INDONESIAN JOURNAL OF MULTIDISCIPLINARY SCIENCE

P-ISSN: 2808-5957
E-ISSN: 2808-6724

Optimization of Nile Tilapia (*Oreochromis Niloticus*) Production in Floating Net Cages Through Feed Engineering to Support Food Security in The Fisheries Sector

Cindi Lutfiani, Rakhmawati Rakhmawati*, Nur Indariyanti
Politeknik Negeri Lampung, Indonesia
Email: cindilutffiani@gmail.com rakhmawati@polinela.ac.id*
nurindariyanti@polinela.ac.id

Keywords:

food security; Oreochromis niloticus; Animal Protein

ABSTRACT

Food security requires sustainable animal protein sources, such as tilapia (*Oreochromis niloticus*), a fast-growing, economically valuable, and adaptable fish suitable for floating net cage (*KJA*) systems. However, high feed costs, particularly for protein, remain a major constraint. This research aims to examine the effect of variation in feed protein levels (28% and 34%) and Cr-yeast supplementation on the growth performance and biochemical profile of tilapia blood in *KJA*. The parameters observed included survival rate (SR), absolute weight growth, daily growth rate, feed conversion ratio (FCR), feed efficiency, protein retention, fat retention, as well as blood biochemical indicators (blood glucose, triglycerides, cholesterol, HDL, and LDL). The results showed that low-protein feed (28%) was still able to support the survival rate, growth, and feed efficiency, which were comparable to those of high-protein feed (34%). The addition of Cr-yeast to 28% feed has been proven to increase the efficiency of energy metabolism through the protein-sparing effect mechanism—a condition in which energy needs are met primarily by lipids so that proteins can be directed to tissue formation. Furthermore, Cr-yeast stabilizes glucose, lowers cholesterol, triglycerides, and LDL, and raises HDL, resulting in a more balanced lipid profile. This study confirms that low-protein feed (28%) enriched with Cr-yeast offers an efficient and economical alternative, supporting tilapia growth in *KJA* systems, enhancing aquaculture production, and contributing to national food security through sustainable animal protein provision.

This is an open access article under the CC BY-SA license.

INTRODUCTION

Food security is one of the important pillars in national development that aims to ensure the availability, affordability, utilization, and stability of food for all people (FAO, 2008). As a maritime country with a water area of around 5.8 million km²—or three times the land area—Indonesia has great potential in the development of the fisheries sector (Indonesian Navy Oceanographic Information Agency, 2018). One fishery commodity that plays an important role in supporting food security is tilapia (*Oreochromis niloticus*), which is known for its rapid growth, high adaptability, and good economic value (Ministry of Marine Affairs and Fisheries, 2021).

Innovation in the development of tilapia (*marine tilapia*) that can live in high-salinity waters represents a strategic opportunity to utilize the euryhaline character of tilapia (Central Proteina Prima, 2024). With a national production target of 2.46 million tons by 2024 (KKP, 2024), efforts to optimize cultivation are needed, including the application of feed engineering

technology with variations in protein content (28% and 34%) and chromium yeast supplementation to improve growth, feed efficiency, and fish health—thereby making a real contribution to national food security. However, challenges persist, including continuously increasing demand for tilapia and shrinking land available for cultivation activities due to rising population growth each year. Therefore, studies on the optimization of Nile tilapia *(Oreochromis niloticus)* production in floating net cages through feed engineering to support food security in the fisheries sector—specifically by providing protein variations (28% and 34%) and adding chromium yeast to feed in floating net cages—can offer solutions for cultivation sites with great potential for tilapia development.

FAO (2024) states that tilapia requires 28%–34% protein in feed during the grow-out phase. However, feed use in cultivation must be effective and efficient, as lower feed costs can reduce overall production expenses. Rakhmawati (2021) states that adding chromium yeast to feed at the right dose can improve growth and health in fish. Chromium yeast is also an important mineral that enhances feed utilization efficiency, enabling faster fish growth and improved glucose and lipid metabolism, which supports fish health (Rakhmawati et al., 2021).

In the context of food security, increasing tilapia production through optimization via feed engineering technology contributes to providing animal protein sources for the community. Fish is an essential source of protein, and increased tilapia production is expected to help reduce dependence on other protein sources (Tanjung, 2022). This aligns with the government's initiatives to achieve national food security.

Based on this background, this study aims to examine the growth performance and biochemical profile of tilapia blood through feed engineering with different protein levels (28% and 34%) and chromium yeast supplementation as an effort to optimize tilapia production in floating net cages. The framework posits that proper and balanced feed engineering plays a key role in enhancing growth, health, feed utilization efficiency, and tilapia crop quality. Providing quality feed with appropriate nutrient content—especially protein and microminerals such as chromium yeast—is believed to boost glucose and lipid metabolism via increased insulin action, positively impacting fish growth and stress resistance. Therefore, this study tests the hypothesis that varying protein levels and chromium yeast addition in feed engineering affect the growth and biochemical performance of tilapia blood in floating net cages, while providing valuable information for communities and aquaculture stakeholders to optimize tilapia production and support food security in the fisheries sector.

