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# Literature study of Zn supplementation in feed for optimizing Nile tilapia *Oreochromis niloticus* growth

# Studi pustaka suplementasi Zn pada pakan untuk peningkatan pertumbuhan ikan nila *Oreochromis niloticus*

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## ABSTRACT

Micro minerals play a crucial role in the physiological processes of fish, acting as enzyme cofactors and stabilizing enzyme and protein structures. One of the essential micro minerals needed in the body is zinc (Zn). Zinc is utilized for various physiological processes, including the maintenance of enzymatic processes within the fish's body. The aim of this literature review is to analyze the optimal level of zinc supplementation in feed to enhance the growth performance of Nile tilapia (*Oreochromis niloticus*), based on the reported findings of conducted research. The literature sources were obtained from accredited national journals, international journals, research outcomes, theses, and dissertations over the past 20 years. The results of this literature review indicate that zinc supplementation in feed can have a positive impact on overall fish growth by increasing digestive enzyme activity, particularly protease enzymes. The level of zinc supplementation in fish is influenced by several factors, including fish size, feed consumption quantity, and duration of maintenance. The optimal dietary zinc intake for Nile tilapia growth is reported to be in the range of 20–50 mg/kg.

Keywords: growth, literature study, Nile tilapia, zinc

## ABSTRAK

Mikro mineral memiliki peran yang sangat penting dalam fisiologi tubuh ikan yang berfungsi sebagai kofaktor enzim dan menjadi penstabil struktur enzim maupun protein. Salah satu mikro mineral yang memiliki fungsi penting dan diperlukan dalam tubuh adalah unsur seng (Zn). Unsur Zn digunakan untuk proses fisiologis termasuk pemeliharaan proses enzimatik dalam tubuh ikan. Tujuan studi pustaka ini adalah menganalisis tingkat suplementasi Zn yang optimum dalam pakan untuk meningkatkan performa pertumbuhan ikan nila *Oreochromis niloticus* berdasarkan laporan hasil-hasil penelitian yang telah dilakukan. Sumber pustaka didapatkan dari jurnal nasional terakreditasi, jurnal internasional, hasil penelitian, tesis, dan disertasi pada kurun waktu 20 tahun terakhir. Hasil studi pustaka ini menunjukkan bahwa suplementasi Zn dalam pakan dapat memberikan pengaruh positif pada pertumbuhan ikan secara umum melalui peningkatan aktivitas enzim pencernaan terutama enzim protease. Tingkat suplementasi Zn pada ikan dipengaruhi oleh beberapa faktor di antaranya, ukuran ikan, jumlah konsumsi pakan, dan lama pemeliharaan. Nilai asupan Zn yang memberikan pertumbuhan optimum pada ikan nila adalah sebesar 20–50 mg/kg.

Kata kunci: ikan nila, pertumbuhan, seng, studi pustaka

## INTRODUCTION

One of the crucial components in fish feed is micro minerals. The function of micro minerals within the fish's body is to act as enzyme cofactors and stabilize enzyme and protein structures. The requirement for micro minerals must be met, as a deficiency can lead to negative effects in fish. One of the important micro minerals that needs to be supplemented to the body is zinc (Zn) (Prashanth *et al*., 2015).

Zinc intake must be supplemented in daily feed, as the body cannot synthesize this element. Zinc plays a vital role in various physiological processes, including maintaining enzymatic processes within the fish's body (Kumar *et al*., 2020). Zinc deficiency in fish can lead to cataracts in eyes, skin erosion, increased mortality rates, and decreased growth performance (Akram *et al*., 2019). Zinc has been reported to enhance digestive enzyme activities such as protease, amylase, and lipase and positively correlated with growth performance (Mondal *et al*., 2020).

Nile tilapia (*Oreochromis niloticus*) is a fish species known for its high growth rate and adaptability to a wide range of environmental conditions (Marie *et al*., 2018). Global tilapia production reached 4.5 million tons in 2018, with Indonesia, China, and Egypt being the dominant producers (FAO, 2020). Due to these reasons, Nile tilapia is one of the most widely farmed freshwater fish species. Feed cost constitutes a significant variable cost in tilapia farming, with the highest composition (Omasaki *et al*., 2017).

As feed prices rise, which subsequently affects feed costs, the efficiency of feed utilization needs to be improved. One strategy to enhance feed efficiency is by improving fish growth performance, through micro mineral supplementation such as zinc (Welker *et al.,* 2016). Research on the requirements of zinc to improve Nile tilapia growth has been conducted by several researchers. These studies indicate that the optimal zinc dose for Nile tilapia growth can vary, necessitating further cross-referencing to determine factors influencing zinc requirements and the extent of zinc supplementation's impact on growth performance, particularly for Nile tilapia.

## MATERIALS AND METHODS

In this study, a literature study methodology was used by collecting various sources that have been published in the last 20 years (from 2002 to 2022). The selected literature sources in this study adhere to strict criteria. Firstly, these literature sources come from reputable international scientific journals, thereby ensuring the accuracy and reliability of the scientific basis of this research. Furthermore, the focus is on the in-depth literature regarding the optimal dose of zinc (Zn) that provides increased growth performance of tilapia.

