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A COMPREHENSIVE REVIEW ROLE OF DIETARY MODIFICATIONS IN ENHANCING THE SUSTAINABILITY OF AQUACULTURE THROUGH THEIR IMPACT ON WATER QUALITY AND NUTRIENT UTILIZATION EFFICIENCY

Fatima Muhammad Abdul-Jabbar[1]
fatima.mohmed95@mu.edu.iq

Dhamea Aliwi Abdul-Hussein Al-Saadi[2]
dhamyaa.o@coagri.uobaghdad.edu.iq

Alhamzah Ahmad Fayyad[3]
alhmazh1995@gmail.com

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ABSTRACT

Protein is the most expensive nutrient in fish feed, while the dietary leeches provided at the initial stages of fish feeding contain high levels of protein, which affects metabolism in early feeding with high nutrition in the diet through the digestive and metabolic capacity of fish importance of artificial nutrition is embodied as the main element in aquaculture projects, whether intensive aquaculture projects or semi-intensive secondary projects in which the nutrition is of good quality to ensure its use in breeding to give productive performance and at the same time protect the aquatic environment aim of the article is to protect the environment by reducing the impact of fish waste on water quality, which leads to a reduction in pollution and enhancing the health of aquatic ecosystems.

Keywords: Fish Farming, Nutrients, Dietary Modifications, Water Quality.

INTRODUCTION

Common carp *Cyprinus carpio* L. belongs to the Cypriniformes order and the Cyprinidae family, which is the most prominent freshwater fish family and is the third most globally bred species, because of its high adaptability to both the environment and food [32]. Fish is an essential and effective pillar in covering an important part of the population's basic needs for meat and eggs, containing a protein content of 13-20% of the wet weight, in Iraq and the world [28]. Carp farming is one of the fastest-growing sectors of food production, playing a significant role in the global capital and enhancing food

[1] College of Physical Education, Al-Muthanna University - Al-Muthanna, Iraq.
[2] College of Agricultural and Engineering Sciences, University of Baghdad, Baghdad, Iraq.
[3] Iraqi Company for Seed Production- Ministry of Agriculture. Baghdad, Iraq.

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production, thereby contributing to food security [22]. The influence of the feeding system on the rate and efficiency of fish growth is a key factor in breeding, so the management of feed in terms of its proportions, feed rates, periods and components of the Bush is an important aspect in the management of farmed fish farming and among all feeding practices, nutrition levels is the primary variable that affects the growth of fish and their nutritional transformation [45]. One of the most important components of the success of fish farming is that artificial feeding is required and necessary in high-intensity aquaculture systems to increase the production rate of farmed fish, as the provision of sufficient quantities of good-quality food leads to faster growth of fish [1]. Nutrition affects the growth, well-being, and physiological functioning of fish. Under natural conditions, especially in a favorable climate, fish nutrition has developed significantly in recent years with the development of new, balanced commercial diets that promote optimal growth and health of fish [22].

Nutrition is an essential element to provide the reasons for the life and sustainability of fish and plays an important role in the growth and reproduction of many developing and developed countries, and contributes to the intake of animal protein in building its system, and its levels vary depending on the season and the physiological state of the fish [41]. Nutrition is based on well-thought-out scientific foundations that are necessary for the economic production and for a high-quality healthy product, in fish farming, nutrition is essential, because feed usually accounts for approximately 70- 76% of the cost of fish production, both in aquaculture projects in earthen ponds and fish farming in floating cages, overfeeding leads to deterioration of water quality, increased labor costs, increased feed quantities, which causes increased cost, and reduced profit [4]. The development of the feed industry supports aquaculture because it meets the growing demand for fish, and integrated diets should provide all the needs (proteins, carbohydrates, fats, vitamins, and minerals) necessary for optimal growth and promote fish health [37].

The nutritional needs of farmed fish are influenced by various factors, including the species, size, environmental conditions such as water temperature, pH, and dissolved oxygen levels, as well as the fish's physiological state and its sensitivity to stress. Since nutrition represents approximately 60–70% of aquaculture production costs, it plays a critical role in establishing a balanced and efficient nutritional system [40]. Nassif and Nasser [27] pointed out that the amount of feed that must be provided depends on the weight of the living mass, if you give more than needed, this leads to a part of the food will not be eaten, leading to a conversion rate. Therefore, it is necessary to accurately calculate the quantities of feed needed by fish, especially fish that are farmed in floating cages and at high densities, because the fish's dependence on processed food only and the excess quantities of it, if not eaten directly by the fish, will drift with the current and cause economic losses to the breeder. One of the most important factors in aquaculture is water quality. Therefore, water quality must be monitored to achieve optimal production in aquaculture, ensure the growth and survival of fish, and provide ideal conditions that vary depending on the type of fish.