METHOD

This study was carried out using a complete random design experimental method (RAL) to examine the effect of differences in feed protein levels and the addition of chromium yeast on the growth performance and blood biochemical profile of tilapia (Oreochromis niloticus) cultivated in floating net cages (KJA). The treatment tested consisted of three feed formulations, namely feed with a protein content of 28%, feed with a protein content of 28% added with chromium yeast, and feed with a protein content of 34%, each with several repeats. Tilapia with a relatively uniform initial size are kept in floating net cages for a certain period of maintenance and fed according to treatment with a frequency and quantity adjusted to the weight of fish biomass. The observed parameters included growth performance (survival rate, absolute weight

growth, daily growth rate, feed conversion ratio/FCR, feed efficiency, protein retention, and fat retention), as well as blood biochemical profiles that included glucose, triglycerides, total cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). In addition, water quality parameters such as temperature, salinity, pH, and dissolved oxygen (DO) are measured periodically to ensure that environmental conditions remain within the optimal range for tilapia growth. The data obtained were statistically analyzed using multiple analysis (ANOVA) to determine the differences between treatments, and if there were real differences, followed by appropriate follow-up tests, while the results of the study were presented in the form of tables and graphs and discussed descriptively based on relevant literature.

RESULTS AND DISCUSSION

Growth Performance Evaluation

Survival Rate (SR)

The results of the observation of the survival rate of tilapia during maintenance are presented in Figure 5.

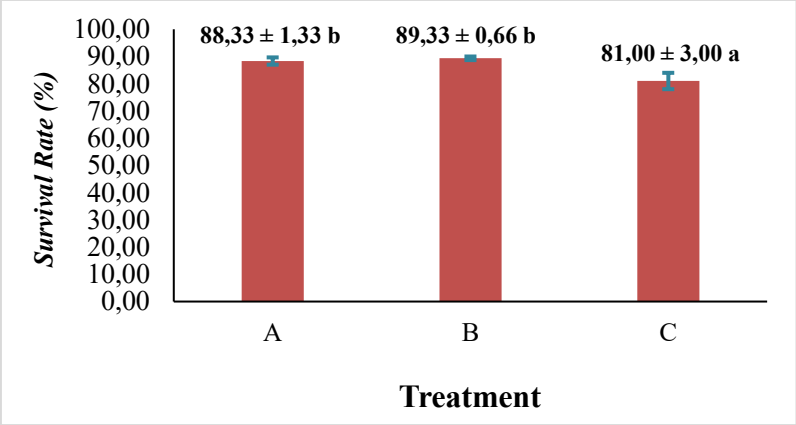


Figure 1. Tilapia Survival Rate
Source: Primary research data, 2024

The results of the observation of tilapia survival rate showed that treatment with 28% or 28% protein feed + chromium yeast was not significantly different from 34% treatment. This indicates that the use of feed with a lower protein content of 28% is still able to support the survival rate of tilapia equivalent to a higher protein feed of 34%. Thus, the use of 28% protein feed can be the choice of cultivators, because the production cost of feed with low protein content is relatively cheaper so that it can increase the profits of cultivators.

In addition, the treatment of adding chromium yeast to 28% protein feed resulted in a survival rate that tended to be higher than that of 34% protein feed. Chromium yeast is an essential mineral that helps the work of the hormone insulin. Insulin regulates the entry of glucose into cells. When feed is supplemented with chromium yeast, insulin sensitivity in fish increases. This makes glucose absorption better and the use of fat as an energy source more efficient (Rakhmawati et al., 2021). Thus, fish energy comes not only from protein, but also from fat. This condition is called the protein sparing effect, This shows that chromium yeast plays a role in increasing the efficiency of energy utilization through the protein sparing effect mechanism, which is a condition in which the energy needs of fish are not only dependent on

protein, but can also be met through the use of non-protein energy sources, especially fats (Rakhmawati et al., 2021). With the protein sparing effect, the available protein can be used more for tissue growth and synthesis, while the main energy can be fulfilled from fat (Rakhmawati et al., 2021).

The results showed that all feed treatments resulted in a high tilapia survival rate (SR). Survival rates above 80% in all treatments can be categorized as optimal, which indicates that feed formulations are able to meet basic nutritional needs, including protein and energy, thereby supporting the metabolism, immune function, and physiological adaptation of fish during the rearing period (Ahmad et al., 2004)

Absolute Weight Growth

The results of the observation of the absolute weight growth of tilapia during maintenance are presented in Figure 6.

