

Factors Affecting Sperm and Egg Quality in Trout (*Oncorhynchus mykiss*) Culture

Alabalık (*Oncorhynchus mykiss*) Yetiştiriciliğinde Sperm ve Yumurta Kalitesini Etkileyen Faktörler

Mustafa DOĞAN¹ 

¹Tuzla Mah. Fethiye, Muğla, TÜRKİYE



ABSTRACT

The aim of this review is to examine the factors affecting sperm and egg quality in trout (*Oncorhynchus mykiss*) and to evaluate the effects of these factors on reproductive success. In particular, nutrition, environmental conditions, stress and age on sperm and egg quality have been investigated. Several factors affecting sperm and egg quality in trout have been compiled in a certain order. The effects of parameters such as genetic factors, nutrition, environmental conditions, stress and age on sperm and egg quality, and strategies and methods for improving them were evaluated. The main determinants of sperm and egg quality are genetic factors. Therefore, genetic improvement programs can enhance sperm and egg quality. In addition, nutrition and diet have a significant impact on sperm motility and egg health. Nutrients such as omega-3 fatty acids and vitamins can improve quality. Factors such as environmental conditions, water temperature and pH affect sperm and egg quality. Stress factors and age can negatively affect sperm and egg quality. Strategies such as genetic selection, appropriate nutrition, environmental optimization, and hormonal regulations are recommended to improve the quality of sperm and egg in trout. In future studies, more factors affecting sperm and egg quality need to be examined and improvement methods need to be tested.

Keywords: Trout, sperm, egg, genetic, nutrition

Öz

Bu derleme, alabalıklarda (*Oncorhynchus mykiss*) sperm ve yumurta kalitesini etkileyen faktörleri incelemeyi ve bu faktörlerin üreme başarısına olan etkilerini değerlendirmeyi amaçlamaktadır. Özellikle genetik, beslenme, çevresel koşullar, stres ve yaş gibi etkenlerin sperm ve yumurta kalitesine olan etkileri araştırılmıştır. Alabalıklarda sperm ve yumurta kalitesini etkileyen çeşitli faktörler belirli bir düzen içinde derlenmiştir. Genetik faktörler, beslenme, çevresel koşullar, stres ve yaş gibi parametrelerin sperm ve yumurta kalitesi üzerindeki etkileri, iyileştirilmesine yönelik stratejiler ve yöntemler değerlendirilmiştir. Sperm ve yumurta kalitesinin asıl belirleyicisi genetik faktörlerdir. Bu nedenle genetik iyileştirme programları, sperm ve yumurta kalitesini artırabilir. Bunun yanında beslenme ve diyet, sperm motilitesi ve yumurta sağlığı üzerinde önemli bir etkiye sahiptir; omega-3 yağ asitleri ve vitaminler gibi besin maddeleri kaliteyi iyileştirebilir. Çevresel koşullar, su sıcaklığı ve pH gibi faktörler, sperm ve yumurta kalitesini etkiler. Stres faktörleri ve yaş, sperm ve yumurta kalitesini olumsuz yönde etkileyebilir. Alabalıklarda sperm ve yumurta kalitesini artırmak için genetik seleksiyon, uygun beslenme, çevresel optimizasyon ve hormonal düzenlemeler gibi stratejiler önerilmektedir. Sonraki yapılacak araştırmalarda, sperm ve yumurta kalitesini etkileyen daha fazla faktörün incelenmesi ve iyileştirme yöntemlerinin test edilmesi gerekmektedir.

Anahtar Kelimeler: Alabalık, sperm, yumurta, genetik, beslenme

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Sorumlu Yazar/Corresponding author:

E-mail: tamdogan02@hotmail.com

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1. Introduction

Trout is an economically and ecologically important freshwater fish species. Trout farming plays a critical role in both the management of freshwater ecosystems and commercial fish production. However, for successful trout (*Oncorhynchus mykiss*) breeding, Trout is an economically and ecologically important freshwater fish species, many biotic and abiotic factors that affect the health of fry and larger fish are effective in the production process of fish. The most important of these factors are environmental, genetic, and physiological factors that affect sperm and egg quality (Sirkecioğlu et al., 2023). Determining sperm and egg quality is a factor that directly affects reproductive success, and many factors play a role in this quality. Water quality, nutrition, genetic factors, and environmental conditions can significantly affect the quality of these two reproductive materials (Maral Beşlioğlu, 2023).

