farming, and it is also crucial to determine the most suitable sizes. In particular, narrow and long, channel-type ponds, where water velocity is high, oxygen is abundant, and substances that may cause pollution are eliminated quickly, are used (Çelik, 2013). The nutritional quality of rainbow trout, which ranks first among the aquaculture products farmed in Türkiye, recently in particular, is as important as the farming conditions.

Minerals such as calcium, phosphorus, magnesium, sodium, potassium, sulfur, chlorine, iron, copper, cobalt, iodine, manganese, zinc, molybdenum, selenium, and fluorine play an influential role in biological functions in fish containing more than 90 elements present in nature (Akyurt, 1994; Küçükgülmez, 2005).

Due to the increase in industrialization and climate change, we see domestic wastes, industrial wastes, and other pollutants spreading to our water resources and posing a danger. The most noteworthy characteristic of these pollutants is that they cause water toxicity. Among these, heavy metals at acceptable limits have a positive impact on organisms in terms of vital functions; however, they pose a danger when they are above certain limits and have adverse effects (Gündoğdu and Erdem, 2008).

Inorganic substances such as heavy metals and metal compounds accumulated in the sediment are considered potential pollutants when present in excessive amounts (Dökmeci, 2005). Due to the outcomes of heavy metals caused by water pollution, it is seen that organisms in inland water and marine ecosystems have become a threat to human health, and this substance transmission between organisms occurs through the food chain (Meroka, 2010; Yıldırım, 2013; Sönmez et al., 2018). Metals, which must only be present in food products within certain limits, have harmful impacts on humans through food, in addition to their effect on the deterioration and durability of food (Yıldırım, 2013; Sönmez et al., 2016).

Heavy metal accumulation in fish varies depending on metal concentration, exposure time, intake route, environmental conditions (water temperature, pH, hardness, salinity), and internal factors (fish age, feeding habits). Metals not only migrate into fish through food and inhabited water but also the gills and skin. The residence time of metals in the fish depends on the concentration of the environment, the tissue in which they accumulate, their amount, and impact. Heavy metals accumulate in different tissues and amounts even in the same species of fish (Ersoy, 2006; Jezierska, 2006; Kuzu, 2010; Murat, 2015). Heavy metal toxicity varies depending on fish size, water pH, dissolved oxygen, and temperature. Metal levels in fish are typically in the following order: Fe > Zn > Pb > Cu > Cd > Hg, and these levels can be as high as 300 (µg/g) or even significantly higher (Jezierska, 2006). Some heavy metals, especially cadmium (Cd), mercury (Hg), zinc (Zn), copper (Cu), nickel (Ni), chromium (Cr), cobalt (Co), titanium (Ti), iron (Fe), manganese (Mn), silver (Ag), and tin (Sn) are characterized as metals that raise environmental concerns. In addition, arsenic (As) and selenium (Se), called metalloids though they are not metals, are commonly included in this group. Since heavy metals such as arsenic, nickel, zinc, chromium, lead, cadmium, copper, nickel, chromium, lead, cadmium, and copper have toxic effects, they increase the amount of dissolved matter through migration between organisms (Dökmeci, 2005; Ersoy, 2006; Kuzu, 2010; Yıldırım, 2013).

This study aims to determine the meat yield, nutritional composition, mineral matter, and heavy metal contents of Rainbow trout farmed in cages in Kozan Dam Lake and concrete ponds in the higher parts of the Taurus

Mountains. Kozan Dam Lake was built in Adana, on the Kilgen Stream, between 1967 and 1972 for irrigation purposes. The present study aims to determine the meat yield and chemical properties of Rainbow trout, one of the most farmed species in Türkiye, and contribute to the industry and the studies to be conducted on the subject.

MATERIAL AND METHOD

Materials: Rainbow trout (*Oncorhynchus mykiss*) was used as the fish material in the study. The just harvested dead fish were obtained from a net cage trout farm in Adana-Kozan dam lake and concrete ponds in Saimbeyli Pağnik (Kızılçam) village located in the high parts of the Taurus Mountains (Figure 1).