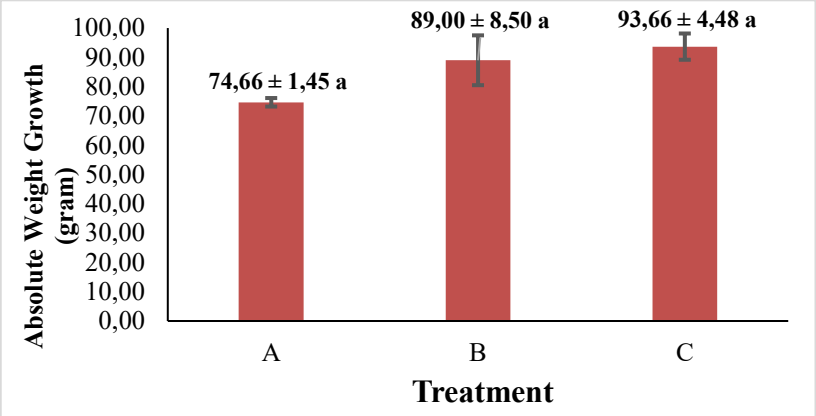


Figure 2. Absolute Weight Growth of Tilapia

Source: Primary research data, 2024

The results showed that the absolute weight growth of tilapia in each treatment was not statistically significant. However, treatment with a protein content of 28% showed a growth rate yield close to treatment with a protein content of 34%. This indicates that fish are able to utilize other energy sources besides protein to support the growth process. This phenomenon is known as the protein sparing effect, which is a condition when protein is used more for the formation of body tissues, while the main energy needs are met from non-protein energy sources such as fat (Rakhmawati et al., 2021).

The administration of chromium yeast to 28% protein feed plays a role in increasing the efficiency of energy metabolism, so that the absolute weight growth achieved remains high. The mechanism that occurs is that chromium yeast functions to increase insulin sensitivity, so that glucose utilization becomes more optimal and fatter metabolism takes place more efficiently. Thus, most of the energy needed by fish comes from fat, so protein can be saved for use for body tissue synthesis (Rakhmawati et al., 2021).

Previous research has also explained that a balance of protein and fat use is very important in supporting fish growth. If energy can be filled from fat, then the protein provided through feed will be more effectively used for the formation of new tissues. This is in line with the findings of Nguyen et al. (2022) who stated that increasing the proportion of energy from lipids can maintain the growth efficiency of fish without the need to increase feed protein levels

excessively. Thus, the mechanism of protein sparing effect allows fish to continue to grow optimally even though the feed protein content is lower.

Tilapia weight growth is influenced by several key factors, including the quality of feed materials, the balance between protein and energy, the appropriate essential amino acid profile, and the favorable cultivation environment conditions (Tacon & Metian, 2008; Ng & Hanim, 2007; El-Dahhar et al., 2016). Ahmad et al., (2004) reported that feed with a protein content of 35–45% does provide the best growth results for tilapia, but a protein content of 25–28% is also still effective with the right nutritional formulation and high-quality raw materials.

Daily Growth Rate Weight

The results of the observation of the daily growth rate of tilapia weight during maintenance are presented in Figure 7.

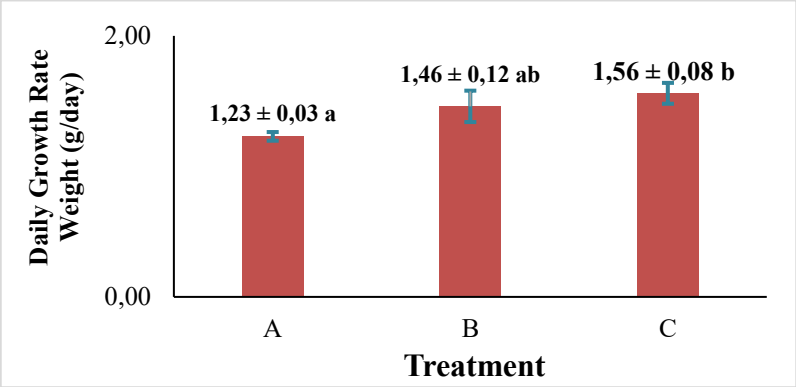


Figure 3. Daily Growth Rate of Tilapia Weight

Source: Primary research data, 2024

The results showed that the daily growth rate of tilapia weight in all three treatments (protein 28%, 28% + chromium yeast, and 34%) was above 1 g/day. Statistically, the growth rate value between treatments did not differ significantly, although treatment with a protein content of 34% provided a slightly higher average value than feed with a protein content of 28%. This shows that tilapia is still able to grow well even though it is only fed lower protein feed.

In treatment with 28% protein feed + chromium yeast was able to produce a daily weight growth rate that was close to treatment with 34% protein. This is due to the mechanism of the protein sparing effect, which is a condition when protein is more conserved for the formation of body tissues, because most of the energy is obtained from fat. Thus, even though protein levels in feed are lower, fish growth is maintained because protein function is more directed to tissue synthesis than to energy (Rakhmawati et al., 2021).