These selected sources describe the method, including details such as the exact dose of Zn, the parameters measured during the experiment, the data collected, and analysis of the results obtained. In addition, the literature includes the initial weight, final weight, and specific growth rate of in each treatment with the amount of Zn supplemented to the feed. The selected literature sources are shown in Table 1. The collection of literature sources was carried out by downloading references that discuss the varying effects of Zn dosage in feed on the growth of Nile tilapia.

These sources were obtained thorugh search engines on platforms such as Google Scholar, Elsevier, Science Direct, and Pubmed. The search was conducted using keywords such as "zinc requirements for tilapia fish", "effects of zinc supplementation", "dietary zinc level on growth", and "effect of zinc on growth performance". The literature sources obtained were reviewed and the literature that was not related to the effect of Zn dose are excluded.

The obtained literature sources are then selected based on criteria and requirements. There are 10 primary sources that serve as the main data, and 11 others are used as supporting references. Other literature sources that do not use Nile tilapia as the tested fish species are utilized as supporting references. The next step after the literature sources that have been selected is to compare the data obtained from the references. The literature review flow chart can be seen in Figure 1.

### Data analysis

The data research data was processed and analyzed using Microsoft Excel 2016. This study employs a data analysis method through descriptive analysis. The data obtained from literature sources are compared and analyzed concerning the appropriate Zn dosage for Nile tilapia growth. The relationship of zinc intake and relative weight gain was analyzed using quadratic regression and the relationship of initial weight

Table 1. The selected literature sources.

| No | References | Title |
|---|---|---|
| 1 | Carmo e Sá *et al*., 2004 | Optimum zinc supplementation level in Nile tilapia |
| 2 | Lin *et al*., 2008 | Dietary zinc requirements of juvenile hybrid tilapia *Oreochromis niloticus x Oreochromis aureus* |
| 3 | Khater, 2008 | Effect of different levels of zinc on growth performance and gonadosomatic index of Nile tilapia (*Oreochromis niloticus*) females |
| 4 | Luo *et al*., 2011 | Quantitative dietary zinc requirement of juvenile *Pelteobagrus fulvidraco*, and effects on hepatic intermediary metabolism and antioxidant responses |
| 5 | Tan *et al*., 2011 | Growth, body composition and intestinal enzyme activities of juvenile Jian Carp (*Cyprinus carpio* Var. Jian) fed graded levels of dietary zinc |
| 6 | Zhao *et al*., 2011 | Effect of supplemental dietary zinc sources on the growth and carbohydrate utilization of tilapia smith 1840, *Oreochromis niloticus X Oreochromis aureus* |
| 7 | Liang *et al*., 2012 | Effects of dietary zinc sources and levels on growth performance, tissue zinc retention and antioxidant response of juvenile common carp (*Cyprinus carpio* var. Jian) fed diets containing phytic acid |
| 8 | El-Saidy *et al*., 2012 | Effect of zinc supplementation on the growth performance, feed utilization, body composition and hematological parameters of Nile tilapia, *Oreochromis niloticus* |
| 9 | Wu *et al*., 2015 | Influence of dietary zinc on muscle composition, flesh quality and muscle antioxidant status of young grass carp (*Ctenopharyngodon idella* Val.) |
| 10 | Huang *et al*., 2015 | Dietary zinc requirement of adult Nile tilapia (*Oreochromis niloticus*) fed semi-purified diets, and effects on tissue mineral composition and antioxidant responses |
| 11 | Olukunle & Umma, 2016 | Evaluation of African Catfish *Clarias gariepinus* Responses to Graded Levels of Zinc Practical Diet |
| 12 | Singh *et al*., 2017 | Growth and Nutrient Utilization of *Pangasianodon hypophthalmus* (Sauvage, 1878) fed with Graded Level of Zinc |
| 13 | Bem *et al*., 2018 | Assessment of the optimal inclusion level of dietary zinc requirement for catfish *Clarias gariepinus* production |
| 14 | Kishawy *et al*., 2020 | Comparing the effect of diet supplementation with different zinc sources and levels on growth performance, immune response and antioxidant activity of tilapia, *Oreochromis niloticus* |
| 15 | Kumar *et al*., 2019 | Effect of zinc on growth performance and cellular metabolic stress of fish exposed to multiple stresses |
| 16 | Akram *et al*., 2019 | Dietary zinc requirement of *Labeo rohita* juveniles fed practical diets |
| 17 | Musharraf & Khan, 2019 | Dietary zinc requirement of fingerling Indian major carp, *Labeo rohita* |
| 18 | Liang *et al*., 2020 | Effects of dietary zinc sources and levels on growth performance, tissue zinc retention and antioxidant response of juvenile common carp (*Cyprinus carpio* var. Jian) fed diets containing phytic acid |
| 19 | Mohammady *et al*., 2021 | Comparative effects of dietary zinc forms on performance, immunity, and oxidative stress-related gene expression in Nile tilapia, Oreochromis niloticus |
| 20 | Yang *et al*., 2022 | Improving heat resistance of Nile tilapia (*Oreochromis niloticus*) by dietary zinc supplementation |
| 21 | Ibrahim *et al*., 2022 | Nano zinc versus bulk zinc form as dietary supplied: effects on growth, intestinal enzymes and topography, and hemato-biochemical and oxidative stress biomarker in Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) |

gain and zinc intake was analyzed using linear regression.

