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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

The health management and medication use in trout farms located in Erzurum province and its districts

Erzurum il ve ilçelerinde bulunan alabalık çiftliklerinde sağlık yönetimi ve ilaç kullanımı

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Abstract: The aquaculture sector is very important both in terms of employment and the contribution of the products obtained to healthy nutrition. In order for this sector to grow at a sufficient speed and at a sustainable level, it is important to determine the diseases and control methods seen in the sector and to take more effective measures in this context. In this study, the level of use of drugs and vaccines currently used in land and dam fish facilities in Erzurum province and districts was determined, information and effective approaches were determined about the infectious diseases of fish in aquaculture environment and the drugs and vaccines used for these diseases. In this context, facility management practices were examined through questionnaires conducted with 41 farm managers in the region. At the end of the study, it was determined that the enterprises used an average of 51.58 kg of medicines, produced with a capacity of 50-100 tonnes and the most preferred water source (59%) was lakes. The enterprises mostly (54%) use open circuit system and 84% use pallet feed and 75% of the production is rainbow trout. The most common diseases are bacterial and fungal infections, parasitic and viral diseases. The preferred medicines are disinfectants, antibiotics, antiparasitics, supplements and fungicides. Although the producers work with 68% capacity, they stated insufficient demand, high costs and diseases as the reasons for this situation. Statistical analyses revealed important findings specific to the region through clustering analysis which identified two different groups on the basis of 22 important criteria. The results, in which the 'Diana' method was determined as the most appropriate clustering approach, provide applicable recommendations for improving facility management strategies. The findings provided detailed information on the drug utilisation patterns of the farms and made it possible to better understand the needs of the enterprises in the region. As a result, this study will provide important contributions not only to the strategic management of enterprises, but also to policy development processes for regional development.

Keywords: Fish disease, medication, control, protection, management

Öz: Su ürünleri sektörü gerek istihdam ve gerekse elde edilen ürünlerin sağlıklı beslenmeye katkısı nedeniyle oldukça önemlidir. Bu sektörün yeterli hızda ve sürdürülebilir düzeyde büyüyebilmesi için sektörde görülen hastalıklar ve mücadele yöntemlerinin belirlenmesi ve bu bağlamda daha etkin önlemlerin alınması önem arzetmektedir. Bu çalışmada Erzurum il ve ilçelerinde bulunan kara ve baraj balık tesislerinde hali hazırda kullanılan ilaç ve aşıların kullanım düzeyleri belirlenmiş, aquakültür ortamında balıkların enfeksiyon hastalıkları ve bu hastalıklar için kullanılan ilaçlar ve aşılar hakkında bilgiler ve etkili yaklaşımlar belirlenmiştir. Bu kapsamda bölgedeki 41 çiftlik yöneticisiyle yapılan anketler aracılığıyla tesis yönetimi uygulamalarını incelenmiştir. Çalışma sonunda işletmelerin ortalama 51,58 kg ilaç kullandıkları, 50-100 ton kapasite ile üretimde bulundukları ve en çok tercih edilen su kaynağının (%59) göller olduğu belirlenmiştir. İşletmeler çoğunlukla (%54) açık devre sistem ve %84 oranında palet yemi kullanmakta olup üretimin %75'ini gökkuşağı alabalığı oluşturmaktadır. En sık görülen hastalıklar bakteri ve mantar enfeksiyonları ile paraziter ve viral hastalıklardır. Tercih edilen ilaçların dezenfektan, antibiyotik, antiparaziter, takviye ve fungusitler olduğu tespit edilmiştir. Üreticiler %68 kapasite ile çalışmakla birlikte bu duruma yetersiz talep, yüksek maliyetler ve hastalıkları sebep olarak ifade etmişlerdir. Yapılan istatistiksel analizler, 22 önemli kriter temelinde iki farklı grup belirleyen kümeleme analiziyle bölgeye özgü önemli bulgular ortaya koymuştur. 'Diana' yönteminin en uygun kümeleme yaklaşımı olarak belirlendiği sonuçlar, tesis yönetimi stratejilerinin iyileştirilmesi için uygulanabilir öneriler sunmaktadır. Elde edilen bulgular, çiftliklerin ilaç kullanım alışkanlıklarına dair detaylı bilgiler sağlamış ve bölgedeki işletmelerin ihtiyaçlarını daha iyi anlamayı mümkün kılmıştır. Sonuç olarak, bu çalışma, yalnızca işletmelerin stratejik yönetimine değil, aynı zamanda bölgesel kalkınmaya yönelik politika geliştirme süreçlerine de önemli katkılar sağlayacaktır.

Anahtar kelimeler: Balık hastalığı, ilaç, kontrol, koruma, yönetim

INTRODUCTION

Aquatic product production is becoming an increasingly significant sector not only due to its importance in nutrition but also because of its contribution to global food security. This sector, which has seen rapid growth in production in recent years, is making a significant impact on the global economy through its growing share in international trade. The export of fish and fish products plays a key role in the economic structure of many countries (Çöteli, 2024).