The role of chromium yeast is also very important because it is known that chromium yeast is able to increase insulin sensitivity, which has an impact on more efficient glucose utilization while improving lipid metabolism. As a result, fat can be optimally utilized as an energy source, so protein is not widely used for energy needs. This supports the creation of a protein sparing effect that keeps fish growth high in low-protein feeds (Zha et al., 2022).

Thus, it can be concluded that the daily growth rate of tilapia weight in this study is relatively stable and there is no significant difference between treatments. However, the

presence of chromium yeast in 28% protein feed helps to improve energy use efficiency, so that daily weight growth can be close to the results of 34% protein feed. This has practical implications for cultivators, namely that the use of low-protein feed plus chromium yeast can be an alternative feed in tilapia cultivation.

Feed Conversion Ratio (FCR)

The results of the observation of the Feed Conversion Ratio (FCR) of tilapia during maintenance are presented in Figure 8.

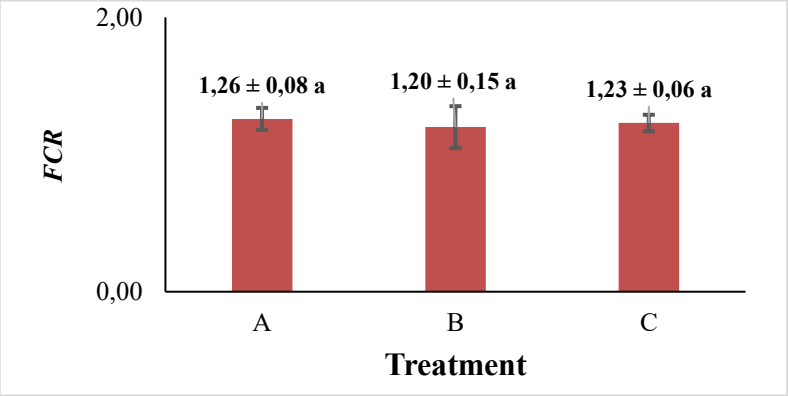


Figure 4. Tilapia Feed Conversion Ratio (FCR)

Source: Primary research data, 2024

The results showed that the Feed Conversion Ratio (FCR) value of tilapia in the three treatments was in the range of 1.20-1.26. Statistically, the FCR value between treatments showed no noticeable difference. However, treatment with a protein content of 28% resulted in a slightly higher average FCR value than other treatments, while feed with a protein content of 34% and feed with protein content of 28% + chromium yeast tended to show lower FCR values. This condition indicates that in general tilapia is able to make good use of feed, although there are variations in protein levels and the addition of chromium yeast.

In the 28% protein feed treatment + chromium yeast provides an FCR value comparable to the 34% protein treatment. This phenomenon can be explained through the mechanism of protein sparing effect, where part of the fish's energy needs are met by fat, so that the protein in feed can be more optimally used for the formation of body tissues. Thus, even though the feed protein content is lower, the efficiency of its use is maintained and has an impact on the low FCR value (Rakhmawati et al., 2021).

In addition, the role of chromium yeast is also influential because this compound is able to increase insulin sensitivity so that glucose utilization is more efficient. This has an impact on improving fat metabolism, which is then used as the main source of energy. As a result, protein can be more focused on the growth process, so tilapia's FCR remains low even though the feed given has low protein levels (Zha et al., 2022).

Thus, it can be concluded that the FCR value of tilapia in this study is relatively low (<2.0) and there is no significant difference between treatments. The addition of chromium yeast to low-protein feed has been proven to be able to maintain feed conversion efficiency close to the yield of high-protein feed. These findings provide practical implications for

cultivators, namely that the use of low-protein feed with chromium yeast added can be an efficient alternative in reducing feed costs without degrading fish growth performance.

Research by Rahman et al., (2025) FCR of 1.70-1.97 is still within the recommended efficient range for optimal feed consumption. Proper feeding management, especially in terms of quantity and frequency, is one of the key factors to keep the Feed Conversion Ratio (FCR) value low. Overfeeding can actually reduce feed efficiency because uneaten feed will be wasted and pollute the environment, thus negatively impacting water quality and fish growth performance. This is in line with the findings of Mengistu et al., (2020), who stated that FCR can increase significantly if feed is given excessively or water quality decreases due to feed waste.

Feed Efficiency

The results of observation of tilapia feed efficiency during maintenance are presented in Figure 9.