## RESULTS AND DISCUSSION

### Result

The informations obtained from the literature investigation carried out in this study contains various key aspects. Firstly, it addresses the function and significance of zinc (Zn) in relation to fish growth, explaining the underlying mechanisms that explains how Zn facilitates and sustains fish growth processes. Subsequently, it investigates the contribution of zinc (Zn) to fish health, outlining the mechanisms by which Zn supports and maintains fish health. Additionally, the study assesses the diverse forms in which zinc (Zn) is utilized as an additive in fish feed. Moreover, the research investigates the optimal dosage of zinc (Zn) supplementation for freshwater fish, aiming to determine the most effective dosage for enhancing various growth-related parameters.

### Discussion

*The role and function of Zn on fish growth*

Zinc (Zn) is an essential nutrient required by fish, as it cannot be naturally produced within the body and must be obtained externally (Lall & Kaushik, 2021). One known function of Zn in fish is its ability to enhance growth performance. Zn functions as a cofactor for various enzymes within the body. Cofactors act as enzyme catalysts that enhance enzymatic reactions (Oktaviana, 2018). Zn is also a component of numerous metalloenzymes, which are enzymes formed through metal ion bonding. Types of metalloenzymes containing Zn bonds include carbonic anhydrase, carboxypeptidase, alcohol dehydrogenase, glutamate dehydrogenase, lactate dehydrogenase, malate dehydrogenase, alkaline phosphatase, ribonuclease, and DNA polymerase (NRC, 2011).

Enzymes composed of Zn play roles in various metabolic pathways such as protein synthesis, growth, and energy metabolism (Akram *et al*., 2019). Metalloenzymes containing Zn, like carbonic anhydrase, carboxypeptidase, and alkaline phosphatase, regulate carbohydrate, lipid, and protein metabolism. One such metalloenzyme that regulates protein digestion is carboxypeptidase. This metalloenzyme involves in protein digestion, a vital nutrient for their body composition (Zhou *et al*., 2021).

Protein is a major macronutrient required by fish in substantial quantities for growth. Zn bound to metalloenzymes regulates various nutrient metabolisms needed by fish, contributing to enhanced growth performance. Role of zinc in growth can also be attributed to its stimulation of DNA and RNA synthesis and cell formation, which promotes somatic growth in fish (Kumar *et al*., 2018). Numerous studies conducted on various freshwater and marine fish species indicate that Zn is a micronutrient playing a role in growth. Houng-Yung *et al*. (2014) reported that groupers

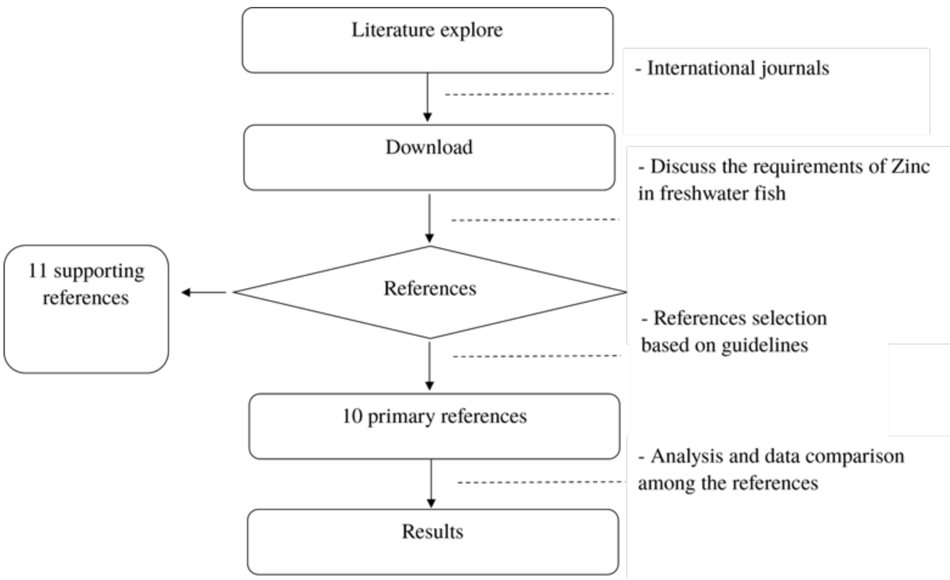


Figure 1. Flow chart of the literature review process.

(*Epinephelus malabaricus*) supplemented with Zn through feed at a dosage of 33.7 mg/kg exhibited optimal growth.