Technological innovations and the rising demand for fish as an animal protein source are among the primary factors supporting the growth of the sector. With the expansion of the industry, farming methods have become more intensive in order to achieve higher yields (Rico et al., 2012). Today, aquaculture has become the fastest-growing agricultural food production sector in the world and makes significant contributions to the socio-economic development and food

security of many countries. Global aquaculture production practices have transitioned from traditional, extensive methods to intensive and semi-intensive systems, where industrial feeds are used to farm key fish species at higher stocking densities (Assefa and Abunna, 2018; Plant and LaPatra, 2011). In recent years, Türkiye has shown significant progress in aquaculture. As of 2023, aquaculture accounted for 55% of Türkiye's total aquatic product production. Of this aquaculture production, 72% is in marine environments, and 28% is in inland waters. Among marine fish, sea bass and gilt-head bream are the most preferred species, while trout is the most preferred species among freshwater fish. Türkiye is progressing towards becoming one of the leading countries in Europe for aquaculture. Aquaculture in Türkiye has become diversified with the production of various species. Of the species raised in both marine and inland waters, 40% are trout, 29% are sea bass, and 28% are gilt-head bream. Additionally, species like salmon and tuna stand out as high-value products, while local species such as carp, catfish, and crayfish are widely consumed in the Turkish market. These species are in high demand, particularly in European and Asian markets (Çöteli, 2024).

The sustainable growth of the aquaculture sector faces several challenges, with diseases being one of the primary obstacles. Particularly in intensive and semi-intensive farming systems, diseases can lead to significant economic losses. The healthy and disease-free cultivation of fish is a fundamental condition for sustainable aquaculture production. Preventing and controlling fish diseases requires the implementation of measures that minimize losses in this field. This is particularly important in commercial fish farms, where treatment and intervention options are limited (Chong et al., 2011). A large portion of the fish produced in aquaculture is intended for human consumption. However, various reasons have caused significant production losses in the aquaculture sector. The primary cause of these losses is diseases, which lead to job losses and income reductions, negatively affecting farmers' livelihoods. According to studies, nearly half of production losses are caused by diseases, and these losses are more pronounced in developing countries. This is because the majority of aquaculture businesses are located in developing countries. Annual income losses due to diseases are reported to reach as high as 6 billion dollars (Assefa and Abunna, 2018).

The improvement of genetic material (germplasm) and the support of effective management practices, along with the careful use of chemicals, biological products, and veterinary medicinal products (VMPs), play a critical role in ensuring the economic sustainability of the sector. Pharmaceutical products and chemicals have made significant advancements in global human and animal health and livestock production. Similarly, in aquaculture, the use of chemicals, biological agents, and VMPs that improve environmental and health conditions is applied to achieve higher production efficiency. In aquaculture businesses, chemicals, nutritional supplements, probiotics, disinfectants, antimicrobials, and antiparasitic drugs are commonly used to maintain environmental quality, improve health status, promote growth and production, and combat microbial and parasitic diseases (Patil et al., 2022). To reduce infection-related losses in aquaculture, it is important to intervene in each health constraint based on scientifically supported and locally applicable methods (Peeler and Taylor, 2011). Climate change, limited water resources, and growth pressures increase the need for epidemiological approaches to protect aquatic animal health. Based on the principle "prevention is better than cure," focusing on preventing the emergence of diseases is more logical (Romero et al., 2012). In the control of infectious diseases, advanced management practices, movement restrictions, genetically resistant stocks, diet supplements, general immune stimulants, vaccines, probiotics, prebiotics, medicinal plant products, water disinfection, biological control, antimicrobial agents, and movement control are the most effective methods (Kumar et al., 2016).

The main objective of this study is to identify the diseases occurring in fish farming facilities operating in Erzurum province and its districts and to determine the usage rates of vaccines, medications, and disinfectants used for the treatment of these diseases. It is believed that this study will benefit the aquaculture and fishing industry in terms of disease management, treatment methods, cost analysis, sustainability, and awareness.

MATERIALS AND METHODS

Erzurum province has an area of 25,066 km², located between 40° 14' 15" and 42° 33' 35" east longitudes, and 40° 54' 57" and 39° 06' 10" north latitudes, with an approximate surface area of 25,000 km². Erzurum province consists of 19 districts. This study focuses on the medications, antimicrobials, dietary supplements used by fish farms operating in Erzurum province and its districts, their quantities, and the annual fish production capacities. Through interviews and surveys conducted with fish farms, detailed data was collected on the health management practices and production performance of the businesses. The findings will provide significant contributions to evaluating the fish farming practices in the region and the sustainability of these practices. According to official records, there are currently 54 active fish farms in Erzurum province, of which 19 are land-based facilities and 35 are dam-based facilities. The fish farms are located in the districts of Aziziye, Yakutiye, İspir, Oltu, Olur, Pasinler, Pazaryolu, Şenkaya, Tortum, and Uzundere. Rainbow trout, brown trout, and brook trout are cultivated in these facilities.

