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Potential Role of Zeolite on Improvement of Aquaculture Sector

Durali DANABAS*, Mustafa DORUCU

Munzur University, Fisheries Faculty, Tunceli, Turkey

***E-mail:** dalid07@gmail.com

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Abstract

Aquaculture, which is very important in many regions of the world, attracts attention as the fastest growing sector in the livestock sector in our country. The share of our country's aquaculture production in the production of total aquatic products is increasing day by day. Studies have been carried out to solve feed problems and importance has been attached to additives that reduce cost and feed conversion ratio (FCR) to contribute to feed quality. Zeolites came to the forefront as feed additives. Due to the gap between 20 and 50 % in the structure, the molecules can be taken into the structures and they are named as molecular sieves. Zeolites are used for purposes such as controlling the pollution in pools in the aquaculture sector, increasing the growth parameters of the fish by incubation, fish transport and removal of nitrogen compounds from aquarium water, increasing ambient oxygen in aquarium and fish transport, and as feed additive. In Turkey, billions of tons of zeolite have been detected and clinoptilolite type zeolite is found mostly in the beds of Ankara-Polatlı-Mülk-Oğlakçı Region and Bigadiç, Şaphane, Gediz, Emet and Gördes Districts. We believe that the use of zeolites produced in Turkey as a local and natural product as feed additive substance in the aquaculture industry in the aquaculture sector will contribute to the production of lower cost fish as well as contribute to the development of 2 different sectors (aquaculture and mining) in interaction with each other.

Su Ürünleri Yetiştiricilik Sektörünün Gelişiminde Zeolitin Olası Rolü

Makale Bilgisi

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Öz

Dünyanın birçok bölgesinde çok büyük önem arz eden su ürünleri, Ülkemizdeki hayvancılık sektörleri içerisinde en hızlı gelişen sektör olarak dikkati çekmektedir. Ülkemizin toplam su ürünleri üretimi içerisindeki su ürünleri yetiştiriciliğinin payı da her geçen gün artmaktadır. Bu yem ile ilgili sorunların çözümüne yönelik çalışmalar yürütülmüş ve yem kalitesine katkıda bulunacak, maliyeti ve yem dönüşüm oranını (FCR) azaltıcı katkı maddelerine önem verilmiştir. Yem katkı maddesi olarak zeolitler öne çıkmıştır. Yapılarında % 20 ile 50 arasında boşluk olmasından dolayı molekülleri yapılarına alabilmekte ve moleküler elek olarak ta adlandırılmaktadırlar. Zeolitler, yetiştiricilik sektöründe havuzlarda kirlilik kontrolünün sağlanması, kuluçka, balık nakil ve akvaryum suyundan azotlu bileşiklerin uzaklaştırılması, akvaryum ve balık naklinde ortam oksijeninin artırılması ve yem katkı maddesi olarak kullanımıyla, balık büyüme parametre değerlerinin artırılması gibi amaçlar için kullanılmaktadır. Türkiye'de ise milyarlarca tonluk zeolit varlığı ortaya konmuş olup, Ankara–Polatlı–Mülk–Oğlakçı Bölgesi ile Bigadiç, Şaphane, Gediz, Emet, Gördes Bölgeleri'ndeki yataklarda çoğunlukla klinoptilolit türü zeolitin yoğun olarak bulunduğu tespit edilmiştir. Yerel ve doğal bir ürün olarak Türkiye'deki üretimi yapılan zeolitlerin yetiştiricilik sektöründe yem fabrikalarınca temelde yem katkı maddesi olarak kullanılması, daha düşük maliyetli balık üretimine katkı sağlayacağı gibi, birbirleriyle etkileşim içerisinde 2 farklı sektörün (su ürünleri yetiştiriciliği ve madencilik) gelişimine de katkıda bulunacağı kanaatindeyiz.

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INTRODUCTION

Aquaculture, which is of great importance in many parts of the world, draws attention as the fastest growing sector among the livestock sectors in our country. The share of aquaculture in the total aquaculture production in our country is increasing day by day. According to statistical data of TURKSTAT, while the total fisheries production in 2003 was 587715 tons, the aquaculture amount was 79943 tons with a rate of 13.6%. These amounts reached 785811 tons in 2020 and the share of aquaculture reached 421411 tons with a rate of 53.62% (TUİK, 2021). While the amount of products obtained by aquaculture increased each year, the rate of increase decreased after 2007. One of the most important reasons for this is the problems experienced in the supply and quality of feed and feed raw materials. Studies have been carried out to solve these problems and importance has been attached to some feed additives that will contribute to feed quality and reduce the cost and feed conversion ratio (FCR). Among these substances, zeolites came to the fore.