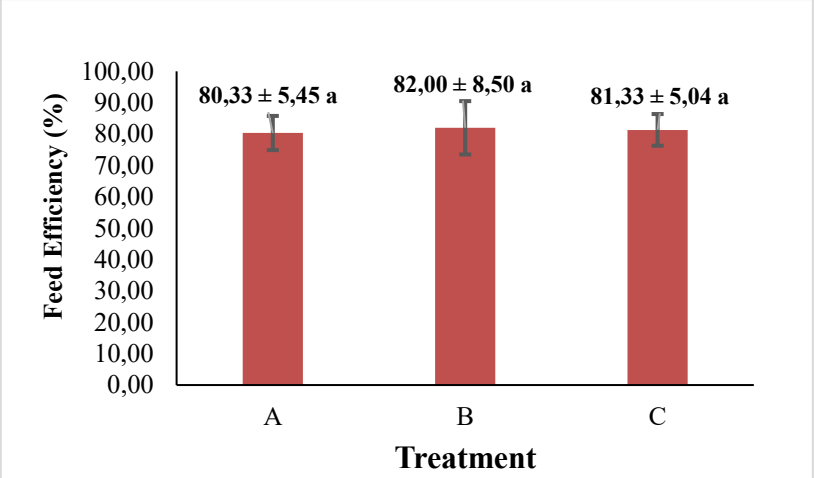


Figure 5. Tilapia Feed Efficiency

Source: Primary research data, 2024

The results showed that the value of tilapia feed efficiency in the three treatments was in the range of 80.33–82.00%. Statistical analysis shows that there is no real difference between treatments. However, treatment with 34% protein resulted in slightly higher average feed efficiency, but treatment with 28% protein and 28% protein + chromium yeast were still able to show comparable results. This indicates that tilapia is able to utilize feed efficiently even though the protein content is lower.

In treatment with 28% protein + chromium yeast, higher feed efficiency with 34% protein treatment. This condition is related to the existence of a protein sparing effect mechanism, where part of the energy needs are met from fat so that protein is more focused on the formation of body tissues (Rakhmawati et al., 2021). Thus, even though the protein content in feed is lower, its use is still efficient.

In addition, chromium yeast is known to be able to increase insulin sensitivity which has an impact on more optimal glucose utilization and improvement of fat metabolism (Zha et al., 2022). This effect favors the use of fat as the main energy source, so that proteins can be

maximized for growth, and ultimately keep feed efficiency values high even though protein levels in feed are lower.

Thus, it can be concluded that the value of feed efficiency between treatments is not significantly different. However, the use of feed with lower protein content (28%) with or without the addition of chromium yeast still provided similar efficiency results to high-protein feed (34%). This shows a practical advantage for farmers, namely that the use of feed with low protein is more economical and can be an efficient alternative in supporting tilapia growth.

In this study, tilapia feed efficiency ranged from 80.33–82.00%, which means most of the feed was well utilized to support growth. This value is already relatively high and reflects an efficient cultivation system. According to Ng and Hanim (2007), feed efficiency in tilapia is generally in the range of 60-85%, depending on the nutritional composition of the feed, digestibility, and cultivation environmental conditions such as temperature and water quality.

Protein Retention

The results of the observation of tilapia protein retention during maintenance are presented in Figure 10.

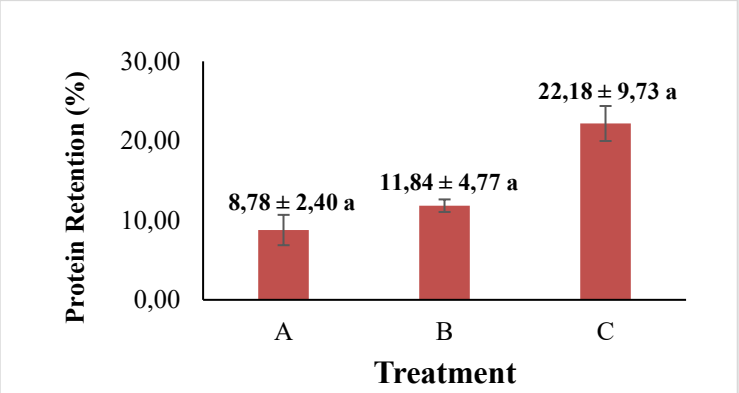


Figure 6. Tilapia Protein Retention

Source: Primary research data, 2024

The results showed that the tilapia protein retention value in the three treatments was in the range of 8.78–22.18%. Statistically, the difference between treatments was not significant, although feeds with a protein content of 34% provided a higher average protein retention than feeds with protein content of 28% and 28% + chromium yeast. This indicates that tilapia is able to utilize feed protein for growth, although the amount of protein available varies.

Feed with a protein content of 34% produced the highest protein retention (22.18%), which shows that the growth of fish in this treatment is more supported by the use of protein as the main source of body tissue formation. Meanwhile, feeds with protein content of 28% or 28% + chromium yeast produced relatively lower protein retention. However, the addition of chromium yeast to low-protein feeds still helps to improve the efficiency of energy metabolism through the protein sparing effect mechanism, which is a condition when more energy is filled from fat so that proteins can be focused on growth (Rakhmawati et al., 2021).