The study was conducted to cover fish producers operating in Erzurum province (Figure 1). The data were collected through surveys conducted via telephone. The study adopted a census method, and a total of 53 fish producers were contacted. However, due to varying levels of participation from the businesses, 41 facility managers agreed to respond to the survey questions. This was taken into account during the process of evaluating the study's findings, and the data were

processed using relevant analytical methods. The research used a 27-question survey form consisting of both open-ended and closed-ended questions, which were developed by the researchers. Prior to analysis, responses to the open-ended questions were standardized to reduce interpretive variability and ensure a consistent data structure. Synonymous expressions were merged into unified categories, spelling errors were corrected for consistency, and longer responses were examined to extract and classify significant patterns. Additionally, some responses were assigned to multiple codes or thematic groups, facilitating a multidimensional evaluation of the data. This approach aligns with established qualitative coding practices, where similar meanings are grouped under the same code to enhance clarity and analytical depth (Brailas et al., 2023; Hensley et al., 2024).

Figure 1. Map of the fish farms reached in the study

The Shapiro-Wilk test was used to test the normal distribution assumption in the analyses. The homogeneity of the data was examined using the Levene test. It was observed that the continuous variables in the data set did not show normal distribution. Therefore, the Mann-Whitney U test, which does not require parametric assumptions, was preferred when comparing mean differences between groups.

While preparing the graphs, cumulative percentage totals were incorporated in accordance with the principles of Pareto analysis. Pareto Analysis, also known as the Pareto Principle or the 80/20 Rule, is an analytical method used as a rough approach to understand and prioritize the root causes of a problem or situation (Parmenter, 2007). A Pareto diagram typically consists of two elements: vertical bars and a cumulative percentage curve. The bars are vertical columns that represent the factors ranked according to their impact. The cumulative percentage curve is represented by a line illustrating the effects of these bars and the percentage of total impacts. This analysis is commonly applied to identify critical factors essential for productivity improvements or the efficient use of resources (Souza, 2022).

In the preprocessing phase, the dataset was first examined for any missing data. It was found that there was a missing observation in the "medicine" variable, which was addressed using the bagging tree algorithm. This imputation method was chosen due to its ability to handle missing data effectively by generating multiple decision trees and combining them to make predictions (Kuhn and Johnson, 2013).

Subsequently, the dataset was linearized using the Yeo-Johnson method (Yeo and Johnson, 2000). This transformation was applied to stabilize variance and make the data more normally distributed, which is essential for ensuring the reliability of subsequent analyses.

After linearization, all values were normalized to z-scores, standardizing the dataset with a mean of zero and a standard deviation of one to prevent bias in scale-sensitive methods (Brailas et al., 2023).

Clustering is one of the fundamental data mining techniques used to uncover patterns and latent structures in multidimensional datasets. The primary objective of this method is to create a meaningful structure by grouping items within a dataset that share similar characteristics (Kassambara, 2017). Clustering analysis is performed using various algorithms, which are based on features such as distances between data points, density values, or statistical distributions (Toomey, 2014).

In this study, clustering analysis was conducted due to its suitability for identifying underlying patterns and grouping similar items within the dataset. Before proceeding with clustering analysis, the suitability of the dataset for clustering was assessed using the Hopkins test (Hopkins and Skellam, 1954). The Hopkins test is a method employed to determine whether a dataset has a random structure or one conducive to clustering (Banerjee and Dave, 2004). This statistical test evaluates whether a given dataset was generated by a uniform distribution and analyzes the spatial randomness of the data (Kassambara, 2017).

Standard clustering methods are broadly classified into

hierarchical and non-hierarchical techniques. Non-hierarchical approaches aim to find the optimal partition for items in clusters by minimizing a cost function, while hierarchical methods iteratively merge (agglomerative) or split (divisive) clusters, producing a sequence of partitions. Traditional clustering methods are termed "hard" clustering, where each item is assigned to a single cluster. In contrast, fuzzy and model-based clustering allow more flexibility, termed "soft" clustering (Giordani et al., 2020). Agglomerative clustering (e.g., Agnes) builds clusters bottom-up by merging the most similar ones, while divisive clustering (e.g., Dıana) works top-down, splitting the most heterogeneous clusters (Kassambara, 2017).

Center-based algorithms, such as k-means, k-medoids Pam and Clara are effective for large datasets. K-means minimizes the total within-cluster sum of squares but is sensitive to outliers. Pam, uses medoids instead of means, offering robustness against noise. Clara extends Pam by sampling subsets of data to improve scalability (Gan et al., 2020). Model-based clustering assumes data are generated by probabilistic processes, modeling clusters as components of a mixture model. Parameters are estimated using the Expectation-Maximization algorithm, and cluster validity is assessed using Bıc (Kassambara, 2017).

For the clustering analysis, the Ward.D2 method was applied in conjunction with the Euclidean distance metric. The Ward.D2 method was chosen for its effectiveness in minimizing the variance within clusters while maximizing the variance between them. Euclidean distance was used as the similarity measure to calculate the distance between data points, enabling the identification of natural groupings within the data (Charrad et al., 2014; Kassambara, 2017).

In this study, the “NbClust” package in R was used to determine the optimal number of clusters by considering various indices. Clustering analyses were conducted using seven different consistency criteria, including internal consistency and stability. Hierarchical clustering, k-means, Dıana, Pam, Clara, Agnes, and model-based clustering methods were applied. These procedures were performed using the “clValid” package in the R statistical programming environment. Analyses were conducted in R (v4.2.2) using packages such as dplyr, ggplot2, NbClust, mclust, and clValid. Code implementation was adapted from Duman (2024).