Zeolites, which are one of the important raw materials of recent years, as the word "boiling stone (This name was given because it explodes when heated)"; chemically known as "hydrated alumino silicates". Zeolites are hydrated aluminosilicates of alkali and alkaline earth metals with a crystalline structure and are in the frame silicates group. Despite some changes in the Si/Al ratios in the skeletal structure and the type and amount of cations they contain, they can be expressed with the general formula **$(M^{+}, M^{+2})\ O.Al_2O_3.9SiO_2.nH_2O$**. M^{+} is an alkali cation, usually Na^{+} or K^{+}, rarely Li^{+}. M^{+2} is an alkaline earth cation and is usually Mg^{+2}, Ca^{+2}, Fe^{+2}, rarely Ba^{+2}, Sr^{+2} (Leung, 2004; Anonymous I, 2006; Virta, 2014; Erdogan et al. 2019).

The smallest structural unit of any zeolite crystal is the SiO_4 and AlO_4 tetrahedras. Single and double ring secondary structure units and highly symmetrical parameters are formed by the combination of primary structure units formed by Si and Al tetrahedras. The zeolite skeleton with micropores emerges with the arrangement of these polyhedra and secondary structure units in three dimensions in different ways. These micropores, located between the polyhedra and the secondary structure units that connect them, combine with micro windows and form one, two or three-dimensional space systems and/or channels. The amount of space is between 20-50% of the total volume. The most important feature of zeolite minerals is these spaces, and the "molecular sieves" feature that is originated from liquid and gas molecules that can easily enter and displace these spaces, and alkaline earth ions (Mumpton, 1999; Leung, 2004; Anonymous II, 2006; Chowdhury et al., 2016).

Zeolites are of two types, natural and artificial. Today, more than 150 zeolite structures have been classified, of which about 40 are natural (the most common are analcim, cabazite, clinoptilolite, erionite, ferrierite, heulandite, laumontite, mordenite, and phillipsite), and about 110 are artificial (the most common synthetic zeolites, Zeolite A, X, Y, and ZMS-5) (Anonymous III, 2002; Virta, 2014). The most well-known of the natural type zeolites is “clinoptilolite” (Tepe et al., 2005). The molecular sieve structure of clinoptilolite and its absorption of a substance are given schematically in Figure 1. and the cation selectivity is as follows (Mumpton, 1999; Leung, 2004):

$Cs > Rb > K > NH^4 > Ba > Sr > Na > Ca > Fe > Al > Mg > Li$

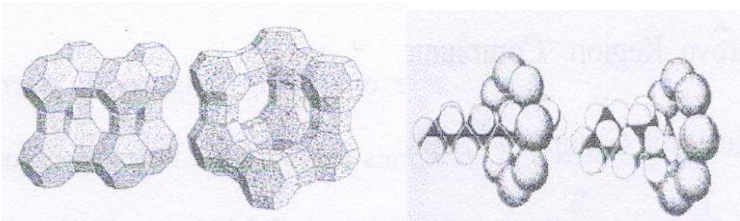

Figure 1. Molecular sieve structure of a zeolite (sodalite) for an example and schematic representation of absorption of a substance (Leung, 2004)

The main physical and chemical properties of zeolites are; ion exchange, adsorption and its sieve structure, silica content, light color in sedimentary zeolites, lightness, pore structure of small crystals, have caused zeolites to be used in a wide variety of fields (Tepe et al., 2005).

Usage Areas of Zeolites

Areas benefiting from zeolites, which have become an important industrial raw material in recent years, may be grouped under 5 main headings.

Use in Pollution Control

Soil Pollution Control: It has been determined that the use of concrete type clays and clinoptilolite type zeolites together has a positive effect on the soil and soil stabilization of the landfills, and also contributes to the formation of soil with thinner lining material. At the same time, zeolite also acts as a filter by keeping harmful ions in the water that may leak from these areas (Anonymous IV, 2005). In addition, zeolite minerals can retain isotopes such as Sr_{90}, Cs_{137}, Co_{60}, Ca_{45}, which are found in nuclear power plant wastes and are dangerous for environmental health. In this way, radioactive materials taken from wastewater are rendered harmless by being buried with zeolite minerals. For this purpose, clinoptilolite and mordenite are used because they are resistant to acids (Bish et al., 2003; Alp, 2005; Anonymous IV, 2005; Kibaroğlu, 2008; Gülen et al., 2012).

Air Pollution Control: Oxygen-rich air can be provided by utilizing the adsorbing properties of zeolite minerals (Alp, 2005; Anonymous V, 2006; Anonymous VII, 2006; Kibaroğlu, 2008). In addition, they can be used for supplying oxygen with a purity of 60% in hospitals, increasing the oxygen ratio by reducing air pollution in small units (Aybal, 2001) and adsorbing the gases coming out of the chimneys of the facilities using oil and coal. For this purpose, artificial zeolite minerals, and mordenite, clinoptilolite, erionite and chabazite from natural zeolite minerals are used (Alp, 2005; Anonymous I, 2006; Kibaroğlu, 2008; Gülen et al., 2012).