Water quality is important at all times of the year, and it plays a critical role during the trout breeding season. Water temperature, pH level, amount of oxygen and other water parameters are the main factors affecting sperm and egg quality. Water quality is important at all times of the year, and it plays a critical role during the trout breeding season. Water temperature can affect the trout's reproductive cycle and sperm production and quality. High temperatures can reduce sperm quality and reduce egg fertilization rates (Jones & Lee, 2018). Likewise, low pH levels and low oxygen concentrations can negatively impact sperm motility and egg development (Harris, 2021). Regular monitoring and control of water quality is important to reduce these negative effects.

Nutrition is another principal factor affecting sperm and egg quality. The diets of trout directly affect their reproductive health and gamete quality. Adequate and balanced nutrition can increase sperm production and ensure the healthy development of eggs. Especially omega-3 fatty acids and vitamins are among the nutrients that support sperm and egg quality (Miller & Adams, 2019; Miller, 2020). Nutritional adjustments can help improve sperm and egg quality and improve reproductive performance.

Genetic factors are also crucial factors affecting sperm and egg quality. Genetic diversity and genetic disorders can determine sperm and egg quality. The genetic structure of the breeding material directly affects the reproductive success and offspring health of the fish. Genetic selection and breeding programs are among the strategies used to improve sperm and egg quality (Moblely et al., 2021). These

strategies contribute to the cultivation of healthy and productive fish.

As a result, there are several factors that affect sperm and egg quality in trout, and effective management of these factors is critical for successful trout farming. This article aims to compile the current knowledge on this subject and make recommendations for future research by examining in detail the environmental, nutritional, and genetic factors affecting sperm and egg quality in trout.

1.1. Trout Farming

Trout is one of the most cultivated species today and has an important economic value. It is produced in cold and clean waters, especially far from the settlements of the countries where it is cultivated (Liu et al., 2020). Trout is cultivated in different water sources (dams, streams, and artificial lakes) for both commercial and sport purposes. Cultivation makes trout more attractive with its high productivity and short production period (Smith & Jones, 2018). However, environmental effects in trout farming; factors such as water quality, seasonal changes, ecosystem balance and use of source waters play a critical role in these interactions (Miller & Adams, 2019; Smith, 2021). Rainbow trout is a species adapted to cold water conditions. Factors such as water temperature, oxygen level and ammonia should be carefully controlled during the cultivation of this species. The optimal temperature range is between 12-16°C, and if this level is exceeded, metabolic stress increases and growth rate decreases (Brett, 1956).

Biotechnology has provided significant developments in trout farming in recent years. Genetic improvement programs increase disease resistance, while selective breeding strategies optimize growth rate. In addition, sperm and egg cryopreservation allows the preservation of genetic material and its worldwide trade (Cabrita et al., 2010). Therefore, an effective farming strategy requires balancing environmental and economic factors.

Bacterial, viral, and parasitic infections are a major problem in closed-circuit systems where rainbow trout are reared. These infections, especially those caused by *Flavobacterium* species, lead to serious production losses (Nematollahi et al., 2003). In addition, fungal infections are particularly problematic during the egg incubation process (Timmons et al., 2010).

1.2. Reproductive Biology and the Concept of Quality

The reproductive biology of trout is important to ensure the sustainability of the species. The reproductive period involves mating and fertilizing of female and male fish

under suitable conditions after reaching puberty (Brown et al., 2021). Sperm and egg production can be achieved by photoperiod application in all year seasons in enterprises where intensive production is conducted. Sperm and egg quality are critical factors that determine reproductive success and efficiency. While sperm quality is measured by the morphology, motility, and concentration of sperm cells, egg quality is evaluated by the size, shape, and maturity levels of the eggs (Johnson, 2018; Johnson & Lee, 2022). These factors will determine the health and growth rate of the fry by affecting fertilization rates and embryo development.

In previous studies, the effects of genetic, environmental, nutritional, and health factors on reproductive success have been examined and evaluated (Taylor et al., 2022; Williams et al., 2023). This review aims to comprehensively examine the factors affecting sperm and egg quality in trout. In addition, detailed information about how these factors affect sperm and egg quality will be presented and existing improvement methods will be evaluated.