RESULTS

Both the quantitative and qualitative aspects of the survey data were descriptively analyzed. The duration of activity of the participating businesses ranges from 1 to 22 years (Figure 2). The average number of years in operation is 7.29 years, with a standard deviation of 5.58 years. According to the results of the Shapiro-Wilk test, no statistical evidence was found to suggest that the data follows a normal distribution (W=0.820; p<0.001). It was found that the annual effective capacity amounts of the businesses showed a wide range of distribution. Among the participating businesses, there are fish farms of different scales, producing between 10 tons and 1500 tons of fish annually. The average effective capacity is 199.49 tons, with a standard deviation of 308.19 tons. However, it was determined that these data do not conform to a normal distribution (W=0.610, p<0.001).

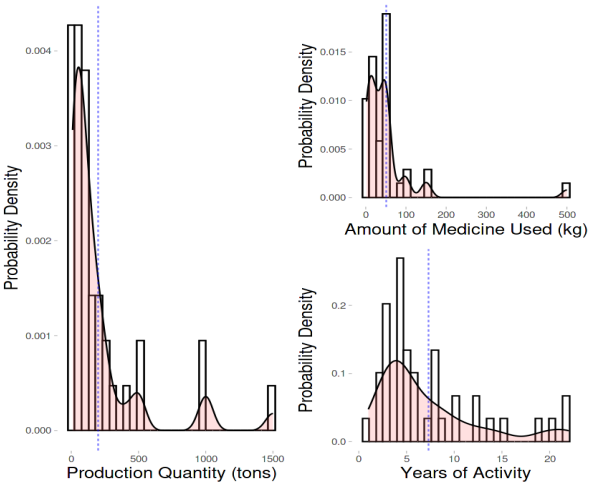

Figure 2. Histogram charts of quantitative variables

In terms of the amount of medication used, a high variation and a wide range [2-500 tons] were observed, similar to the variation in business sizes. The average amount of medication used was calculated to be 51.58 kg, with a standard deviation of 81.10 kg. Additionally, according to the results of the Shapiro-Wilk test, it was determined that the data does not follow a normal distribution (*W=0.493, p<0.001*). It was observed that the data for all three variables (the establishment year of the business, annual production quantity, and the amount of medication used) did not follow a normal distribution. When examining the districts where the businesses are located, it was determined that 34% of the participants operate in Oltu, 20% in İspir, 16% in Aziziye, 11% in Olur, 7% in Tortum, 5% in Pasinler and Yakutiye, and 2% in Pazaryolu. Furthermore, it was found that three businesses operate in multiple districts.

Survey participants were asked about the theoretical capacity of their businesses. It was determined that 7% of the businesses have a production capacity of 0-10 tons (n=3), 15% have a capacity of 10-50 tons (n=6), 61% have a capacity of 50-100 tons (n=25), and 17% have a capacity of over 100 tons (n=7). These data show that a large portion of the businesses are concentrated in the 50-100 ton capacity range. According to the research results, the most common source for meeting the water needs of businesses is lakes. 59% of the participating businesses indicated that they mainly meet their water needs from lakes. Rivers follow with 22%, and groundwater accounts for 12%. Other sources make up 7% in total.

54% of the participating businesses reported using the open circuit system. This system is followed by other systems with 44%, and the closed circuit system ranks third with the lowest percentage of 2%. Looking at the cumulative values, almost all businesses (98%) use either the open circuit or other

systems. The findings revealed that the dominant production type is rainbow trout, which constitutes approximately 75% of total production. Rainbow trout is followed by brown trout, other trout species, and brook trout. These results indicate that rainbow trout is the dominant species in trout production in Erzurum. This situation may have been influenced by various factors, including the physical and chemical properties of the ecosystem, as well as production strategies applied in the past.

68% of the participants stated that they are unable to fully utilize their production capacities, while 32% reported that they are utilizing it fully. When examining the reasons for not reaching theoretical capacity, 41% of the participants (n=24) cited insufficient demand, 32% (n=19) pointed to high costs, and 20% (n=12) mentioned that diseases prevent them from reaching theoretical capacity. The remaining 7% (n=4) highlighted other various reasons.

When evaluating the annual production changes over a five-year period, 35% of the participants (n=14) reported a 35% decrease in production, while 32% (n=13) expressed a 32% increase in production. The remaining 32% of participants (n=13) reported that the production level remained constant. When examining fish feed preferences, it was found that 84% of the participants (n=36) prefer pellet feed. The proportion of those who prefer other types of feed was found to be 12% (n=5). Only 5% of participants (n=2) reported using organic feed.

In terms of preferred types of medication, 27.62% of participants (n=29) most frequently preferred disinfectants. Disinfectants were followed by antibiotics at 24.76% (n=26), antiparasitics at 20.95% (n=22), supplements at 15.24% (n=16), fungicides at 10.48% (n=11), and vaccines at 0.95% (n=1). The results of the Pareto analysis show that disinfectants, antibiotics, and antiparasitics are the most frequently preferred types of medication (Figure 3).