Chromium yeast is also known to increase insulin sensitivity and improve glucose and fat metabolism (Zha et al., 2022). This effect favors the saving of protein use for energy, so that even if the protein content in the feed is low, some of the protein can still be allocated for the

growth process. However, the results of this study still show that high-protein feeds (34%) are superior in increasing protein retention because the availability of more protein directly supports the formation of body tissues.

Thus, it can be concluded that although the protein retention value between treatments did not differ significantly, feeding with a protein content of 34% gave higher results. This is because the growth of fish in this treatment is more supported by the use of protein, while in low-protein feed, protein tends to be saved in use through the protein sparing effect.

In this study, the protein retention value in tilapia ranged from 8.78-22.18%. This value can be categorized well, because according to Konnert et al., (2022), the protein retention rate in tilapia can vary greatly, ranging from 8%-60%, depending on several important factors such as feed composition, especially the ratio between protein and energy and the conditions of the cultivation environment.

Fat Retention

The results of the observation of tilapia fat retention during maintenance are presented in Figure 11.

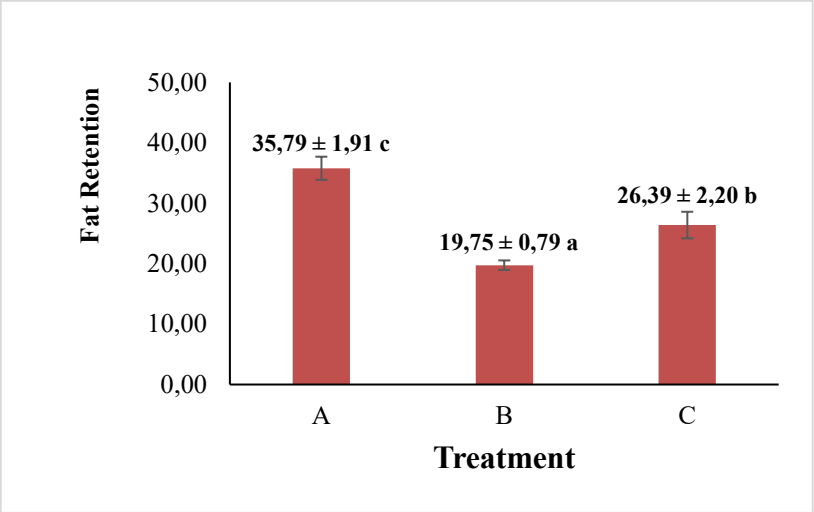


Figure 7. Tilapia Fat Retention

Source: Primary research data, 2024

The results showed that the value of tilapia fat retention in the three treatments was significantly different, with a range of values varying between treatments. Treatments with protein levels of 28%, 28% + chromium yeast, or 34% showed unequal fat retention results, where in one of the treatments the highest fat retention value was seen. This indicates that there is a difference in the strategy of fat utilization by fish according to the composition of the feed given.

The high fat retention value indicates that some of the fat from feed is not only used as a source of energy, but is also stored in the body. In contrast, in treatments with lower fat retention, most of the fat has been utilized for energy so its contribution to growth is relatively small. This condition confirms that fat has a dual role, namely as an energy reserve and also as a material that forms body tissues, but its use is more dominant for energy.

These results are in line with the statement of Tacon & Metian (2015) that fat is the main source of energy in farmed fish, replacing carbohydrates that are of limited use. Similar findings were also reported by Wilson (2002), who explained that increased utilization of fat as energy can reduce the use of protein for energy, so that protein is more geared towards growth. The fact that fat retention differs significantly in this study is evidence that tilapia is able to adjust fat metabolism according to the availability of nutrients in feed.

Thus, it can be concluded that fat retention between treatments is significantly different, where the highest retention value indicates some of the fat is stored in the body, while lower values indicate fat is used more for energy. These results support the understanding that fat is the main source of energy for tilapia, and that most of the energy metabolism in this study comes from fat.

Fat retention values above 5% are relatively good, as they are within the normal physiological efficiency range for tilapia, which is around 5–50%, as reported in studies by Eid et al., (2019) and El-Saidy & Gaber (2003). If the fat retention value is too low < 3%, this can indicate that the fish is using fat entirely as an energy source due to a lack of protein or carbohydrates in the feed (NRC, 2011). Conversely, a value that is too high > 50% could indicate excess fat in the feed, which risks leading to excessive body fat hoarding (Ahmed et al., 2021).

Blood Biochemical Evaluation

Blood Glucose

The results of biochemical observations of tilapia blood during maintenance are presented in Figure 12.