2. Factors Affecting Sperm Quality

2.1. Genetic Factors

Genetic factors are among the determining factors of sperm quality. The genetic structure of trout affects the morphological characteristics and functional competence of sperm cells (Anderson & Brown, 2020). Genetic variation can lead to significant differences in sperm quality and quantity. While high quality sperm is produced in some individuals, this quality may decrease in others (White et al., 2019; Doğan, 2023). Selective breeding and genetic improvement programs play a vital role in improving sperm quality. Selecting and crossing genetically superior individuals can improve sperm quality (Davis et al., 2022). Such improvement efforts can increase the overall reproductive success and sustainability of the population.

2.2. Nutrition and Diet

The feeding habits of fish directly affect sperm quality (Jones & Lee, 2018). An adequate and balanced diet ensures the preservation of sperm production and quality. Omega-3 fatty acids, vitamins and minerals show positive effects on sperm motility, fertilization ability and morphology (Miller, 2020). For example, it has been found that omega-3 fatty acids increase sperm quality and quantity by supporting the membrane structure and energy metabolism of sperm cells (Smith, 2021). Additionally, antioxidants such as vitamins A and E can improve the

quality of sperm cells by protecting them from the damage of free radicals (Williams & Brown, 2019; White et al., 2019).

2.3. Environmental Conditions

Environmental conditions that affect sperm quality include water temperature, pH, and oxygen levels (Clark et al., 2019). Water temperature has a significant impact on sperm production and motility; Extreme temperatures can deteriorate sperm quality, which negatively affects the morphological and genetic structure and motility of sperm (Roberts et al., 2020). Maintaining water pH and oxygen levels within optimum ranges supports the maintenance of sperm quality (Evans & Miller, 2021). Water pollution and other environmental stressors can also negatively affect sperm quality.

2.4. Stress Factors

In fish, stress can significantly affect sperm quality (Williams & Brown, 2019). Stress factors include excessive stocking density, water temperature, other chemical parameters of the water, diseases, and environmental changes. Stress can reduce reproductive success by reducing sperm production and quality (Taylor et al., 2022). Stress management strategies can improve fish quality of life and preserve sperm quality. For example, stress-reducing measures (stocking density, nutrition, vitamin supplementation) can help reduce fish stress levels and improve reproductive performance (Harris, 2021).

2.5. Age and Health Status

The age and general health of the fish are crucial factors affecting sperm quality (Johnson, 2018). While young fish generally produce fewer but higher quality sperm, older fish may experience a decrease in sperm quality (Adams & Clark, 2020). In addition, the good health of the fish positively affects sperm quality. Diseases and nutritional deficiencies can negatively impact sperm quality (Green & Taylor, 2021). Therefore, it is important to monitor and manage the health of fish.

3. Factors Affecting Egg Quality

3.1. Genetic Factors

Egg quality is greatly influenced by genetic factors (Brown et al., 2021). Genetic structure affects the size, development, and fertilization ability of eggs (White et al., 2019). Genetic improvement programs can help improve

egg quality. Selective breeding and genetic modifications can produce higher quality eggs (Johnson & Lee, 2018). Selecting genetically superior female fish can be effective in increasing egg quality and number.

3.2. Nutrition and Diet

Nutritional factors affecting egg quality are elements such as vitamins, minerals, and fatty acids in the fish's diet (Jones & Lee, 2018). Adequate nutrition positively affects the nutritional value and development process of eggs (Miller, 2020). Omega-3 fatty acids, vitamin A, vitamin E, Selenium and vitamin C are critical in improving egg quality (Smith, 2021). Nutritional supplements increase the egg production capacity of female fish, providing healthier eggs.

3.3. Environmental Conditions

Environmental conditions are one of the key factors affecting egg quality. Water temperature, pH, and oxygen levels directly affect the health and development of eggs (Clark et al., 2019). Optimal environmental conditions ensure proper development of eggs and maintain their quality (Evans & Miller, 2021). Water pollution and other environmental stress factors can lead to a decrease in egg quality and may also inhibit egg production.

3.4. Hormonal Regulations

Hormonal balances are another important factor affecting egg quality. Hormone levels of female fish determine egg production and quality (Roberts et al., 2020). Hormone treatments and adjustments can be effective in improving egg quality. Hormonal irregularities can affect the maturation and fertilization ability of eggs (Williams & Brown, 2019). Therefore, maintaining and managing hormonal balance can improve egg quality.

3.5. Stock Density

Stocking density is an environmental factor that affects egg quality. High stocking density can increase stress levels of female fish, resulting in a decrease in egg quality and quantity (Harris, 2021). Managing stock density according to the volume of the area where the fish are located, the amount of water entering, and the quality of the water can help to preserve egg quality. Proper arrangement of fish habitats and prevention of overcrowding can improve egg quality (Taylor et al., 2022).