A **B**

Figure 1. A. Dam Lake Net Cage System, **B.** Concrete Pool System.

Small and large dead trout samples obtained from 2 different regions on autumn were stored under ice in styrofoam boxes and brought to the laboratory under a cold chain. The fish were primarily divided into four groups (15 fish in each group) depending on the region where they were caught and their weight (small and large). Groups;

1- Small size Rainbow trout caught from the Dam Lake Net Cage System
2- Large size Rainbow trout caught from the Dam Lake Net Cage System
3- Small size Rainbow trout caught from the Concrete Pond System
4- Large size Rainbow trout caught from the Concrete Pond System

The average length and weight of each group of fish are shown in Table 1.

Table 1. Lenght and weight values of rainbow tout.

Groups	Lenght (cm)	Weight (g)
1	22.46±0.94	180.86±9.07
2	28.45±0.75	426.60±17.07
3	23.45±0.42	183.55±16.55
4	31.00±1.00	448.86±42.23

± Standard deviation (1) Small size and (2) large size rainbow trout caught from the dam lake net cage system; (3) Small size and (4) large size rainbow trout caught from the concrete pool system.

Meat yields were calculated by extracting the fillets of fish whose length and weight measurements were completed. The boneless and skinless meat was homogenized and prepared for nutritional composition, mineral, and heavy metal analyses.

Methods;

Meat Yield and Proximate Analysis: Meat yield was calculated after removing the head, viscera, bones, and skin of the fish. The AOAC (1990) procedures were employed to determine the moisture and ash contents of the fish. The nitrogen content, which was analyzed as per Kjeldahl's method (AOAC, 1990), was converted to estimate the crude protein content. Bligh & Dyer (1959)'s method was used to analyze the lipid content. All analyzes were carried out in triplicate.

Mineral Matter and Heavy Metal Analyses: Homogenized 0.25 g fish meat samples were digested with 10 ml HNO_3 using a microwave digestion system (CEM MARS6) at 200°C for 15 min under 45 bar pressure. The samples were then cooled at room temperature and diluted, and the mineral and heavy metal contents were determined with Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (SpectroBlue, Spectro Analytical Instruments GmbH).

Statistical Analysis: Data were compared with one-way variance analysis (ANOVA). Duncan's multiple range test was employed to determine significant differences at the confidence level of 5%. Statistical analyses were performed using the SPSS software (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Meat Yield and Nutritional Composition of Rainbow Trout Obtained from Different Aquaculture Systems: In the study, meat yield, protein, crude ash, crude oil, and water contents of Rainbow trout samples obtained from aquaculture systems were determined, and the results are presented in Table 2.

Table 2. Meat Yield and Proximate Composition of Rainbow Trout Obtained from Different Aquaculture Systems (%).

(%)	GROUP			
	1	2	3	4
Meat yield	57,43±1,14^{a}	63,17±1,33^{c}	59,16±0,76^{b}	66,40±0,87^{d}
Protein	17,28±0,04^{b}	19,93±0,08^{d}	16,99±0,03^{a}	19,00±0,06^{c}
Lipid	3,07±0,02^{a}	3,82±0,03^{c}	3,55±0,04^{b}	4,18±0,04^{d}
Ash	1,50±0,01^{c}	0,98±0,02^{a}	1,46±0,01^{b}	1,58±0,03^{d}
Moisture	77,65±0,30^{d}	75,10±0,12^{a}	76,90±0,16^{c}	75,44±0.32^{b}

Standard deviation. Different letters within the row denote significant differences ($p< 0.05$).
(1) Small size and (2) large size rainbow trout caught from the dam lake net cage system; (3) Small size and (4) large size rainbow trout caught from the concrete pool system.

The meat yields of small and large-sized Rainbow trout obtained from the net cage system in the lake varied between 57.43-63.17%, whereas the meat yields of Rainbow trout obtained from concrete ponds ranged between 59.16-66.40% (Table 2). In the 2nd and 4th groups, meat yield values increased as the fish size increased.