1. Relationship between Nutrition and Productive Performance

World is currently witnessing a significant growth in fish farming, despite the existence of differences in the weather and ecosystems of the breeding areas and the different economic level of the communities engaged in this activity, in addition, we note the expansion of farmed areas and increased breeding intensities with the integration of the role of nutrition with production performance, the importance of artificial feeding is embodied as the main element in aquaculture projects, whether intensive farming projects

or semi-intensive secondary projects in which the nutrition is of good quality to ensure its use in breeding to give productive performance and at the same time protect the aquatic environment [36]. Although the feeding of farmed fish is only one aspect, its production is growing faster and more diversified, especially in common carp farming, as a result of local feed processing. When the optimal feed rate is not known to the breeder or has not been determined correctly, there may be an increase in feed costs, which leads to a decrease in economic yield, deterioration of water quality, and, consequently, a decrease in production [2].

The contribution of carp fish farming is through the provision of affordable and available alternatives from multiple low-cost sources. However, due to high feed prices, the excessive use of feed has hindered the growth performance and sustainability of fish farming projects [20]. The feeding of common carp in high densities is more prevalent under intensive farming systems. As the most consumed source of protein in Southeast Asian communities, common carp farming poses numerous challenges for farmers, including water quality issues, high feed prices, and poor environmental conditions [8]. Protein is one of the nutrients that provides the amino acids necessary for muscle formation. It is the most expensive component of the diet in the composition of fish feed and is a significant determinant of fish growth. Proper nutrition enhances the productive performance of these fish, as it contributes to improving the quality of their meat and nutritional components [34].

The relationship between nutrition and production performance is crucial for achieving the production goal. This is achieved by providing nutritionally balanced sources of processed feed, which may contain different food sources or their protein substitutes. Therefore, understanding the actual nutritional requirements of fish is essential for improving commercial aquaculture [41]. Protein requirements also vary depending on the breeding environment, water temperature, and quality, as well as the genotype and feeding rates of fish. Fish use protein to produce energy for sustainability in case of insufficient levels of fats and carbohydrates in the diet and to provide the energy necessary for life [24]. A common strategy of fish feed manufacturers is to use relatively large concentrations of animal and vegetable oil sources to produce meals with a high energy content to increase the feeding efficiency of common carp [9].

1.1 Nutrition Ratios

Scientific research has proved that the growth rate of fish depends not only on the chemical composition of the feed, but also on the management method used for fish farms, the method of providing feed (manual, automatic), feeding times, and the percentage of feed provided [11]. The level of feed rates is important in fish farming, and their different ratios effectively contribute to the growth and production of fish, so fish breeders use a large amount of feed, which makes the feed rate higher and leads to increased nutrition to feed waste, which affects the economic return and the environmental balance [34].

The importance of the feed ratio is due to the frequency of feeding, which increases the efficiency of the digestive system in fish, as the feed passes slowly through the digestive canal and thus increases the efficiency of digestion, absorption, nutrition, and utilization of feed while reducing the resulting waste and waste in small quantities [1]. Determining the percentage of feed provided to aquariums is one of the tasks in the management of breeding, so care should be taken to provide feed according to the proportions for feeding 3-7% to ensure maximum efficiency of food conversion, and achieving the percentage of feed provided to farmed fish helps reduce feed residues and increase the efficiency of food conversion [3]. However, the focus on the issue of feed

costs is an essential part due to the various sources of nutrition, including protein sources, which must be compatible with the multi-species aquaculture environment, which contributes to greater productivity, and the proportion of fish feed that would help farmers reduce the high costs of feed as well as reduce feed losses, which ultimately leads to a deterioration in water quality [46]. Food has contributed significantly to global food security in the 21st century through its high production standards and quality. Fish, in particular, represents a substantial portion of aquatic food—estimated at around 40%—and is a rich source of omega-3 fatty acids, high-quality proteins, and essential micronutrients. However, this information should be carefully reviewed and verified, and the identity of the exporter must be confirmed [14].