Water Pollution and Waste Water Control: Zeolite minerals are used in cleaning the pollution caused by organic wastes in lakes, ponds and rivers, and in the purification of wastewater from heavy metals, especially with N compounds (Tarasevich et al., 1997; Mumpton, 1999; Aybal, 2001; Alp, 2005; Sarioglu, 2005; Anonymous VI, 2006; Anonymous VII, 2006; Sevgi et al., 2007; Kibaroğlu, 2008; Zorpas et al., 2008; Wang et al., 2008; Sprynskyy, 2009); in adsorption of oil on the water surface in marine environments (Anonymous I, 2006). However, they can be used to clean fish pond waters and increase the oxygen rate, to control possible pollution in live fish transport and to remove the hardness of drinking water (Anonymous VIII, 2000; Hargreaves and Tucker, 2004; Örgev and İnanç, 2004; Alp, 2005; Sarioglu, 2005; Anonymous IX, 2006; Kibaroğlu, 2008; Zorpas et al., 2008; Chowdhury et al., 2016).

Use in the Field of Energy

In addition to petroleum and coal, energy needs are tried to be met from sources such as nuclear energy and solar energy, and natural zeolites are used in the conversion of these resources into energy.

Obtaining Energy from Coal: In this area, zeolites are used to produce the oxygen necessary for burning the coal underground and to clean the explosive nitrogen oxides and hydrocarbons, as well as SO_2 formed during combustion. However, their use is not common.

Purification of Natural Gases: Zeolites have been used to remove CO_2 from polluted or impure natural gases since 1969 (Anonymous IV, 2005).

Utilizing Solar Energy: Zeolites are used as a heat exchanger in the transfer of solar energy due to their ability to exchange water depending on the temperature. Clinoptilolite and chabazite are used for heating and air-conditioning of small buildings (Anonymous IV, 2005; Anonymous I, 2006).

Petroleum Products Production: Natural zeolites, which provide important information in the exploration of oil and gas-containing fields and in the determination of paleoenvironment conditions, can be used in some special applications in oil and gas production and their refining. However, synthetic zeolites are preferred due to their higher adsorption capacity and higher pore diameters. Water and CO_2 are separated from natural gases using mordenite, chabazite and clinoptilolite. In addition, catalysts that can be used in petroleum refining from natural zeolites have been produced (Anonymous IV, 2005).

Usage in Mining and Metallurgy

Exploration of Mineral Deposits: Zeolites, which are formed as a result of hydrolysis of volcanic materials, can be used in exploration as well as explaining the formation of ore deposits (Anonymous IV, 2005; Gülen et al., 2012).

Metallurgy: Waste waters resulting from mining and metallurgical activities containing some heavy metal cations that pose a danger to environmental health, can be treated by utilizing the cation exchange properties of natural zeolites (Anonymous I, 2006; Gülen et al., 2012).

Use in Agriculture and Animal Husbandry

The purposes of using zeolite minerals in agriculture and animal husbandry are tried to be summarized below.

1. Fertilizer preparation (Reháková et al., 2004; Alp, 2005; Kibaroğlu, 2008),

2. Controlling the content of fertilizers and removing bad odours (Reháková et al., 2004; Alp, 2005; Kibaroğlu, 2008),

3. Enabling fertilizer savings by binding NH_4^+ in environments where zeolite minerals are present and enabling this compound to be used more effectively by plants (Alp, 2005; Kibaroğlu, 2008; Zorpas et al., 2008),

4. Delaying deterioration by providing hardening during storage in fertilizers, as it can absorb water molecules in the environment (Reháková et al., 2004; Alp, 2005),

5. Due to its high ion exchange and binding water molecules, it is mostly used for soil preparation and improvement in clay-poor soils (Dyer and White, 1999),

6. Prevention of fungal diseases that may occur in plants due to excessive irrigation in agricultural lands (Anonymous VII, 2006; Zorpas et al., 2008),

7. Removal of pesticide residues in agricultural struggle due to its high ion exchange and adsorbing capacities (Anonymous II, 2006; Anonymous VII, 2006),

8. Increasing the pH values of acidic and volcanic soils (Anonymous IV, 2005; Glisic et al., 2008),

9. Allowing more steam pressure and higher temperature to be used in pelletizing animal feeds, reducing friction and ultimately increasing production with less energy use (Anonymous VII, 2006),

10. As it was started with a study conducted in Japan for the first time in 1965, by adding to cattle, ovine and poultry feeds, reducing the feed utilization rate, which is one of the important parameters in terms of aquaculture, and increasing the growth performance. (Aybal, 2001; Alp, 2005; Kibaroğlu, 2008; Zorpas et al., 2008),

11. Controlling the pollution caused by feed and faecal wastes and preventing diseases in animal shelters such as poultry houses, pens and barns (Elekoglu and Yalcin, 2005; Tepe et al., 2005; Leung et al., 2007; Gülen et al., 2012).