Similar to the present study, Çelikkale et al. (1998) reported meat yields of rainbow trout and brook trout (*Salvelinus fontinalis*) farmed in fiberglass tanks as 64.80% and 62. 28%, respectively; Dikel (1999) determined the meat yields of freshwater trout and sea trout as 68.68% and 66.93%, respectively; Duman and Şen (2003) determined the meat yield of *Oncorhynchus mykiss* as 60.73%; Kaya et al. (2014) determined the meat yield of river trout as 67.85%.

The protein content of small and large-sized rainbow trout obtained from the net cage system was 17.28% and 19.93%, respectively. The protein values of Rainbow trout obtained from concrete ponds varied between 16.99-19.00%. Protein values of the fish with higher weight in the 2nd and 4th groups were higher compared to other groups ($p<0.05$). Diler and Duyar (1997) reported that the crude protein content of rainbow trout farmed in their study was 21.12%, whereas Çelik and Yanar (1998) reported that the protein content of a 550 g rainbow trout was 19.37-19.71%. Similar results have been reported in various studies on the protein content of rainbow trout (Ertan and Bilgin, 1999; Kiriş and Dikel, 2002: Uysal et al., 2002; Korkmaz and Kırkağaç, 2008).

The fat content of rainbow trout obtained from different aquaculture systems ranged between 3.07-4.18%. The difference in aquaculture systems, the fish size, feed and water temperature differences caused variations in fat content. Similar results were obtained in many different studies on trout (Zincir and Korkmaz, 2004; Oğuzhan et al., 2006; Duman et al., 2011).

When the nutritional composition results of rainbow trout groups in different aquaculture systems are evaluated in general, it is seen that the farming conditions affect the nutrient compositions. Moreover, an increase in nutritional composition was observed as the fish size increased. Therefore, it should be considered that fish size and increase in nutritional composition are correlated in aquaculture (Naeem et al., 2016).

Mineral Compositions of Rainbow Trout Obtained from Different Aquaculture Systems: In the present study, the mineral contents of Rainbow trout obtained from net cages in the lake and concrete ponds were determined, and the results are given in Table 3.

Table 3. Mineral Contents of Rainbow Trout Obtained from Different Aquaculture Systems ($mg.kg^{-1}$)

Minarals	GROUP			
	1	2	3	4
Ca	8,69±0,11^{b}	2,66±0,00^{a}	30,58±0,09^{d}	14,31±0,09^{c}
Na	30,94±0,31^{c}	22,04±0,22^{b}	36,04±0,28^{d}	19,53±0,09^{a}
K	252,79±3,56^{a}	273,51±1,35^{b}	310,05±1,19^{d}	282,31±0,75^{c}
Mg	120,75±0,07^{a}	137,44±0,04^{d}	134,86±0,79^{c}	122,62±0,01^{b}

± Standard deviation. Different letters within the row denote significant differences ($p< 0.05$). (1) Small size and (2) large size rainbow trout caught from the dam lake net cage system; (3) Small size and (4) large size rainbow trout caught from the concrete pool system

The Na value of Rainbow trout obtained from the net cages in Kozan Dam Lake was 30.94 $mg.kg^{-1}$ in small-sized and 22.04 $mg.kg^{-1}$ in large-sized fish ($p<0.05$). The Na values of Rainbow Trout obtained from Saimbeyli concrete ponds were 36.04 $mg.kg^{-1}$ in small-sized and 19.53 $mg.kg^{-1}$ in large-sized fish ($p<0.05$).

The Mg value of Rainbow trout, obtained from net cages in the dam lake, ranged between 120.75 and 137.44 $mg.kg^{-1}$ ($p<0.05$). The Mg values of Rainbow trout obtained from Saimbeyli concrete ponds ranged between 122.62 and 134.86 $mg.kg^{-1}$ ($p<0.05$). Compared to the results of the present study, Çelik et al. (2007) found high Mg content (339.7 $mg.kg^{-1}$) in Rainbow trout.