Research by Li *et al.* (2016) indicated that Nile tilapia fed a zinc dosage of 37.2 mg/kg in the feed showed the highest growth performance. A study on Nile tilapia by Ng and Romano (2013) demonstrated that Nile tilapia (*Oreochromis niloticus*) supplemented with Zn in feed at a dosage of 30 mg/kg exhibited the best growth performance. As a comparison, Nile tilapia given low-dose Zn supplementation in the feed (1-5 mg/kg) exhibited poor growth and high mortality during rearing (Pati & Mondal, 2019). Inadequate growth in Nile tilapia with low-dose Zn supplementation can be attributed to impaired metabolic pathways due to insufficient Zn levels. Low Zn levels hinder optimal formation of metalloenzymes, affecting growth performance in fish (Kaliky *et al*., 2019).

*The role and function of Zn on fish health*

One of the known benefits of Zn for fish is its role in enhancing fish health. Zn is a trace element that acts as a cofactor for various enzymes, including those involved in maintaining fish health. The addition of Zn to feed has been reported to minimize cellular damage caused by free radicals within the body (Kumar *et al.* 2018). Zn can act as an antioxidant, reducing the oxidative stress, a condition that the concentration of free radicals in the body is higher than the antioxidants (Marreiro *et al*., 2017). Oxidative stress can lead to cellular damage. Enzyme that helps prevent oxidative stress is superoxide dismutase (SOD).

Zinc, which plays a role in the formation and synthesis of numerous enzymes, also contributes to the formation of superoxide dismutase (SOD). SOD functions as an antioxidant enzyme in the body, counteracting free radicals (Kemal *et al*., 2023). Excessive free radicals have negative effects on the body, as they can react with proteins, lipids, and cellular nucleic acids, causing damage and organ dysfunction (Yu *et al*., 2021). SOD works effectively in the presence of Zn. According to research conducted by Wu *et al.* (2015), SOD levels in fish body increases alongside the increase in dietary Zn levels. The function of SOD involves catalyzing the dismutation reaction of superoxide anions ($O_2^-$) into hydrogen peroxide ($H_2O_2$) and oxygen ($O_2$) (Munawwaroh, 2019).

Numerous studies have explored the effects of Zn supplementation on antioxidant responses in fish, revealing significant impacts on antioxidant production. Feng *et al.* (2011) demonstrated that superoxide dismutase (SOD) enzyme levels in the serum, liver, and muscle tissue of carp increased with elevated dietary Zn levels. Consistent with Feng *et al.* (2011), research by Mohammady *et al.* (2021) indicated that supplementing Zn to the feed elevated SOD enzyme levels, preventing oxidative damage to body cells caused by free radicals. A study conducted by Kumar *et al.* (2018) revealed that catfish (*Pangasius hypophthalmus*) fed with 10 mg/kg of Zn in the feed exhibited better stress response compared to the control group. Providing feed with 10 mg/kg Zn supplementation decreased blood cortisol levels and enhanced the stress resistance of catfish challenged by multiple stressors, including heavy metal exposure, high temperature, and *Aeromonas veronii* bacteria infection (Kumar *et al*., 2018).

*Forms of Zn as feed additives*

Fish generally possess the ability to absorb micro minerals through water and diet (Hossain & Yoshimatsu, 2014). Micro mineral absorption in fish through the environment can occur via gills or the fish's body surface. However, the amount of micro mineral Zn absorbed by fish from the environment cannot meet their requirements, necessitating Zn supplementation through feed (Chanda *et al*., 2015). Concentrations of Zn in both freshwater and seawater environments also fall short of fulfilling fish's Zn needs. Moreover, fish predominantly absorb micro minerals through dietary intake rather than the environment (Mohamed *et al*., 2019).

Fish can utilize Zn more effectively when it is supplemented into feed rather than acquired from the environment. The supplementation of Zn to fish feed can be accomplished using various forms of Zn. Zn types can be categorized into two groups: organic Zn and inorganic Zn. Organic Zn compounds commonly used include zinc methionine (Zn-Met). Organic Zn types are more efficiently utilized by fish, not only as a Zn source but also as an amino acid source (Sallam *et al*., 2020). However, organic Zn is relatively expensive compared to inorganic Zn sources (Zhao *et al*., 2014).

The high cost of using Zn can render the feed economically impractical due to its expense. Consequently, the typical form of Zn added to feed is inorganic Zn, such as zinc oxide (ZnO) and zinc sulfate ($ZnSO_4$). Another reason for using inorganic Zn, such as ZnO, as a source in fish feed is easier to find commercially (Yang *et al*., 2022).

Zinc sulfate is the most commonly used inorganic Zn form for feed supplementation. Zinc sulfate is a chemical compound with the molecular formula $ZnSO_4$. Besides ZnSO4, another common inorganic Zn compound used is zinc oxide, with the molecular formula ZnO.