Zeolite tuffs, clinoptilolite and mordenite type zeolite minerals are generally used for the above-mentioned purposes (Mumpton, 1999; Anonymous VII, 2006).

Other Usage Areas

Paper Industry: High gloss zeolite ores are increasingly used as filling material. Clinoptilolite-added paper is more tough than normal clay-added papers, can be cut easily, is lighter, and disperses ink less (Anonymous IV, 2005).

Construction Industry: Zeolithic tuff deposits are used as pozzolanic raw materials in many countries. Expanded zeolites have higher resistance to compression and abrasion, and expanded lightweight aggregates are produced. They are used as building blocks because they can be easily cut and processed and they are light (Mumpton, 1999; Anonymous IV, 2005).

Health sector: It is used as a brightening additive in clinoptilolite fluoride toothpastes, as a patented drug in the treatment of ulcers and diarrhea in Cuba, and as a powder in the treatment of cut-injured animals to prevent infection of the wound (Mumpton, 1999; Anonymous I, 2006). Natural phillipsite and certain synthetic zeolites have been found to be an effective means of removing NH_4 during hemodialysis of kidney patients (Mumpton, 1999)

Detergent Industry: Synthetic zeolites are used as additives instead of phosphate in detergents due to environmental pollution (Anonymous I, 2006).

Storage and Transport of Fruits and Vegetables: The effect of ethylene gas, which occurs during the collection of vegetables and fruits and causes deterioration, is minimized by coating the products with natural zeolite and can be stored for a longer period of time (Anonymous I, 2006).

Icing Prevention: Natural zeolites are used directly on the road or mixed into asphalt. Thus, both the environment is cleaned of chemical pollutants and damage to asphalt and vehicles such as salt is prevented (Anonymous I, 2006).

Pellet Binders: Zeolite (BRZ) allows more steam and higher heat to be used in pelletizing animal feeds, reducing friction and increasing production by 30% without the need for more energy (Anonymous VII, 2006).

Zeolite species are used for different purposes in aquaculture as well as in the feeding of different animal species.

Use of Zeolites in Aquaculture

Zeolite minerals are mainly used for four purposes in aquaculture applications. These;

1. Ensuring pollution control in ponds,

2. Removal of nitrogenous compounds from hatching, fish transport and aquarium water,

3. Increasing the ambient oxygen in aquarium and fish transport,

4. Increasing fish growth parameter values by using it as a feed additive (Pond and Mumpton, 1984; Watten and English, 1985; Dryden and Weatherley, 1989; Mumpton, 1999; Aybal, 2001; Peyghan and Azary-Takamy, 2002; Ravendra et al., 2004; Alp, 2005; Tepe et al., 2005; Anonymous X, 2006; Anonymous XI, 2006; Anonymous XII, 2006; Kaiser et al., 2006; Töre, 2006; Kanyılmaz, 2008; Danabas, 2009, Danabas and Altun, 2009; Danabas and Altun, 2011; Aksu, 2016; Chowdhury et al., 2016).

Some of the studies carried out for these purposes are summarized below.

Water and/or waste water management becomes increasingly important issue worldwide for many animal culture as more as the aquaculture. Guo et al. (2013) reported that synthesized zeolite from coal fly ash and chemically modified zeolite (treated with MgO), respectively, were effective (up to 95% and 87%, respectively) for NH^{4+} removal of swine wastewater. However, Markou et al. (2014) used natural clinoptilolite to adsorb NH^{4+} from poultry wastewater, in which the removal efficiency was about 9 mg N $g1^{-1}$ of zeolite. Nutrient-enriched zeolites can be used to produce microbial biomass. For instance, Markou et al. (2014) used natural zeolite as a medium for the sorption of ammonia from wastewater, and subsequently as nitrogen releaser in cultures of *Arthrospira platensis*. Markou et al. (2015) reported that modified zeolite (treated with $Ca[OH]_2$) was a significant adsorbent for PO_4 in synthetic wastewater, and subsequently a P source for the cultivation of green microalga (*Chlorella vulgaris*) and cyanobacterium (*A. platensis*).