When examining the factors affecting the frequency of medication use, 51% of participants (n=32) identified disease frequency, and 46% (n=29) identified preventive measures as the most important determinants. Other factors and legal obligations were mentioned by only 4% of participants (n=2). These findings indicate that disease frequency and preventive measures are the factors that most influence medication use decisions. When asked about the methods of medication application, the most frequently preferred method was adding medication to feed (52%, n=33). This was followed by the method of mixing medication into water (46%, n=29). Injection application was preferred by only 2% of participants (n=1).

When examining the most common fish diseases in the farms operating in Erzurum province over the past year (Figure 4), it was found that *Aeromonas* bacteria and fungal infections were the most prevalent diseases, each accounting for 26.67% (n=16) of cases. These were followed by *Yersinia Ruckeri* infection (18.33%, n=11), parasitic diseases (10%, n=6), and viral diseases (6.67%, n=4). Other diseases made up only 2% of the total cases. When the frequency of these diseases was examined, it was observed that most cases occurred "occasionally" (49%, n=20), but some diseases were reported as occurring "frequently" (39%, n=16). Particularly, *Aeromonas* and fungal infections were defined as "very frequent" in 7% of the cases (n=3). When participants were asked about the methods used to combat diseases, it was found that the most commonly preferred method was medication (40%, n=23). This was followed by preventive measures (18%), vitamin supplementation (14%), vaccination and feed adjustment (9%), disinfection (7%), and isolation with probiotic use (2%). These results indicate that fish farmers prioritize medication when dealing with diseases. However, it was also observed that methods such as preventive measures, vitamin supplementation, and vaccination were significantly used. Specifically, feed adjustment and disinfection can be considered critical methods in disease prevention. Additionally, the use of alternative methods for disease control was examined. While 72% of participants (n=29) stated that no alternative methods other than medication were used, 28% (n=11) indicated that such methods were employed.

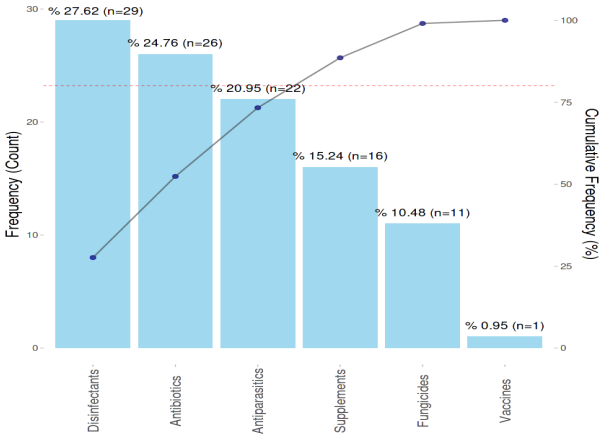

Figure 3. Types of medications most frequently used in fish farms

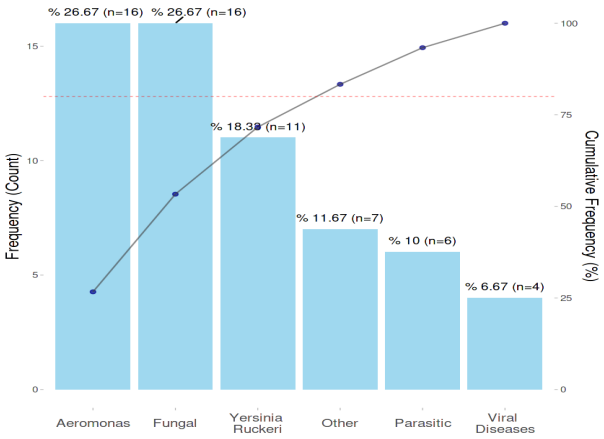

Figure 4. Common fish diseases

When the preventive measures taken by participants for fish health and production efficiency were examined, appropriate feeding (32.14%, n=18) emerged as the most

common practice, followed by hygiene and water quality measurement (16.07%, n=9). Other preventive measures included capacity-appropriate production (7.14%, n=4), disinfection (5.36%, n=3), medication (5.36%, n=3), isolation (5.36%, n=3), vitamin supplementation (5.36%, n=3), egg quality (3.57%, n=2), and others (3.57%, n=1). Based on the evaluation of the findings, feeding emerged as a key factor; a large portion of participants indicated that appropriate feeding is essential for fish health. This reflects the direct impact of nutritional balance on the growth, development, and disease resistance of the fish. Hygiene and water quality measurement were also commonly used as important preventive measures, indicating that farmers are aware of the impact of water quality on fish health (Figure 5).