1 .2 **Feeding Conditions**

Feeding management is one of the most critical administrative aspects of fish farming. Key factors include feeding times, meal frequency, feed distribution locations within the farm, and maintaining consistency in the type of feed as much as possible. When changes in feed are necessary, they should be introduced gradually. Additionally, maintaining a stable work routine and a consistent team is essential. The size and shape of the feed should also be appropriate for the fish's developmental stage and mouth size [19].

Understanding nutrition requirements and strategies can reduce costs and increase profits, and feed efficiency is vital in fish farming, as many studies have been conducted to link the optimal feeding rate of the species under breeding, growth rates, efficiency of feed use indicators, and survival rate in farmed fish, and can be available at appropriate and economical prices [18].

1 . **3 Number of Meals**

The frequency of feeding meals for common carp fish improves growth parameters and daily growth rate, increases body fat content, feed conversion rate and feed utilization efficiency, as the fish were fed to saturation with multiple meals of 3, 5, 6, 7, 8 meals a day for young common carp fish with an initial weight of 2.4 G for 60 days, the weight gain by the number of meals reached 15.2 g (one meal a day), 37.5 g (three meals a day), 50.4 g (five meals a day), and 53.6 G (six meals a day), 55.4 G (seven meals a day), and 51.1 G (eight meals a day), the fish showed a marked superiority in the final weight of the highest that were fed on six meals and seven there is no significant difference in the final weight, qualitative growth rate, feed intake amount and nutritional conversion rate between the groups fed from six and seven meals a day, as feeding six meals a day is the optimal feeding rate for young common carp.

Craig *et al.* [12] and Fashina [16] has shown that the goal of multiple diets is to enhance the feed support available to carp at any stage of their life [1]. It was pointed out that multiple feeding meals per day increase the efficiency of the digestive system in digesting the feed intake, as the feed passes through the digestive tract, which improves the efficiency of digestion, absorption, and utilization of feed while reducing the loss of waste products. The increase of fish farming on a large scale using automatic feeding equipment in the number of feeding meals and the amount of feeding The number of feeding times can lead to a state of overfeeding and the identification of feeding habits carp fish with high accuracy can effectively conversely, an increase in the number of feedings leads to a waste of feed, a decrease in the efficiency of feed conversion and, consequently, a decrease in the efficiency of breeding [28]. Scientific research has indicated that the daily adjustment through feeding time and the number of meals while

maintaining a constant composition and the percentage of feed delivery from the living mass results in important explanations in the transit of the digestive tract and the duration of stay in the digestive canal, thus modifies the absorbability and utilization of the feed provided and that environmental influences repeated feeding led to better digestion results of feed provided through feeding more than one meal and the period of presentation of the bush at different times [16]. Increasing the number of feed times more efficiently than feeding one or more times a day achieves the benefit of food conversion through better nutrition and weight gain for farmed fish [37]. Diets that use animal protein concentrate as the primary source of protein differ from those that adopt soybean or cassava as the primary source of protein, as each provides different types of amino acids and nutrients that affect the growth and development of fish [6].

1.4 Feeding Times

Department of fish farming projects is working on developing a feeding program that proves the type of feed, the amount of feed provided (relative to the living mass), the daily meal times and adherence to them, as the fish adapt to the timing of the program, which stimulates the secretion of enzymes for digestion, and also adapt to the voices and workers [1].

Confirmed that it is difficult to accurately determine a specific feeding and clarify a fixed strategy for farmed fish, and it is possible to study various strategies based on a set of welfare criteria and indicators to determine the optimal among these, in general, a self-feeding system appears as a good option and reduce welfare levels [25].

1.5 Feeding Methods

Previous research has shown that the growth rate of fish depends not only on the chemical composition of the feed, but also on the way the feed is fed, the duration of feeding and the percentage of feed from the live Mass are important [11]. Manual feeding is one of the oldest and simplest feeding methods used in fish farming, provided the farmer has the necessary experience to distribute the feed and can identify when the fish have reached satiety. One of the main advantages of manual feeding is the daily interaction between the farmer and the fish, allowing for close observation of their activity and feeding behavior, especially for certain species.