The content of ammonium ions ($NH4^+$) produced by fish metabolism is unfavourable for the fish culture including the fish breeding industry and requires frequent water change. Water pollution can be reduced by using zeolite materials capable of removing ammonium cations more efficiently than nitrifying bacteria used in biological filters (bacterial carriers). Skleničková et al. (2020) researched the three zeolite materials (Bear Blanked Clinoptilolite, Mordenite Manganese and Geopolymeric Zeolite A) in the breeding tanks of Koi carp for their ammonium cations exchange kinetics. The zeolite prolonged the water quality improvement without any negative effects. Because of zeolite Mordenite Manganese, water consumption can be decreased by almost 70 % in aquaria setting and by 40 % in fish-breeding conditions

Yu et al. (2020) used the lanthanum modified zeolite (La-Z) to adsorb chlortetracycline (CTC) from aquaculture wastewater and obtained 98.4% removal rate. Zeolites reduce ammonia and hydrogen sulphate levels in fish/shrimp lakes and increase fish/shrimp growth rates and population density (Anonymous VI, 2006; Tepe et al., 2005). In Far East Asia, zeolite is applied to shrimp ponds by sprinkling it on the water surface at a rate of approximately 200 kg ha^{-1} every month. The purpose of this zeolite application is to remove halogen sulfide and carbon dioxide by absorption, and to remove ammonium from the environment at the end of ion displacements (Tepe et al., 2005). Both zeolite and biochar are sustainable alternatives of biomedia for nitrate removal (Paul and Hall, 2021).

Aksu (2016) studied the effects of natural zeolites clinoptilolite (0 (control), 1, 2, 4 and 8 g l^{-1}) on some water quality parameters (water temperature, dissolved oxygen, pH, total hardness, ammonium, nitrite, nitrate, sulfate, phosphate, chlorine, fluorine, calcium, lithium, magnesium, potassium, sodium and bromine) and mortality rates in the crayfish (*Astacus leptodactylus* Eschscholtz, 1823) culture. In order to control the constant organic input to the experimental environment, 400 g crayfish (34.01±1.78 g) per m^2 were stocked in each tank and the zeolite was used by laying it on the ground. It was observed that there were statistical differences among the periods for all measured parameters ($P<0.05$). It was determined that there were statistical differences between the periods and groups for the analyzed parameters and mortality rates ($P<0.05$). In terms of mortality rates at the end of the trial, it was determined that all crayfish in the Control and A Group died (100%), while the B (48.15%) and C (47.83%) Groups showed the lowest statistical mortality rates.

Kaiser et al. (2006) used clove oil and clinoptilolite (20 mg/l) during 48-hour transplant of *Haplochromis obliquidens*. In this study, they found the NH_3 concentration to be 360% higher in the group that clinoptilolite were used, compared to the group that did not use clinoptilolite.

Jain (1999), in his study to determine the toxicity of $Pb(NO_3)_2$ and the protective effect of clinoptilolite in catfish (*Heteropneustes fossilis*), 20 mg l^{-1} (for 12 days) and 60 mg l^{-1} (for 35 days) Pb $(NO_3)_2$ on fish was investigated by adding clinoptilolite at a rate of 50 mg l^{-1}. As a result, in the groups that did not add clinoptilolite, growth of fish, soluble protein, glycogen and ribonucleic acid (RNA) content in their livers decreased, but cholesterol levels increased. In the group with clinoptilolite added, all findings were found to be closer to the Control Group.

James et al. (2000) investigated the effects of 5 different clinoptilolite concentrations (0, 0.5, 2, 4 ve 8 g zeolit l^{-1}) on the complete removal of Cu from the pond waters, added 2.14 mg l^{-1} Cu and growth of *Oreochromis mossambicus*, in their research for the 180 days. In the study, in the group with 0.5 g clinoptilolite added, the complete removal of Cu from the environment took 150 days, while it took 120 days in other groups added 2, 4 and 8 g. As a result, the group added 2 g of clinoptilolite gave the highest values in preventing the accumulation of Cu from body tissues, removing metal from pond water and body tissues, and improving the RNA:DNA (deoxyribonucleic acid) ratio and protein amount. Therefore, this ratio is expressed as the optimum ratio.

In the study conducted by Peyghan and Azary-Takamy (2002), 150 mg l^{-1} NH_3 and 5, 8, 10, 15 and 20 g l^{-1} clinoptilolite were added to the water of carp ponds, respectively. At the end of the experiment, the mortality rate in the first three application groups (5, 8, 10 g l^{-1}) was determined as 100, 80 and 30%, respectively, while no death was observed in the other two groups. The differences among the experimental groups and the control group mortality rates were found to be statistically significant ($P<0.05$). In addition, no difference was found in serum alanine aminotransferase (ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST) and lactate dehydrogenase (LDH) levels in fish blood, and the cholesterol and urea levels of groups containing 15 and 20 g l^{-1} clinoptilolite and the Control Group was found to be statistically significant ($P<0.05$). Researchers have reported that clinoptilolite can be used in the prevention of acute NH_3 toxicity.