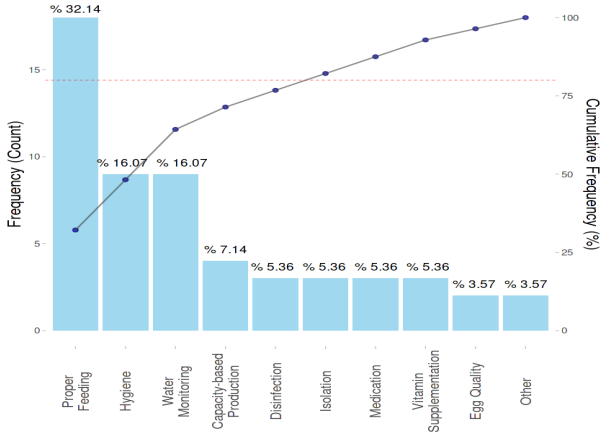

Figure 5. Preventive measures implemented for fish disease management

The current study did not include data on the frequency and parameters of water quality measurements or specific details about the disinfection process, including items subjected to disinfection and substances used. These factors are crucial in understanding the influence of environmental conditions on disease occurrence and spread in trout farming. Future research should focus on these aspects to provide a more comprehensive understanding of the interplay between water quality, disinfection practices, and disease management.

The widespread practice of capacity-appropriate production highlights that fish density is critical for healthy production, preventing fish from experiencing stress and the increase of diseases. Disinfection and medication are commonly used methods for controlling diseases, but it should be noted that excessive use of medication could lead to issues such as antibiotic resistance.

The responses to the open-ended question "What are your suggestions for improving fish health and production in your farm?" have been categorized and standardized under six main thematic groups: Feeding and Nutrition, Health and Hygiene, Environmental and Production Conditions, Marketing and Economic Factors, Production Strategies, and Support and Policies. Each response contains suggestions associated with these groups, and one response may cover multiple groups (Figure 6). For example, suggestions such as using quality feed (Feeding and Nutrition) and ensuring hygienic conditions (Health and Hygiene) to improve fish health have been evaluated simultaneously. This standardized approach allows for a systematic analysis of the responses and ensures that the suggestions are more effectively assessed in practice, contributing to the development of more effective strategies for increasing production efficiency and ensuring sustainability in fish farms.

According to the Pareto analysis, Health and Hygiene (29%), Feeding and Nutrition (27%), and Marketing and Economic Factors (24%) account for a total of 80% of the impact. The remaining three factors Production Strategies (11%), Environmental and Production Conditions (8%), and Support and Policies (2%) represent only 20% of the total impact. This analysis indicates that when prioritizing areas for improvement in fish farms, special attention should be given to Health and Hygiene, Feeding and Nutrition, and Marketing and Economic Factors. These three areas have been perceived by farm managers as the most critical factors affecting performance and production on the farms.

When participants ranked the biggest challenges in the sector, the main issues identified were costs (37%), diseases (34%), market competition (22%), and other factors (7%). These findings indicate that the main challenges in the sector stem from cost pressure, health issues, and competitive conditions. Rising feed, energy, and labor costs have been predicted to increase production costs and reduce profit margins, while fish diseases can lead to both production losses and cost increases. Increased market competition may lead producers to sell at lower prices, thus reducing their profit margins. Furthermore, seasonal fluctuations, raw material supply, environmental regulations, and changes in consumer preferences should also be considered as factors that could affect the challenges in the sector.

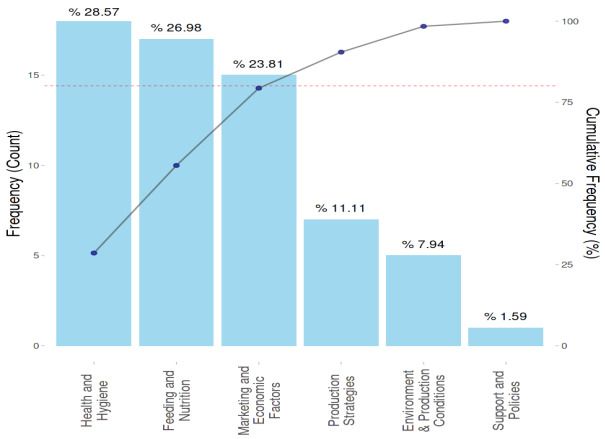

Figure 6. Suggestions for improving fish health and production on the farm

When the open-ended question "Which diseases do you use vaccines for?" was subjected to content analysis, it was found that 66% (n=21) of the participants did not use any vaccines. Among the participants who used vaccines, the most commonly reported vaccines were for *Yersinia Ruckeri* (45%, n=5), vaccines for all diseases (27%, n=3), *Aeromonas* (18%, n=2), and parasites (9%, n=1). When evaluating all participants, the vaccine usage rates for *Yersinia Ruckeri* (16%, n=5), vaccines for all diseases (9%, n=3), *Aeromonas* (6%, n=2), and parasites (3%, n=1) were identified. This study relies on subjective responses from business owners, which may lead to misclassifications or misunderstandings, such as claims of using vaccines against parasites an option not currently available in routine aquaculture.

When the responses of the participants in the study were examined regarding the challenges they faced in obtaining medications and vaccines, it was found that cost (64%, n=21) emerged as the most significant barrier. Other factors such as the procurement process, lack of qualified personnel, insufficient knowledge, indifference, and usage preferences were also frequently mentioned challenges by the participants (24%, n=8). Additionally, 12% (n=4) of the participants stated that they did not encounter any difficulties in this regard.