4. Methods to Improve Egg and Sperm Quality

4.1. Genetic Selection

In production enterprises, genetic selection is an effective method to increase sperm and egg quality. Selecting genetically superior individuals can increase the reproductive success of fish and improve sperm and egg quality (Anderson & Brown, 2020). Intensive farming practices can cause a decrease in genetic diversity. When the genetic diversity of rainbow trout obtained through farming was compared with natural populations, it was observed that genetic deterioration and productivity losses occurred (Christie et al., 2012). Genetic improvement programs increase reproductive potential and enable the breeding of healthier and more productive individuals (Davis et al., 2022). Genetic selection is of critical importance for long-term sustainability.

4.2. Nutritional Supplements

Nutritional supplements contain vitamins, minerals and fatty acids added to the fish's diet. These supplements may be effective in improving sperm and egg quality (Jones & Lee, 2018). Omega-3 fatty acids and vitamin A can be used to improve quality (Smith, 2021). Regular administration of nutritional supplements supports the reproductive health of fish and improves quality.

4.3. Environmental Optimization

Optimizing environmental conditions can improve sperm and egg quality. Maintaining water temperature, pH, and oxygen levels within ideal ranges is essential to maintain quality (Clark et al., 2019). Environmental improvements can increase reproductive success and support the overall health of fish (Evans & Miller, 2021). Environmental management strategies are important for sustainable fish farming. Water quality issues such as high temperature, low oxygen levels, and pollution are significant constraints to trout farming. Global climate change also complicates this issue, as trout are cold-water species and increasing temperatures are pushing their physiological limits, directly affecting egg and sperm quality (Ficke et al., 2007).

5. Evaluation of Quality

5.1. Laboratory Techniques

Various laboratory techniques are used to evaluate sperm and egg quality. Parameters such as sperm motility, morphology, and concentration are used to determine sperm quality (Davis et al., 2022). Sperm motility measures the mobility of sperm cells, while morphology evaluates the shape and structure of sperm cells. Quality evaluation of eggs is done according to size, shape, and developmental stages (Green & Taylor, 2021). These evaluations show that

it positively affects the fertilization potential of eggs and embryo development.

5.2. Reproductive Success and Productivity

Assessing sperm and egg quality is critical to determining reproductive success and fertility. High-quality sperm and eggs can increase fertilization rates and promote reproductive success (Williams et al., 2023). Productivity indicates reproductive performance and results in fish farming. Efficiency analysis can help optimize reproductive processes and increase economic returns (Johnson & Lee, 2022).

6. Conclusion and Recommendations

This study comprehensively examined various factors affecting sperm and egg quality in trout. The effects of factors such as genetics, nutrition, environmental conditions, stress, and age on sperm and egg quality were highlighted (Williams et al., 2023). Understanding the effects of these factors is important to improve the gamet quality and increase reproductive success.

Several suggestions have been made for trout farmers to improve sperm and egg quality. Strategies such as genetic selection, appropriate nutrition, and environmental optimization can effectively improve gamete quality (Johnson & Lee, 2022; Taylor, 2021). Implementing these suggestions can improve reproductive success and enhance fish farming production.

Genetic engineering and selective breeding techniques enable the breeding of disease-resistant species. For example, gene editing techniques enable the editing of genes that increase immune responses in fish (Wargelius et al., 2016).

Closed-loop systems such as recirculating aquaculture systems (RAS) allow for more efficient use of water and reduced waste discharge. These systems are an important production model to increase the sustainability of trout farming in regions where water resources are limited (Badiola et al., 2012).

The sustainability of feed used in farming is also a prominent issue. Since fish meal and oils are limited resources, alternative feeding methods such as plant-based proteins and oils have been developed (Kaushik et al., 2004).

In future studies, it is recommended to examine more factors affecting sperm and egg quality and test

improvement methods (Davis et al., 2022). In addition, evaluating recent technologies and methods will reveal the potential to increase quality in fish farming, increase production, and contribute to achieving healthy generations. In addition, evaluating recent technologies and methods will reveal the potential to increase quality in fish farming, increase production, and contribute to achieving healthy generations. In addition, evaluating recent technologies and methods will reveal the potential to increase quality in fish farming, increase production, and contribute to achieving healthy generations.

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