Ravendra et al. (2004), during the transportation of 3 common carp species (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) cultured in India, zeolite (0, 7, 14, 21 and 28 g l^{-1}), tris-buffer (0.01, 0.02, 0.03 and 0.04 M), 2-phenoxyethanol (0. 0.09, 0.13, 0.18 and 0.22 ml l^{-1}) and oxyflov (0, 250, 500, 750 and 1000 mg l^{-1}) were added and evaluated the effects of these substances on fish for 48 hours. 1500 fry (30.00±0.76 mm total length (L) and 410.00±7.66 mg body weight (W)) were stocked in plastic bags each containing 3 l freshwater (pH, 7.4; dissolved oxygen, 5.4 mg l^{-1} and NH_3, 0.0012 mg l^{-1}) and 20 mg l^{-1} neomycin sulfate was added to control bacterial growth. At the end of the experiment, a 100% survival rate (SR) and 0.052±0.0008 mg l^{-1} NH_3 ratio was obtained in the group to which 7 g l^{-1} zeolite was added and and with the increase of the amount of zeolite added to the transport bags, the SR decreased and the NH_3 ratio increased. However, in the group with 0.01 M tris-buffer added, 100% SR and 0.0076±0.0003 mg l^{-1} NH_3 ratio were obtained and with the increase in the amount of tris-buffer added to the transport bags, the NH_3 ratio increased; in the other 3 groups (0.02, 0.03 and 0.04 M), all fish died. In addition, 100% SR and 0.186±0.0033 mg l^{-1} NH_3 ratio was obtained in the group to which 0.09 ml l^{-1} 2-phenoxyethanol was added. Although SR decreased with the increase of 2-phenoxyethanol ratio added to the bags, the NH_3 ratio changed and the lowest ratio was obtained from the 3rd group (0.18 ml l^{-1}). Finally, 100% SR and 0.216±0.0033 mg l^{-1} NH_3 ratio were obtained in the groups with 250 to 500 mg l^{-1} oxyflow added, and with the increase in the added oxyflow ratio, SR decreased and NH_3 ratio increased. They reported that these rates do not affect the post-trial SRs and therefore, they can be used safely during transportation of these fisf species.

When the studies conducted for fish feeding are evaluated, a feed containing 48% crude protein and added 2% zeolite was used in a pond containing 100 trouts and the fish were grown for 64 days without any health problems, and a 10% increase in the total fish biomass was obtained (Tepe et al., 2005). At the end of the trial, the average body weight was determined as 48.6 g in the Control Group and 52.3 g in the group containing clinoptilolite. A remarkable reduction in feed cost was also provided (Leonard, 1979: Pond and Mumpton, 1984; Mumpton, 1999). Lanari et al. (1996), reported that different ratios (2.5, 5.0 and 7.5%) of kuban zeolite (35% pure mordenite, 35% pure clinoptilolite) had no effect on the digestibility coefficient of rainbow trout feed and crude protein and dry matter rates from fish meat nutrient components ($P>0.05$); however, the first two ratios of supplementation had a positive effect on nutritional efficiency and fish growth compared to the Control Group.

James et al. (2000) determined that zeolite was effective in the growth of *Oreochromis mossambicus* and removal of Cu from water and increased the RNA:DNA ratio and protein amount.

Dias et al. (1998) studied the effects of three different additives (cellulose, silicate and zeolite) at different rates (0% (Control), 10 and 20%) on European sea bass (*Dicentrarchus labrax*) fry. They reported that the diets containing 10 and 20% additives did not have a significant effect on the growth performance of fries, protein digestibility and FCR values of the fish, and that the groups containing 20% additives performed a fecal excretion in a longer time compared to the Control Group. However, they stated that diluting the nutrient elements of the rations had an adverse effect on FCR and growth performance.

In a study, effects of clinoptilolite (0, 1, 2, 3, 4, 5 and 6) on the W and L values, condition factor (CF), FCR and some blood serum enzymes (ALT, AST and ALP) activity levels of rainbow trout (initial body weights; 139–140 g) were investigated (Aybal, 2001). At the end of the trial, it has been reported that the W averages of the groups were between 296 and 320 g; the mean of CF is between 1.26 and 1.38; the mean of FCR ranged between 1.33–1.56; serum ALT activities ranged between 3.28–4.94 UI l^{-1}; and the differences between the groups were insignificant ($P>0.05$). On the other hand, it was reported that only the differences between the CF averages, serum AST and ALT activities in period I was significant ($P<0.05$). As a result of the study, the highest W and L averages were obtained in the group III. While the lowest levels of serum AST in the III and IV. Groups, the highest levels also were in the Control and Group II. However, the lowest levels of ALP were in the IV and II Groups; and the highest values were in the Control and Group V.