Additionally, manual feeding allows for more flexibility in feeding frequency based on the environmental conditions surrounding the fish, without being restricted by the fixed feeding times of mechanical systems. It also enables early detection of issues such as disease, mortality, oxygen depletion, or the presence of predators. However, for species that avoid the surface or feed at greater depths, visual observation becomes challenging, and in such cases, underwater cameras or echo sounders are recommended to solve the problem [15]. fish farmers face great difficulty in feeding, especially in feeding large ponds that span large areas, and therefore the use of mechanical feeders has become an economical solution by reducing feed waste, making feeding economical, reducing labor, and shortening feed giving hours, especially in large ponds [42]. Automatic feeding is one of the types of feeding methods used in feeding fish, whether in earthen ponds or floating cages, as the development of mechanical feeding devices has become a necessity in semi-intensive and intensive aquaculture systems [21].

1.6 Fish Feeding Habits

Noted that the behavior of common carp is influenced by - the energy levels of the diet, meal times, growth rates and feed, and the conversion factor through high-energy diets is significantly reduced, which reduces the enhancement of feed by nutritional value [44]. Fish usually depend on both light and ambient environmental conditions and their

ability to eat feed. Carp is a very active fish that can be fed during the day and at night, but prefers to feed during the day [32]. Light is one of the main factors regulating vital processes and is considered a factor that leads to many conditioning mechanisms or physiological processes, regulating habits and other vital functions [35]. Many fish show strong behavioral patterns and similar daily rhythms that occur in fish farming places and it is possible to understand their habit patterns in these captive environments of environmental importance and impacts on the welfare of fish, for example, synchronizing feeding schedules with feed times and methods, and information about the habits of carp is rare and nothing is known about the impact of different feeds it is difficult to monitor their habits in aquaculture ponds due to high turbidity and low visibility [33].

1.7 Fish Feed

Feed is the main factor that determines the success of freshwater fish farming, whether in floating cages or earthen ponds, because the price of feed constitutes the largest part of the total cost of fish production projects, and the high feed prices are the biggest obstacle to the sustainability of fish farming, as the use of grain processing residues such as wheat bran flour, barley, corn and soybeans as an ingredient in the fish diet is an attempt to reduce the use of commercial feed being expensive, however, the use of these materials is limited by their continuity and quantities (the use of these materials is limited by their continuity and quantity) [39].

Fish require a high-quality balanced diet to achieve adequate growth in the shortest possible time so the local production of fish feed using locally available ingredients at low cost is crucial for the development and sustainability of fish farming in Iraq and the promotion of fish production, the development of fisheries and enhances fish production among [4].

Pointed out that the physical properties of aquatic feed pellets are of great importance for fish farming because the feeding and digestion behaviors of different fish species are complex and variable throughout the growth period (larvae, Fry, juvenile, young) the strength of the pellets is necessary to reduce the effect produced during transportation and feeding, as the stability of the feed pellets in the water is the most important factor for fish that feed slowly, and the time of moistening the pellets in the gut and starch gel is also crucial factors in the digestion of feed due to the short digestive system of fish, which is why the cost of floating feed is much more expensive than submersible feed, especially locally produced [23,16].

Good feed in fish farming systems is necessary for high-quality economic production, so feed is very important because it usually accounts for about 50% of variable production commercial fish feed is manufactured in floating or submersible or pressure granules, but some fish species prefer floating feed and some prefer submersible, but most fish species can be reduced to accept floating feed and these feed are more expensive because of the high monitoring the density of Fish and adjusting feeding rates through which it is possible to determine whether the feeding rate is low or high they are important in the aggravation of fish growth and the efficiency of feed use [12]. Among the components of the feed is the use of fishmeal, which is the best component due to its compliance with protein requirements, and replacing fishmeal with ingredients of plant origin and cheaper due to the high cost of fishmeal [10]. The types of feed that are used in the intensive farming system are classified as dry or wet or according to what they contain moisture, as wet feed generally constitutes 50-70% moisture and the granules represent a high humidity of 35-40% moisture, in addition, dry feed contains at least 10% moisture, so the bulk that is used in intensive farming is dry feed commercially produced [5]. In aquaculture, appropriate foundations are being laid to reduce feed waste and disseminated to fish farmers through the management of the best feed and the study of

available scientific information and concepts related to nutrition in the aquaculture environment [17].Different sizes and types of fish, various environmental and management conditions used in aquaculture require different nutritional needs in size and type, and the characteristics of the diet, grain size, texture, density, palatability, should be carefully considered, and the type of feed (floating or submersible) used depends on the method of feeding, the type of fish, the culture system, equipment, as well as personnel [13].