In the evaluation of the use of natural or herbal medicines in the farms, the vast majority of participants (%76) reported that they do not use such medicines. However, a significant proportion (%24) prefers natural or herbal medicines. Among those who use natural or herbal medicines, the most commonly preferred product is salt, with a rate of %47 (n=9). This is followed by clove oil at %26 (n=5) and other products (such as mint, lemon, garlic, etc.) at %26 (n=5). Before starting the clustering process, the data underwent certain preprocessing steps. First, the dataset was checked for any missing data, and it was found that there was a missing observation in the "medicine" variable. This missing observation was completed using the bagging tree algorithm. The data was then linearized using the Yeo-Johnson method, and all values were normalized by converting them into z-scores.

As a result of the clusters analysis, based on the suggestion of 7 different indices, the optimal number of clusters was determined to be 2. Additionally, in the evaluations made to select the best clustering method, the "diana" method, indicated by 3 measures according to the majority rule, was preferred. The silhouette plot for the clusters showed that the clusters are consistent and distinct (Figure 7).

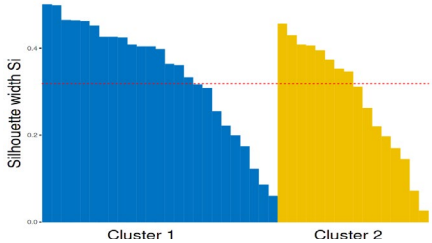

Figure 7. Silhouette chart

The mean differences of the continuous variables between the clusters in the dataset were examined using the Mann-Whitney U test, as it was determined that these variables do not exhibit a normal distribution. As a result of the examination conducted for the obtained clusters, it was found that the mean differences of these variables between the clusters are statistically significant. Descriptive statistics for these variables are presented in the table below for Cluster 1 and Cluster 2 (Table 1).

Table 1. Examination of continuous variables between clusters

Variable	Cluster 1	Cluster 2
Farm service duration (years)	9.48^{a}±6.06	3.88 ±1.96
Actual production capacity (tons/year)	305.00^{a}±357.98	34.62^{b}±26.58
Drug consumption (kg/year)	75.40^{a}±95.20	11.87^{b}±9.23

No statistically significant difference was found between the means of the clusters with the same letter group (α=0.05).

These statistics clearly show the magnitude of the differences between the groups. The means of the farm service duration, actual production capacity, and drug consumption variables are higher in Cluster 1 compared to Cluster 2. This indicates that the farms represented by Cluster 1 have a longer service duration, higher production capacities, and greater drug consumption amounts. Therefore, Cluster 1 can be named "Large and Established Companies." Based on the findings, it is expected that these farms are generally well-established, large-scale, and corporate entities. Cluster 2, on the other hand, can be named "Small and Newly Established Companies." This cluster includes farms with shorter service durations and lower production capacities.

When examining the geographical distribution of the clusters (Figure 8), it was observed that the farms in the "Large and Established Companies" cluster are concentrated in the Aziziye and Yakutiye regions. Similarly, farms in the "Small and Newly Established Companies" cluster were predominantly located in the Pasinler, Pazaryolu, Olur, and Tortum districts. A more heterogeneous distribution was observed in the İspir and Oltu districts, with a notable concentration of "Large and Established Companies" in İspir.