The research conducted by Faiz *et al.* (2015) showed no significant difference in the growth performance of fish fed with ZnO supplementation compared to those fed with ZnSO4 supplementation. Another form of ZnO is zinc oxide nanoparticle (ZnONP). The distinction between ZnO and ZnONP lies in the smaller particle size of ZnONP, ranging from 1 to 100 nm (Thangapandiyan & Monika, 2020). ZnONP's small particle size results in a higher surface area compared to ZnO, facilitating easier absorption by the intestine (Wang *et al*., 2017).

*Optimum dose of Zn in freshwater fish diet*

Zinc is one of the heavy metals that can be toxic to living organisms. Excessive heavy metals can lead to negative effects on fish, such as protein denaturation and disruption of metabolism. Research results indicate that higher doses of Zn in the diet can decrease growth performance (El-Saidy *et al*., 2012). The reduced growth performance might be due to reduced feed palatability caused by high Zn doses, thereby affecting the amount of feed consumed by the fish. Furthermore, excessive Zn doses in fish can lead to toxic effects, inhibiting enzyme formation, reduced growth, tissue damage, and organs dysfunction (Huang *et al*., 2015).

Insufficient Zn intake can be caused by the low Zn concentrations in feed, requiring Zn supplementation to meet the fish's Zn requirements. Inadequate Zn intake or deficiency in fish can results in symptoms like cataracts, fin erosion, decreased growth performance, anorexia, dwarfism, and even mortality (Akram *et al*., 2019). Increasing Zn doses in the diet is known to reduce feed intake and lead to decreased growth performance. This could be attributed to declining feed palatability with rising Zn levels in the diet (Li & Huang, 2015). Reduced feed palatability can cause fish to lose interest in eating, leading to wasted feed. Proper knowledge of the appropriate Zn dose is essential for optimizing fish growth performance and maintaining fish health.

Fish species can be categorized into several groups: silurid, salmonid, and cyprinid groups. This classification is based on species that have a stomach in their digestive system (gastric) and species that lack a stomach (agastric) (Smith, 1989). Literature on the Zn dose requirements for freshwater fish includes various species such as catfish (*Clarias gariepinus*), common carp (*Cyprinus carpio*), catfish (*Pangasianodon hypophthalmus*), yellow catfish (*Pelteobagrus fulvidraco*), rohu (*Labeo rohita*), and grass carp (*Ctenopharyngodon idella*). Based on the obtained literature, fish can be grouped into two family categories: the cyprinid family, consisting of common carp (*Cyprinus carpio*), rohu (*Labeo rohita*), and grass carp (*Ctenopharyngodon idella*) which lack a stomach (agastric), and the silurid family, consisting of catfish (*Clarias gariepinus*), catfish (*Pangasianodon hypophthalmus*), and yellow catfish (*Pelteobagrus fulvidraco*) which has a stomach (gastric).

Parameters used in analyzing the optimal Zn dose requirements in the literature study include initial weight, final weight, duration of rearing, feed intake, dose used in each study, zinc intake, feed conversion ratio, and specific growth rate. The Zn dose requirements for various freshwater fish is shown in Table 2. The zinc dosage requirements for freshwater fish vary among the fish species (Table 2). The zinc requirements for fish can be classified based on fish families: salmonids, cyprinids, and silurids. Based on the obtained fish species data, the cyprinids family consists of carp (*Cyprinus carpio*), rohu (*Labeo rohita*), and grass carp (*Ctenopharyngodon idella*). Meanwhile, catfish (*Clarias gariepinus*), catfish (*Pangasianodon hypophthalmus*), and yellow catfish (*Pelteobagrus fulvidraco*) belong to the silurids family.

According to the optimal zinc dosage, the cyprinids family has a range of 20–58.2 mg/kg, while the silurids family has an optimal range of 16.4–32 mg/kg. This aligns with the study by Prabhu *et al.* (2016), which suggests that the cyprinids family requires a higher micromineral requirements compared to the silurids family. Differences in micromineral requirements can be attributed to variations in fish digestive physiology (Prabhu *et al*., 2016). Differences in optimal zinc dosage requirements for the same fish species can also result from variations in the weight of the test fish used.

The zinc dosage requirements for catfish (*Clarias gariepinus*) studied by Olukunle and Umma (2016) indicate that catfish with a weight of 11 g require 16.4 mg/kg zinc, while adult catfish weight of 72.40 g require a dosage of 32 mg/kg (Bem *et al*., 2018). Research on zinc requirements conducted by Liang *et al.* (2020) shows that carp (*Cyprinus carpio*) weight of 10 g need 20 mg/kg zinc. In contrast, another study on carp weight of 15.7 g indicates a zinc dosage requirement of 58.2 mg/kg. Based on the obtained data, it is evident that there is a difference in optimal zinc dosages for striped catfish (*Pangasianodon hypophthalmus*). The study by Kumar *et al.* (2019) suggests an optimal zinc dosage of 20 mg/kg, while the research by Singh *et al.* (2017) indicates an optimal zinc dosage of 32 mg/kg for catfish. Yellow catfish (*Pelteobagrus fulvidraco*) have a zinc dosage requirement of 24.81 mg/kg.