Töre (2006) investigated the effects of water quality parameters, some blood parameters and body composition of fish in a study in which clinoptilolite and starch were used as additives in tilapia (*Oreochromis niloticus*) feed. In the trial, it has been reported that 49.54±3.83 g live weight gain in 10% starch group (NG), 48.62±3.16 g in 10% clinoptilolite group (KG), 42.36±1.28 g in 20% NG, and 41.26±2.17 g in 20% KG was achieved, and the best FCR average was obtained from 10% KG (1.17±0.08) and 10% NG (1.17±0.10%). In addition, at the end of the trial, there was no statistical differences between and within the groups in terms of protein efficiency ratio, viscerosomatic index (VSI) and hepatosomatic index (HSI) and dry matter, crude protein, crude oil and crude ash analyzes of fillet samples taken from trial fish ($P>0.05$). According to the results of cholesterol, glucose, triglyceride, and LDH blood analyzes in blood samples in the groups, the differences among the groups was found statistically significant ($P<0.05$). According to the results of the water analysis, the lowest NH_3 level is in 20% NG (0.0425±0.02 mg l^{-1}), and the highest level is in the 20% KG (0.154±0.04 mg l^{-1}). As a result, it was reported that the use of these ratios of clinoptilolite as an additive in fish feed instead of starch did not have a significant effect on growth and feed evaluation performances, and it was suggested that lower ratios should be studied.

The efficiency of chelating zeolite to counteract the toxicity of two levels of ammonium chloride (18 and 1.8 mg NH^4cl/l) was evaluated in the culture of Nile tilapia (*O. niloticus*). In this research, the addition of zeolite to ammonia in a contaminated medium is recommended to reduce ammonia concentration in aquaculture, improve growth performance and physiological function and activities in fish (Shalaby et al., 2021). However, in Nile tilapia, it was indicated that zeolite can improve the growth performance and increases fish resistance to undesired effects associated with Pb toxicity (Abbas et al., 2021). The substitution of natural zeolite (1, 3 and 5%) in Nile tilapia (*Oreochromis niloticus*) was decreased ($P< 0.05$) the amount of food per animal (9.08 to 6.50 g) and intake protein (2.95 a 2.09 g). It was proposed to continue researchers with zeolite as partial replacement of protein raw matters in tilapias feed (Llanes and Castro, 2020).

Kanyılmaz (2008) examined the effects of different ratios of clinoptilolite (0% (control) 1, 2, 3 and 4) in the common carp (*Cyprinus carpio* L., 1758) with an initial body weight average of 15.09±0.02 g on growth, body composition, some blood parameters, and intestinal mucosal morphology. In the study, W means of the groups were 73.01±2.68 g, 68.93±2.43 g, 72.51±5.01 g, 69.82±5.29 g, and 72.10±3.28 g, respectively, while the means of FCR were found 1.75±0.01, 1.82±0.04, 1.74±0.05, 1.83±0.07 and 1.76±0.04, respectively. In the trial, it was reported that clinoptilolite had no effect on the W increase, feed consumption, FCR, specific growth rate (SGR), protein efficiency ratio, VSI, carcass yield, CF, crude protein, dry matter, fat and raw ash values; and also on the intestinal surface area and the length of the digestive tract according to the findings obtained from histological examinations of samples taken from small and large intestines ($P>0.05$). However, according to the results of the blood analysis, it was reported that the glucose and blood urea nitrogen levels decreased, the hemoglobin level increased ($P<0.05$) and the cholesterol level remained unchanged ($P>0.05$).

Danabas (2009) was applied the zeolite (clinoptilolite) into the pond water (E1) (0 (Control), 1, 2 and 3 g l^{-1} ratios) and into the feed (E2) (0 (Control), 1, 2 and 3%) of rainbow trout (*Oncorhynchus mykiss*) (20.8984±0.564 g and 12.8263±0.122 cm). It was evaluated in E1, its effects on some water parameters and fish growth, and on the fish growth and body composition in E2. In E1, it was determined that the clinoptilolite ratios applied to the pond water did not affect the water and growth parameters ($P>0.05$). In E2, clinoptilolite added to the feed increased W, L, daily live weight gain (DLWG), SGR, SR, crude protein, dry matter and raw ash values ($P<0.05$); decreased the FCR and VSI ($P<0.05$); however, it did not affect CF, HSI, gonadosomatic index (GSI) and lipid values ($P>0.05$). According to these results, it was concluded that adding 1% clinoptilolite to feeds of this size of rainbow trout fry is beneficial.

Both inside and outside of the filter, the effects of zeolite on water quality and the growth of electric blue hap (*Sciaenochromis ahli*) were investigated for 3 months (Öz et al., 2021). They determined some statistically insignificant differences between weight gain, specific growth rate and feed conversion ratio ($P>0.05$) and it was suggested that low ratios as 0.35 g l^{-1} of zeolite may be used in tulle bags on floor or inside the filter to prevent ammonia rising to high concentrations.

Surmeli et al. (2020) was carried out the zeolite as feed additive (1 and 2%) to juvenile carp species (*Cyprinus carpio*). The comparative analysis of the results obtained for the morpho-productive characters (live weight, total length and maximum body height) revealed that the group fed with 2% clinoptilolite additive feed, obtained the best performances. Clinoptilolite in feed has contributed at maintaining favorable media conditions for the growth and development of fish from the controlled systems used.