The Na value of Rainbow trout obtained from the net cages in Kozan Dam Lake was 30.94 $mg.kg^{-1}$ in small-sized and 22.04 $mg.kg^{-1}$ in large-sized fish ($p<0.05$). The Ca values of Rainbow Trout obtained from Saimbeyli concrete ponds were 30.58 $mg.kg^{-1}$ in small-sized and 14.31 $mg.kg^{-1}$ in large-sized fish ($p<0.05$). Çelik et al. (2007) reported the Ca content of Rainbow trout as 126.7 $mg.kg^{-1}$, and another study reported that the Ca value of rainbow trout ranged between 0.014 and 0.016 $mg.kg^{-1}$ (Sirakov, 2015).

The K value of Rainbow trout obtained from net cages in the dam lake was 252.79 $mg.kg^{-1}$ in small-sized and 273.51 $mg.kg^{-1}$ in large-sized fish ($p<0.05$). The K values of Rainbow trout obtained from concrete ponds were 310.05 $mg.kg^{-1}$ in small-sized and 282.31 $mg.kg^{-1}$ in large-sized fish ($p<0.05$).

As a result of the study, it was observed that Mg and K values of Rainbow trout farmed in net cages at the Kozan Dam Lake increased in parallel with the increase in the length and weight of fish, whereas Na and Ca values decreased. In the samples obtained from Saimbeyli concrete ponds, with the increase in length and weight, Na, Mg, Ca, and K values decreased (Table 4.2).

Heavy Metal Contents of Rainbow Trout Obtained from Different Aquaculture Systems**:** Heavy metal contents of Rainbow trout obtained from net cages in the lake and concrete ponds were determined, and the results are given in Table 4.

Table 4. Heavy Metal Concentrations of Rainbow Trout Obtained from Different Aquaculture Systems ($mg.kg^{-1}$).

Heavy Metals	GROUP			
	1	2	3	4
As	0,42±0,03^{a}	0,56±0,00^{b}	0,56±0,02^{b}	NA
Fe	2,54±0,03^{b}	2,50±0,02^{b}	3,69±0,02^{c}	2,16±0,02^{a}
Zn	2,67±0,02^{a}	3,24±,0,03^{b}	4,69±0,02^{d}	3,46±0,00^{c}
Se	0,50±0,04^{b}	0,77±0,03^{d}	0,70±0,01^{c}	0,17±0,01^{a}
Mn	ND	ND	ND	ND
Co	ND	ND	ND	ND
Cu	ND	ND	ND	ND
Pb	ND	ND	ND	ND
Ni	ND	ND	ND	ND

± Standard deviation. Different letters within the row denote significant differences ($p< 0.05$). ND: Not Detection (1) Small size and (2) large size rainbow trout caught from the dam lake net cage system; (3) Small size and (4) large size rainbow trout caught from the concrete pool system

As seen in Table 4, it was observed that the heavy metal contents of rainbow trout in different farming conditions and with different length-weights were Zn>Fe>Se>As in terms of size.

The As value of Rainbow trout obtained from the net cages in the dam lake was 0.42 mg.kg^{-1} in small-sized and 0.56 mg.kg^{-1} in large-sized fish ($p<0.05$). The As values of Rainbow trout obtained from concrete ponds in the Saimbeyli region were 0.56 mg.kg^{-1} in small-sized fish, whereas this value could not be detected in large-sized fish ($p<0.05$). Harkabusová et al. (2009) determined that the As content in rainbow trout (*Oncorhynchus mykiss*) varied between 0.72 and 2.23 mg.kg-^{1} in muscle tissue, and Kuzu (2010) determined the As content in trout to be 0.02 mg.kg-^{1}. In another study, Robinson et al. (1995) determined the As in rainbow trout (*Oncorhynchus mykiss*) as 0.02-0.05 mg.kg^{-1}.