Research on zinc dosages for rohu (*Labeo rohita*) indicates an optimal dosage range of 42–51.42 mg/kg. A study on grass carp (*Ctenopharyngodon idella*) conducted by Liang *et al.* (2012) reveals that fish with a size of 2.44 g require a higher zinc dosage than the study by Wu *et al.* (2015), which used adult grass carp weight of 257.78 g. Based on the results of literature study, differences in zinc requirements

Table 2. Zinc dose requirements for various freshwater fish.

| Species | Initial weight (g/fish) | Final weight (g/fish) | Day of culture (days) | Feed Intake (g/fish/ day) | Zn dose (mg/kg) | Optimal dosage (mg/kg) | Zinc Intake (mg/ fish/day) | FCR | SGR (%/day) | References |
|---|---|---|---|---|---|---|---|---|---|---|
| African catfish | 12.50 | 21.39 | 84 | 0.105 | 0, 5.4; 10.9, 16.4, 21.8, 27.3 | 16.4 | 0.0008 | 1.70 | 0.48 | (Olukunle & Umma, 2016) |
| African catfish | 72.40 | 80.40 | 60 | 0.240 | 20, 23, 26, 29, 32, 35, | 32.0 | 0.0032 | 1.60 | 1.03 | (Bem *et al.*, 2018) |
| Common carp | 10.00 | 44.10 | 70 | 0.701 | 0, 5, 20,; 35, 50,; 65 | 20.0 | 0.0056 | 1.44 | 2.14 | (Liang *et al.*, 2020) |
| Common carp | 15.70 | 42.20 | 42 | 0.764 | 15.3, 26.9, 40.8, 58.2, 68.9, 92.5 | 58.2 | 0.0176 | 1.21 | 2.35 | (Tan *et al.*, 2011) |
| Striped catfish | 3.65 | 10.72 | 75 | 0.155 | 0, 10, 20 | 20.0 | 0.0012 | 1.64 | 1.45 | (Kumar *et al.*, 2019) |
| Striped catfish | 11.00 | 20.45 | 60 | 0.276 | 20, 23, 26, 29, 32, 35 | 32.0 | 0.0036 | 1.12 | 1.03 | (Singh *et al.*, 2017) |
| Yellow catfish | 6.15 | 23.33 | 56 | 0.414 | 7.6, 11.9, 16.24, 24.81, 38.75, 76.36 | 24.8 | 0.0040 | 1.35 | 2.38 | (Luo *et al.*, 2011) |
| Rohu | 2.12 | 20.70 | 56 | 0.519 | 9.52, 19.73, 29.84, 51.42, 71.91, 93.14, 112.32 | 51.42 | 0.0108 | 1.10 | 4.07 | (Musharraf & Khan, 2019) |
| Rohu | 3.15 | 17.57 | 90 | 0.184 | 0, 21, 42, 63, 84, 104 | 42.00 | 0.0032 | 1.14 | 1.90 | (Akram *et al.*, 2019) |
| Grass carp | 2.44 | 66.98 | 56 | 1.286 | 13, 25, 34, 53, 89, 135 | 53.00 | 0.0272 | 1.12 | 2.18 | (Liang *et al.*, 2012) |
| Grass carp | 257.78 | 670.33 | 56 | 10.42 | 14.2, 29.2, 44.2, 59.2, 74.2, 89.2 | 44.20 | 0.1844 | 1.41 | 1.71 | (Wu *et al.*, 2015) |

SGR: specific growth rate; FCR: feed conversion ratio.

exist between small-sized and large-sized fish. Studies on catfish, carp, and catfish indicate that smaller fish require larger zinc doses. In opposite, research on rohu and grass carp suggests that larger fish require higher zinc doses.

This variation may be due to the fact that smaller fish exhibit faster growth rates compared to adult fish. Rapid growth necessitates a higher nutrient intake, exceeding that of adult fish. Adult fish, however, tend to experience a decline in growth rate, resulting in lower nutrient requirements compared to smaller fish (NRC, 2011). Therefore, it is suspected that smaller fish also require a higher zinc intake than larger fish. However, the differences in literature review results, such as larger fish requiring higher zinc doses than smaller fish, could be attributed to several factors. Factors influencing zinc dosage requirements in fish, besides fish size, include different cultivation conditions such as environmental factors (salinity, mineral content in water, water temperature) and feeding practices (diet composition, nutrient interactions) (Prabhu *et al*., 2016).

Feeding factors, such as the presence of phytic acid in the diet, can reduce the ability of fish to absorb microminerals. Phytic acid is found in certain feed ingredients such as wheat and legumes (Gupta *et al*., 2015), leading to reduced bioavailability of microminerals. Reduced bioavailability occurs because phytic acid can bind to microminerals, preventing their absorption in the body. Consequently, fish may require higher micromineral intake compared to those on diets without phytic acid (Akram *et al*., 2019). Any physiological changes occurring in fish can lead to differences in their micromineral requirements (Lall, 2022). The level of fish needs for microminerals, which may be in accordance with the physiological and environmental conditions of fish in a given condition, may turn out to be excessive or insufficient due to changes in cultivation conditions. Knowledge of various factors that can cause changes in the level of micromineral requirements in fish needs to be understood.