1.8 Water Tests

Temperature in closed systems varies between 20°C-25°C during the experiment, as described below for one of the previous studies, which is suitable for the growth of common carp [1]. Researcher stated that the suitable temperature for living warm-water fish is between 20-30°C and at different nutritional levels, and the temperature of 25-30°C is suitable for warm-water fish [1].



Figure 1: The water temperatures in closed systems during the duration of the experiment.

Concentration of dissolved oxygen in closed systems ranged between 8.5-10.1 mg L-1 during the breeding period, and this may be due to a temperature difference, as in Figure (2), which makes oxygen more portable during the experiment period, which is an appropriate ratio for the growth and breeding of common carp fish, the oxygen percentage ranges between 8.7-10.2, which is consistent with the Zhou *et al.* study [45]. Oxygen percentage ranges between 8.0-10.5 as in figure 2.

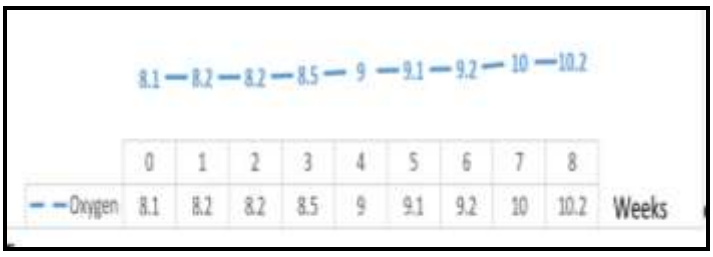


Figure 2: The concentration of dissolved oxygen in closed systems.

As for the pH value, it was between 7.1-7.5 and falls within the appropriate range for breeding carp fish and the results agreed with studies [45]. Which stated that the appropriate range is 6.0-8.0 for breeding fish, as shown in figure (3).

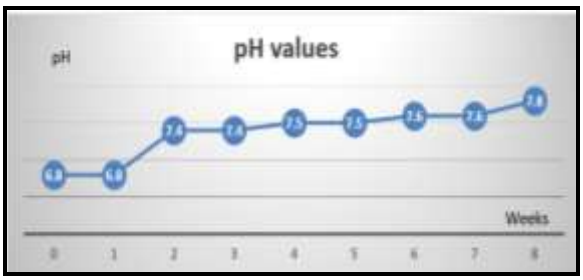


Figure 3: pH values in closed systems

1.9 apparent digestion coefficient of the BlackBerry protein and the time of appearance of the droppings.

It should be noted that the data and information presented in this text are derived from the current master's thesis research study. In reference to previous studies that show its impact on water quality and the efficiency of the use of nutrients, one study showed a significant superiority ($p \leq 0.05$) in the apparent digestion coefficient of blackberries in the fourth treatment with a feeding rate of 5% over the rest of the transactions, recording 89.14% compared with the first, second, third, fourth and sixth treatment. This significant superiority of this treatment may be due to the feed efficiency ratio as well as the protein efficiency ratio shown in Table 1, which gave an excellent result in the overall weight gain and final weight, indicating that it is the best treatment in digesting and making the highest use of the diet protein and its other components, diet digestion factor significantly affects the feeding rates of common carp fish and indicates the percentage of nutrients in the diet that the fish can digest and absorb very effectively.

The results of the statistical analysis shown in Table 1 indicate that the fourth treatment recorded a significantly higher protein digestion coefficient (88.50%) compared to the other experimental treatments ($P \leq 0.05$). This superiority suggests that the protein digestion coefficient is an important factor influencing feed utilization efficiency. A lower digestion coefficient may lead to increased feeding rates, which reduces the proportion of nutrients effectively absorbed by the fish. Therefore, optimizing this coefficient plays a crucial role in enhancing the nutritional performance of carp and ensuring effective feed management in aquaculture systems [26].