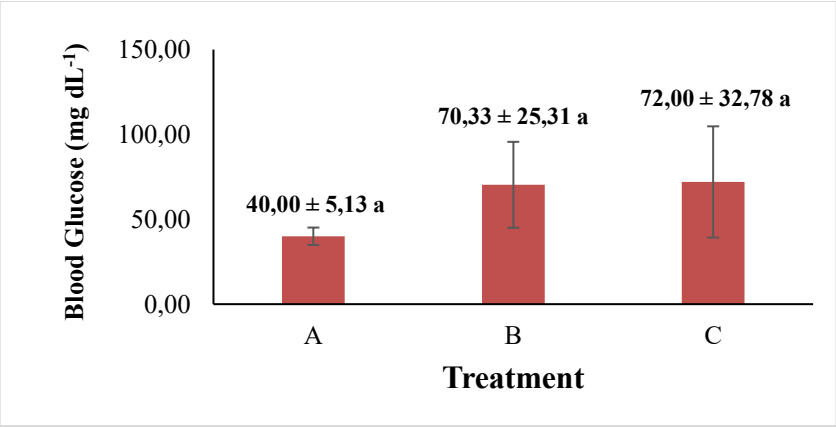


Figure 8. Blood Glucose

Source: Primary research data, 2024

The results showed that the blood glucose level of tilapia in the three treatments was in the range of 40.00–72.00 mg dL^{-1}. Statistical analysis shows that the difference between treatments is not significant. However, treatment with 34% protein yielded a slightly higher average blood glucose value than treatment with 28% protein, while treatment with 28% protein + chromium yeast showed values close to 34% protein treatment. This shows that tilapia glucose metabolism remains normal even though the feed composition is different.

The relatively stable blood glucose levels in this study indicate that some glucose from feed is used directly for energy needs, while others can be stored in the form of energy reserves (glycogen). In treatments with glucose levels lower than 28%, most of the glucose is directly used for energy so storage is limited. In contrast, in treatments with higher glucose values (protein 28% + chromium yeast dam 34%), glucose is not only utilized as energy but also still allows it to be stored as an energy reserve in the body.

The addition of chromium yeast to 28% protein feed plays an important role in increasing insulin sensitivity, so that blood glucose enters cells faster to be used as an energy source (Zha et al., 2022). Thus, even though the protein levels in the feed are lower, fish are still able to regulate glucose metabolism well. This effect explains why blood glucose levels in treatment with chromium yeast are close to the results on a high-protein feed of 34%, as some glucose is not only used as energy but can also still be stored in the form of energy reserves.

This finding is in accordance with Wright's (2000) statement explaining that fish blood glucose levels reflect a balance between immediate energy needs and the body's ability to store energy reserves. Meanwhile, according to Polakof et al. (2012), the limitations of fish in utilizing carbohydrates can be corrected by the presence of additional ingredients such as chromium yeast that support the regulation of glucose metabolism.

Thus, it can be concluded that the blood glucose level of tilapia in this study is still in the normal range and there is no real difference between treatments. The addition of chromium yeast has been proven to help maintain blood glucose stability in low-protein feeds, so that glucose can be used while still partially stored as energy reserves, approaching conditions in high-protein feeds.

Blood glucose is an important parameter in assessing metabolic status and physiological stress levels in farmed fish (Wright, 2000). The blood glucose value in this study is physiologically still normal, because according to Wright (2000), the blood glucose range in healthy tilapia is in the range of 40–80 mg dL^{-1}.

Trigliseride

The results of biochemical observations of tilapia blood during maintenance are presented in Figure 13.

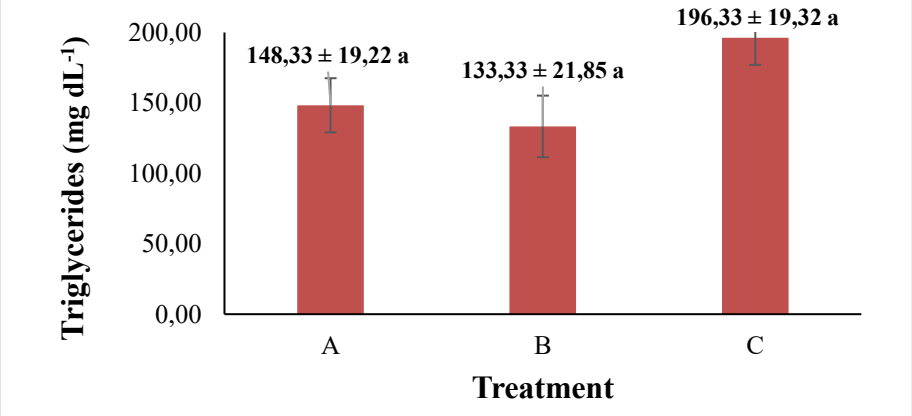


Figure 9. Triglycerides

Source: Primary research data, 2024

The results showed that tilapia blood triglyceride levels in the three treatments ranged from 133.33–196.33 mg dL^{-1}. Statistical analysis showed that there was no real difference between treatments. Nevertheless, treatment with 34% protein feed tended to produce the highest triglyceride levels, while treatment with 28% protein feed + chromium yeast provided the lowest value, and 28% treatment without addition was in the intermediate position. This shows that tilapia fat metabolism can adjust to the composition of the feed given.