*Optimum dose of Zn in tilapia*

Zn has a role as an antioxidant in the fish body in preventing tissue damage due to oxidative damage caused by free radicals (Yu *et al*., 2021). Fish that are deficient in Zn can reduce the immune response and cause fish susceptible to disease. Zn deficiency also causes a decrease in tilapia growth, decreases SOD levels and makes it easier for tissues to run into oxidative damage due to free radicals (Kishawy *et al*., 2020). Zn doses that are too high do not necessarily improve fish growth performance. Excessive amount of Zn can also cause a decrease in fish growth performance (Song *et al*., 2017).

Decreased growth performance can be caused by reduced feed palatability and reduced fish interest in feed. Excessive amount of Zn reduce the amount of feed consumed in fish which is thought to be due to a decrease in feed palatability along with an increase in Zn dose in the feed (Huang *et al*., 2015). There are 10 literature sources used in analyzing the optimum Zn dose in tilapia. The source of the literature used consists of various sizes of fish weights used in each study. Several parameters used to analyze the need for optimum Zn dose in tilapia consisted of initial weight of fish, final weight of fish, increase in weight relative to control, days of culture, feed intake, dose used in each study, optimal dose of Zn in each study, zinc intake, feed conversion ratio, and specific growth rate.

Research on the requirements for Zn doses in tilapia can be seen in Table 3. Based on Table 3, it is shown that there is a difference in the optimal supplementation dose of Zn from the literatures. The literature study results indicate that the supplementation of optimal Zn supplementation dose to tilapia feed ranges between 20–50 mg/kg. The variation in optimal doses among different sources could be caused by differences in cultivation conditions such as salinity, temperature, mineral content in water, and varying nutrient interactions in the feed across different studies (Prabhu *et al*., 2016). The size of the fish can also influence the requirement, as smaller fish generally need higher nutrient intake compared to larger fish (NRC, 2011). Therefore, the Zn dosage for tilapia fish feed falls within the range of 20–50 mg/kg under various cultivation conditions. A simple regression analysis based on the data from Table 3 was conducted to examine the relationship between the initial weight of the fish and Zn intake, as presented in Figure 2, and the relationship between Zn intake and the increase in relative weight, as shown in Figure 3.

*The correlation between fish initial weight and Zn intake*

Simple linear regression analysis with initial weight as independent variable and Zn intake as response variable is shown in Figure 2. Figure 2 shows the close relationship between the initial weight of the tested tilapia and Zn intake from the 10 literature data contained in Table 3. Initial weight is the weight of fish measured before rearing begins, while Zn intake is the amount of Zn that enters the fish body through feed. The relationship between the initial weight of tilapia and Zn intake showed a positive trend. Zinc intake in tilapia increased along with the increase in the initial weight of the test fish. This indicates that as the weight of the fish increases, the need for the amount of Zn that enters the body also increases. These results indicate that the size of tilapia affects the amount of Zn requirement (Zn intake). In accordance with the statement of Prabhu *et al.* (2016) which states that one of the factors that influence the micro-mineral requirements of fish is the size of the fish.

*The correlation between Zn intake with an increase in relative weight*

Quadratic regression analysis with Zn intake as the independent variable and the increase in relative weight as the response variable is shown in Figure 3. The percentage increase in relative weight compared to control is the value of the difference in the final weight of the test fish given the optimum dose compared to the final weight of the fish treated with control or without the

Table 3. Requirements of Zn doses in Tilapia

| Initial weight (g/fish) | Final weight (g/fish) | Increase in relative weight compared to control (%) | Days of culture (days) | Feed Intake (g/fish/day) | Zn dose (mg/kg) | Optimal dosage (mg/kg) | Zinc Intake (mg/fish/day) | FCR | SGR (%/day) | References |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.55 | 4.03 | 9.53 | 56 | 0.085 | 0, 5, 10, 20, 30, 40, 50, 100 | 30 | 0.0016 | 1.37 | 3.55 | (Lin *et al*., 2008) |
| 2.20 | 21.00 | 13.81 | 84 | 0.308 | 0, 30 | 30 | 0.0036 | 1.38 | 2.69 | (Mohammady *et al*., 2021) |
| 3.00 | 25.70 | 16.82 | 56 | 0.601 | 0, 10, 20, 30, 60 | 30 | 0.0072 | 1.38 | 3.82 | (Zhao *et al*., 2011) |
| 5.02 | 43.62 | 36.06 | 84 | 0.812 | 0, 30, 60 | 30 | 0.0096 | 1.77 | 2.57 | (Ibrahim *et al*., 2022) |
| 13.30 | 81.69 | 18.83 | 70 | 1.143 | 0, 25, 50, 100, 150, 200, 300, 400 | 50 | 0.0228 | 1.49 | 2.60 | (Carmo e Sá *et al*., 2004 |
| 26.17 | 45.27 | 21.00 | 56 | 1.039 | 0, 10, 25, 50, 75, 100 | 25 | 0.0103 | 3.43 | 0.98 | (Khater, 2008) |
| 27.35 | 94.20 | 4.09 | 108 | 0.729 | 0, 25, 50, 75, 100, 125 | 50 | 0.0144 | 1.18 | 1.08 | (El-Saidy *et al*., 2012) |
| 31.41 | 52.93 | 1.63 | 60 | 0.773 | 0, 20, 40 | 40 | 0.0124 | 2.16 | 0.38 | Kishawy *et al*., 2020) |
| 76.80 | 214.40 | 6.19 | 45 | 3.794 | 0, 20, 40 | 40 | 0.0608 | 1.24 | 2.28 | (Yang *et al*., 2022) |
| 166.90 | 563.40 | 22.34 | 84 | 4.039 | 0, 10, 20, 40, 80, 160, 320 | 20 | 0.0323 | 1.43 | 1.45 | (Huang *et al*., 2015) |