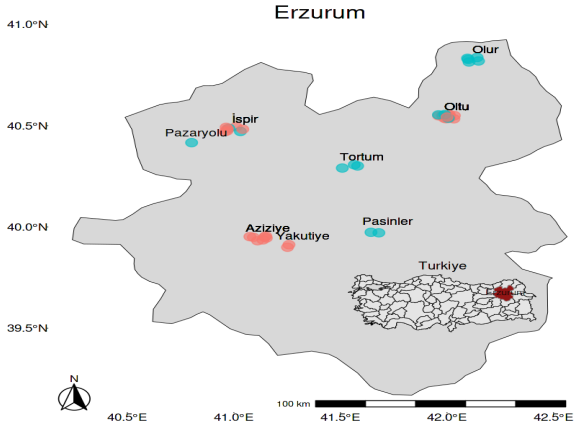

Figure 8. Geographical distribution of the clusters

DISCUSSION

At the and of the study, it was observed that chemical drugs and antibiotics are commonly used in the farms for disease prevention. This raises concerns regarding environmental and consumer health. Similar findings have been reported in other studies; Samanidou and Evaggelopoulou (2007), unconsciously excessive they reported that the use of drugs will lead to accumulation of these drugs in the bodies of fish, destruction of internal organs, resistance of bacteria to these drugs in long-term use and economic losses due to excessive use of drugs. Türk and Oğuz (2013) stated that Türkiye has an important aquaculture potential and when the drug consumption rates are analysed, antibiotics are mostly used in fish farming. Yonar and Sağlam (2013) stated that aquaculture in Türkiye is a rapidly developing sector due to its favourable geographical location and climatic characteristics, but the production potential in aquaculture cannot be fully utilised, sufficient yield level cannot be reached due to feeding errors and diseases, sudden changes in environmental conditions, stress factors such as stock density and the presence of pathogenic microorganisms increase the mortality rate and can cause significant economic losses. Topal (2017) analysed the concentrations of tetracycline and its degradation products in a trout farm and surrounding waters and stated that farm activities may cause antibiotic residues in the environment. Dandi et al. (2024) examined the knowledge, attitudes and practices of fish farmers in Ghana on antibiotic use and found that the level of education had a significant effect on the correct use of antibiotics. Furthermore, improper and indiscriminate drug use can trigger health problems such as bacterial resistance. In the trout farms of Erzurum, production rates were generally found to be satisfactory, although in some farms, production capacity was found to be below potential, and productivity could be improved. This indicates the need for improvements in the management processes of the farms. Similarly, studies conducted in different regions of Türkiye emphasize the need for adopting practices that enhance the productivity of trout farming. Environmental impacts of trout farms, particularly waste management and water use, are discussed. In this context, it is crucial for farm owners to adopt environmentally friendly practices and develop new strategies to protect ecosystems. To increase the efficiency of trout farms and ensure sustainable production, local governments and the Ministry of Agriculture should develop policies and regulations to manage health and drug use. Additionally, promoting biological control methods and organic farming techniques in the farms could reduce the use of drugs. In this regard, increasing educational and awareness programs is also important (Koca et al., 2011). The findings regarding health management, drug use and production rates in the trout farms of Erzurum suggest that existing practices need to be improved. By adopting environmentally friendly and sustainable farming practices, farm owners can enhance productivity and reduce environmental impacts. In the future, regulations and training programs in this field will contribute to moving Türkiye's trout farming sector toward a more sustainable future.

The results of the study indicate that fish farm owners report using vaccines against parasites as part of their disease management practices. However, this finding contrasts with the current state of vaccine availability and usage in aquaculture. At present, vaccines for parasitic diseases are extremely limited. Existing commercial fish vaccines primarily address bacterial and viral pathogens, and no widely available or routinely applied vaccines for parasites exist. The discrepancy observed in the responses may stem from a lack of technical knowledge or misinterpretation of the term "vaccine" by the farm owners. This highlights a critical need for education and outreach efforts to improve understanding of disease prevention tools and their appropriate applications within the aquaculture sector.

CONCLUSION

The phrase "Prevention is more effective than treatment" holds significant importance in the context of fish diseases and health preservation. Disease prevention is not limited to treatment with modern vaccines but begins with the proper management of the organisms. The concept, defined as "good care" in mammals, is also applicable to fish management, where it is critical to raise fish in the most optimal conditions. This means maintaining high water quality and planning the necessary steps to achieve this in advance. Additionally, reducing the pathogen load in the water environment is also important. To achieve this, stocking density should be carefully adjusted, fish should be sourced from "clean" sources, ponds should be regularly emptied and cleaned, and "clean" feed should be used. In marine aquaculture, the cyclical use of farming areas and the proper disposal of dead fish play a key role in maintaining a clean environment. These measures are fundamental strategies to protect fish health and prevent the spread of diseases (Chong et al., 2011).

The results of this study provide detailed descriptive information about the drug usage habits of rainbow trout production farms operating in Erzurum province. Cluster analysis identified two main clusters, referred to as "Large and Established Companies" and "Small and Newly Established Companies." It was observed that the farms in the "Large and Established Companies" cluster are concentrated in the Aziziye and Yakutiye regions, while farms in the "Small and Newly Established Companies" cluster are primarily located in the Pasinler, Pazaryolu, Olur, and Tortum districts. Cluster analysis helps better understand the needs and characteristics of businesses in the region, offering significant advantages from a strategic, economic, and operational perspective. Public institutions and sectoral support organizations can develop broader incentives for large enterprises and support programs focused on training, guidance, and modernization for small businesses based on these analysis results. Additionally, identifying the resource needs of businesses allows for more efficient resource allocation. Cluster analysis can also contribute to monitoring the overall health of regional economic activities and the development of growth strategies, while fostering cooperation between businesses and enabling them

to gain competitive advantages. In terms of risk and crisis management, this analysis enables businesses to understand their risk profiles and provides valuable information, such as larger firms being more resilient to crises and smaller firms being more vulnerable.

This study also underscores the importance of addressing knowledge gaps among aquaculture practitioners, as misconceptions about available disease control measures can lead to ineffective practices and hinder advancements in disease management strategies. Future studies should aim to validate self-reported data and investigate the factors contributing to these misinterpretations to enhance disease control practices and support sustainable aquaculture development.

In conclusion, it can be said that the clustering analysis conducted in this study provides valuable contributions not only to the strategic management of businesses but also to the policy development processes for regional development. The findings allow for targeted planning for the growth and development of businesses.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no financial interests or personal relationships that could influence this work.

AUTHOR CONTRIBUTIONS

Study design, literature review, methodology, data collection: Naime Filiz Karadaş, Hakan Duman. Data analysis: Hakan Duman. Writing the article: Naime Filiz Karadaş, Köksal Karadaş. Supervision: All authors have approved the final draft.

ETHICAL APPROVAL STATEMENT

As this study involved a survey, the necessary Ethical Committee Approval (no. 2024/28) was obtained from Iğdır University.

DATA AVAILABILITY STATEMENT

The data used in this study can be obtained from the corresponding author upon reasonable request.

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