The results presented in Table 1 showed a significant superiority ($P \leq 0.05$) in the time of excrement appearance in the first treatment, which was based on a feeding rate at the saturation limit, compared to the other treatments. This may be attributed to the increased feed consumption observed in the first treatment.

To assess the efficiency of nutrient utilization, the Bush digestion coefficient is used. A high digestion coefficient indicates that fish can digest and absorb a larger proportion of nutrients from the feed, leading to better feeding efficiency and performance. On the other hand, a low digestion coefficient reflects poor nutrient absorption, which may result in lower feeding efficiency and growth rates [43].

Table 1: Effect of feeding ratios on digestion factors and the time of appearance of waste on water quality and the efficiency of nutrient utilization

Treatment	%(ADC)	%(ADP)	Evacuation time
T1 open	80.05± 0.05 d	85.25± 0.05 c	3.50 ± 0.01 a
T2 3%	79.23± 0.03 d	84.35± 0.03 d	3.15 ± 0.03 c
T3 4%	83.80± 0.04 c	86.14± 0.03 b	3.25 ± 0.02 c
T4 5%	89.14± 0.03 a	88.70 ± 0.05 a	3.00 ± 0.01 c
T5 6%	84.64± 0.05 b	83.09 ± 0.01 c	2.22± 0.02 d
T6 7%	82.05± 0.05 C	86.10 ± 0.03 b	3.45± 0.01 b

Conclusion

Artificial feeding is considered the decisive factor in the success of fish farming projects, as it constitutes 60–70% of production costs. This highlights the importance of balancing the amount of feed provided with the actual needs of the fish to improve growth, enhance nutritional efficiency, and reduce waste and environmental pollution. The results showed that maintaining ideal temperatures (25–26°C) enhances the performance of common carp in closed systems. Additionally, the availability of

appropriate dissolved oxygen levels (8.1–10.2 mg/L) and a moderate pH range (7.1–7.5) supports fish health and improves feed conversion. Furthermore, the treatment with a 5% feeding rate showed the highest apparent protein digestibility coefficient (88.5%), indicating the effectiveness of this level in reducing waste and improving water quality. Reducing feed to optimal saturation levels also decreases the time of waste appearance, contributing to a healthier aquatic environment. The study also demonstrated that increasing the number of daily meals to six or seven improves growth rates and feed utilization efficiency. Therefore, proper feed management significantly contributes to enhancing productivity, preserving the environment, and ensuring the sustainability of fish farming operations.

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مراجعة شاملة لدور التعديلات الغذائية في تحسين استدامة تربية الأسماك من خلال تأثيرها في جودة المياه وكفاءة استخدام العناصر الغذائية

فاطمة محمد عبدالجبار[1]
fatima.mohmed95@mu.edu.iq

ضمياء عليوي عبدالحسين السعدي[2]
dhamyaa.o@coagri.uobaghdad.edu.iq

الحمزه احمد فياض[3]
alhmazh1995@gmail.com

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الملخص

البروتين أكثر العناصر الغذائية تكلفة في علف الأسماك، في حين تحتوي العلائق الغذائية المقدمة في المراحل الأولى من تغذية الأسماك على عالية من البروتين مما يؤثر الايض في التغذية المبكرة مع التغذية العالية في النظام الغذائي من خلال قدرة الهضم والتمثيل الغذائي للأسماك تتجسّد أهمية التغذية الصناعية بوصفها العنصر الأساسي في مشاريع تربية الاحياء المائية ، سواء كانت مشاريع استزراع مكثف أو مشاريع ثانوية شبه مكثفة تكون فيها التغذية ذات نوعية جيدة لضمان استخدامها في التربية لأعطاء اداء انتاجي وفي الوقت ذاته حماية البيئة المائية الهدف من المقالة لحماية البيئة عبر تقليل تأثير فضلات الأسماك على جودة المياه، مما يؤدي إلى تقليل التلوث وتعزيز صحة النظم البيئية المائية.

الكلمات الدالة: تربية اسماك، العناصر الغذائية، تعديلات الغذائية، جودة المياه.

[1] جامعة المثنى، كلية التربية البدنية وعلوم الرياضة، المثنى، العراق.
[2] جامعة بغداد، كلية علوم الهندسة الزراعية، بغداد، العراق.
[3] الشركة العراقية لإنتاج البذور، وزارة الزراعة، العراق.

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