supplementation of Zn to the feed from the 10 literatures presented in Table 3. The Zn intake value is the amount of Zn that enters the fish body through feed with units of mg/day. Based on the results of the literature study, it can be seen that the percentage increase in weight relative to the control increased with the addition of Zn intake. However, at the point of Zn intake of 0,0323 mg/day there was a decreasing trend and an increase in Zn intake above 0,0323 mg/day showed a decrease in the increase in weight relative to the control.

The results showing that an excessive increase in Zn intake can cause a decrease in the growth of tilapia is in line with research conducted by Huang *et al*. (2015). Research conducted by Huang *et al.* (2015) showed that high Zn concentrations in tilapia feed can reduce micro-absorption of other minerals such as Fe, Ca, and Mg. Thus, the disruption of the absorption of micro-minerals in the body can affect the metabolism in the fish's body. Based on the results of the literature study obtained, the optimum Zn intake required by tilapia is 0,0323 mg/day. So to determine the optimum dose of Zn in tilapia, reverse calculations can be carried out depending on the target final weight of fish, length of maintenance, and feeding ratio of tilapia. Calculations need to be done to get the dose of Zn that must be added to the feed so that Zn that enters the body of tilapia is 0,0323 mg/day.

## CONCLUSION

The supplementation of Zn can improve growth performance and fish health status. The optimum Zn intake which gave the highest growth performance in tilapia ranged from 20–50 mg/kg.

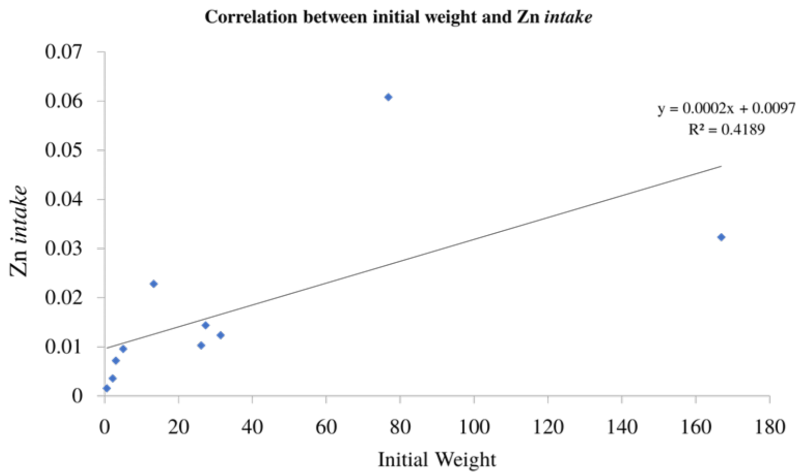


Figure 2. The correlation between initial weight of fish and Zn intake.

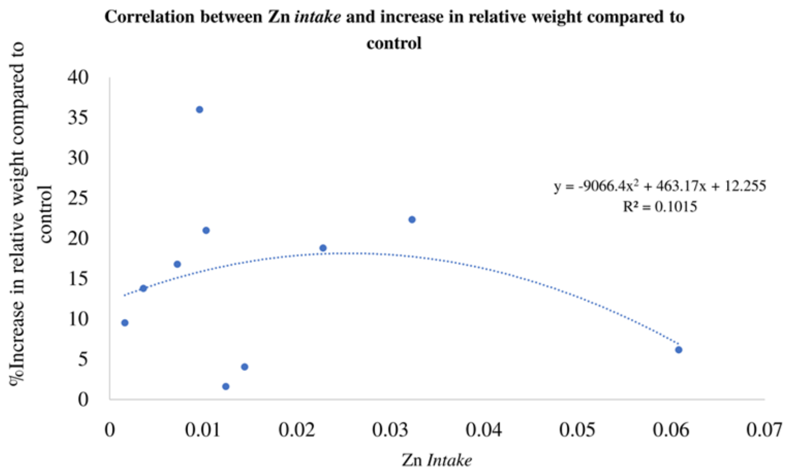


Figure 3. The correlation between Zn intake with an increase in relative weight.

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