The Fe value of Rainbow trout obtained from net cages in the dam lake was 2.54 mg.kg^{-1} in small-sized and 2.50 mg/kg in large-sized fish ($p<0.05$). The Fe values of Rainbow trout obtained from Saimbeyli concrete ponds were 3.69 mg.kg^{-1} in small-sized and 2.16 mg.kg^{-1} in large-sized fish ($p<0.05$). Although the Fe concentration rates were close to each other in small and large-sized Rainbow trout reared in net cages, the highest ratio and difference were observed in small-sized fish farmed in concrete ponds. Ilhak et al. (2012) reported the highest Fe value of Rainbow trout as 3.10 mg.kg^{-1} in their study. In a similar study, Siemianowska et al. (2015) reported that the Fe values of Rainbow trout cultivated in farms and RAS systems were 3.0 and 3.7 mg.kg^{-1}, respectively.

The Zn value of Rainbow trout obtained from net cages in the dam lake was 2.67 mg.kg^{-1} in small-sized and 3.24 mg.kg^{-1} in large-sized fish ($p<0.05$). The Zn value of Rainbow trout obtained from concrete ponds was 4.69 mg.kg^{-1} in small-sized and 3.46 mg/kg in large-sized fish ($p<0.05$). The variation in Zn content among small-sized fish was observed to be relatively high. The Zn content of small-sized fish obtained from concrete ponds was determined to be the highest compared to other fish. Although it was observed that the Zn values decreased as the size increased in fish obtained from concrete ponds, the contrary was found in fish obtained from net cages. Gökoğlu et al. (2004) reported the Zn value of Rainbow trout to be 9.68 mg.kg^{-1}, whereas Sirakov (2015) reported that the Zn value of Rainbow trout ranged between 0.637 and 1.79 mg.kg^{-1}.

The Se values of Rainbow trout obtained from net cages were 0.50 mg.kg^{-1} in small-sized and 0.77 mg.kg^{-1} in large-sized fish ($p<0.05$). The Se values of Rainbow trout obtained from concrete ponds were 0.70 mg/kg in small-sized and 0.17 mg.kg^{-1} in large-sized fish ($p<0.05$). Although the highest Se concentration was found in the large-sized fish in the dam lake, the Se values increased in parallel with the increase in size and weight of the fish. In fish obtained from concrete ponds, the Se values decreased as fish length and weight increased. In their study, Yabanli et al. (2014) determined the mean Se value of Rainbow trout as 0.62 mg.kg-1. In a similar study, Sarma et al. (2013) reported the Se value of Rainbow trout to be 1.66 mg.kg^{-1}.

The Pb, Mn, Co, and Cu values of Rainbow trout, obtained from net cages in the dam lake, could not be detected in small or large-sized fish. Likewise, the Mn, Co, Cu, Pb, and Ni values of Rainbow trout obtained from concrete ponds could not be detected in small or large-size fish. A study reported heavy metal concentrations of Rainbow trout as Cu 0.87 mg.kg^{-1}, Mn 18 mg.kg^{-1}, and Pb 4.7 mg.kg^{-1} (Vosyliene et al. 2006).

CONCLUSION

This study investigated the nutritional composition, mineral matter, and heavy metal contents of Rainbow trout of different sizes obtained from net cages in the Kozan Dam Lake in Adana province and concrete ponds in Saimbeyli. Nutritional compositions, mineral matter contents, and heavy metal accumulations varied depending on farming conditions and the size of the fish. The data obtained were within the limit values specified in the food codexes. This indicates that the farming type and areas were not exposed to domestic or industrial pollutants. It also suggests that rainbow trout farming, which ranks first among the aquaculture products farmed in Türkiye, for the last few years in particular and significantly contributes to the national economy, is carried out under good circumstances regarding animal welfare and human health. Similar monitoring studies should be continued and expanded to further develop the industry, fulfill animal protein needs, and increase the economic added-value.

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