Güler and Ucar (2020) fed the rainbow trout (*Oncorhynchus mykiss*) with feeds containing zeolite (1, 3 and 5%) for three months to evaluate fish growth parameters and hematological indices. The changes in growth parameters were determined ($P>0.05$), and different ratios of zeolite added diets were found to cause a change in the blood indices, of which WBC, ESR and MCV values were statistically significant ($p <0.05$).

Tekeşoğlu and Ergun (2021) performed to evaluate the effects of clinoptilolite on the growth performance and some biochemical blood parameters in juvenile rainbow trout (*Onchorynchus mykiss*). 0.5% zeolite showed the best results in final body weight, weight gain, specific growth rate, feed intake, feed conversion rate, and protein efficiency while 2.5% zeolite has negative effects. However, in terms of blood parameters, all the groups had similar values with no significance ($p>0.05$) compared to the control group. They stated that limited usage of clinoptilolite in rainbow trout diets (no higher than 1% in diets) might have beneficial effects on growth parameters.

It is stated that 75% of the total zeolite reserves in the world are found in Turkey. The Western Anatolia Region is rich in clinoptilolite deposits. The most important reserves of clinoptilolite in Turkey are Manisa-Gördes and Balıkesir-Bigadiç basins, with estimated reserves of 20 million tons and 500 million tons, respectively. Other basins for clinoptilolite with total reserves of 50 billion tons are in Emet-Yukarı Yoncaağaç, Kütahya-Şaphane, Gediz-Hisarcık, İzmir-Urla, Tuzköy-Kayseri and Amasya-Doğantepe. The country with the highest production is China (70% of the total production - 1.75 to 2.25 Mt). Turkey is only in the 4th place with a production of 100000 tons (Bahaallddin, 2010). In Turkey, on the other hand, billions of tons of zeolite have been revealed, and it has been determined that mostly clinoptilolite type zeolites are concentrated in the deposits in Ankara-Polatli-Mulk-Oglakci Region and Bigadic, Saphane, Gediz, Emet, Gordes Regions. It is one of the most important manufacturers in the world. The price of the zeolite produced in Turkey is quite reasonable (15900 TL / 25 t). With the studies summarized above, the importance and potential of zeolite use in the aquaculture sector is evident.

Water quality is also very important in aquaculture as well as in all animal farming. Guo et al. (2013) in swine culture, Markou et al. (2014) and Markou et al. (2015) in the production of phytoplankton and cyanobacteria. reported that the using of the zeolite varieties was effective in removing ammonia from the culture environment. Skleničková et al. (2020) in the koi breeding environment; Yu et al. (2020) in the aquaculture environment; Aksu (2016) in the crayfish culture environment; and Peyghan and Azary-Takamy (2002) in improving the water quality in carp ponds, reported that the addition of zeolite gave positive results. Kaiser et al. (2006) in the transplant of *Haplochromis obliquidens* and Ravendra et al. (2004) in the transportation of common carp species, stated that positive results were obtained with the supplementation of zeolite. Dias et al. (1998) in European sea bass (*Dicentrarchus labrax*) fry; Aybal (2001), Danabas (2009), Güler and Ucar (2020) and Tekeşoğlu and Ergun (2021) in the rainbow trout (*Oncorhynchus mykiss*) culture; Töre (2006), Shalaby et al. (2021), Abbas et al. (2021) and Llanes and Castro (2020) in the tilapia species culture; Kanyılmaz (2008) and Surmeli et al. (2020) in the carp (*Cyprinus carpio*) culture; and Öz et al. (2021) in the water quality and growth parameters of electric blue hap (*Sciaenochromis ahli*) reported to provide more positive parameters with addition of different zeolite rates. Zeolites have given very effective results for purposes such as increasing of the fish growth parameters, because of controlling pollution in ponds in the aquaculture sector, of removing nitrogenous compounds from hatchery, fish transport and aquarium water, of increasing ambient oxygen in aquarium and fish transport, and of using them as feed additives. In addition, it has been considered that it will give very useful results in overcoming the problem of feed raw material and cost, which is the main problem of fish culture.

In conclusion, we believe it will also contribute that as a local and natural product, the use of zeolites produced in Turkey country as a feed additive in the aquaculture sector will contribute to the production of fish with lower costs, as well as to the development of 2 different sectors (aquaculture and mining) in interaction with each other.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' contributions

Author DD had the first idea and the design of the study, He wrote the first draft of the manuscript, MD improved the final version of manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

Statement on the welfare of animals

This manuscript is a review. So, for this type of study, formal consent is not required.

Statement of human rights

For this type of study, formal consent is not required.

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