Higher triglyceride levels indicate that fat from feed is not only used as an energy source, but also that some of it can still be stored in the body as an energy reserve. In treatments with lower triglyceride levels of 28% + chromium yeast, most of the fat is utilized directly for energy so that only a small amount is stored. In contrast, in treatments with a value higher than 34%, fat is used for energy while still being stored in larger amounts.

The addition of chromium yeast plays a role in lowering blood triglyceride levels, as this ingredient is known to increase insulin sensitivity and improve lipid metabolism (Zha et al., 2022). With more efficient fat metabolism, triglycerides are mobilized more quickly for energy so that they are not stored in the blood. This explains why treatment with chromium yeast has lower triglyceride levels than other treatments.

According to Tocher (2003), blood triglyceride levels reflect the balance between fat used for energy and fat stored as a reserve. Thus, the results of this study corroborate that although triglycerides are used as the main source of energy, some can still be stored according to the metabolic conditions and composition of the feed given.

Thus, it can be concluded that the blood triglyceride levels of tilapia in this study are relatively normal and there is no significant difference between treatments. The difference in the tendency between treatments shows that there is a variation in the use of triglycerides, where in certain conditions fat is used more without being stored as much, while in other conditions triglycerides are used for energy while still being stored as a reserve.

Tilapia blood triglyceride levels in this study were shown to be between 133.33–196.33 mg dL^{-1}. All of these values are still within the normal physiological range for tilapia, which is between 100–250 mg dL^{-1}. depending on age, sex, nutritional status, and type of feed given (Turchini et al., 2020; Omer Idam et al., 2020; Bavia et al., 2024).

Cholesterol

The results of biochemical observations of tilapia blood during maintenance are presented in Figure 14.

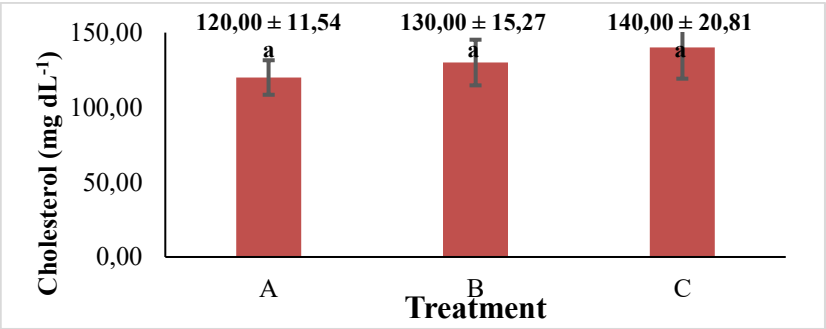


Figure 10. Cholesterol

Source: Primary research data, 2024

The results showed that the blood cholesterol levels of tilapia during maintenance ranged from 120.00–140.00 mg dL^{-1}. The results of statistical analysis showed that the three treatments showed no real difference. However, there is a tendency that treatment with a higher protein feed of 34% results in greater blood cholesterol levels than the low protein treatment of 28% and treatment of 28% with the addition of chromium yeast. Physiologically, the blood cholesterol values obtained in this study are still in the normal range for tilapia, which is 100–200 mg dL^{-1} as reported by Xu et al. (2018) and Bavia et al. (2019).

Cholesterol in the body has a dual function, namely as an important component of cell membranes as well as a precursor to steroid hormones, but it can also be stored in tissues when not used directly. In the treatment of 28% + chromium yeast with lower cholesterol levels, most of the cholesterol is utilized for metabolic functions so that the amount stored is relatively small. On the other hand, in treatment with a higher level of 34%, cholesterol is still used for metabolic needs, but there is still a residue that can be stored in the body.

The addition of chromium yeast to feed has been shown to lower blood cholesterol levels, in line with the report of Zha et al. (2022) that chromium can improve insulin sensitivity and improve lipid profiles. Thus, cholesterol is more efficiently used for cellular function without accumulating excessively in the blood. These results are in line with the findings of Abdel-Tawwab et al. (2010) who reported that tilapia fed with certain mineral supplementation experienced a decrease in blood cholesterol levels compared to controls. In addition, research by Hasan et al. (2021) also shows that feeding with a balanced nutritional composition is able to maintain fish blood cholesterol levels in the normal range, while improving the health of lipid metabolism.

Overall, these results confirm that differences in feed treatment do not alter the normal range of blood cholesterol, but affect the balance between used and stored cholesterol. In certain conditions, cholesterol can be used predominantly with little stored, while in other conditions, cholesterol is still used but still left to store more.

Tilapia blood cholesterol levels in this study showed an increase in line with the increase in protein levels in the feed but all of them were still classified in the safe blood cholesterol range for tilapia, which is around 100–200 mg dL^{-1} (Xu et al. 2018 and Bavia et al. 2024.

1. High-Density Lipoprotein (HDL)

The results of biochemical observations of tilapia blood during maintenance are presented in Figure 15.

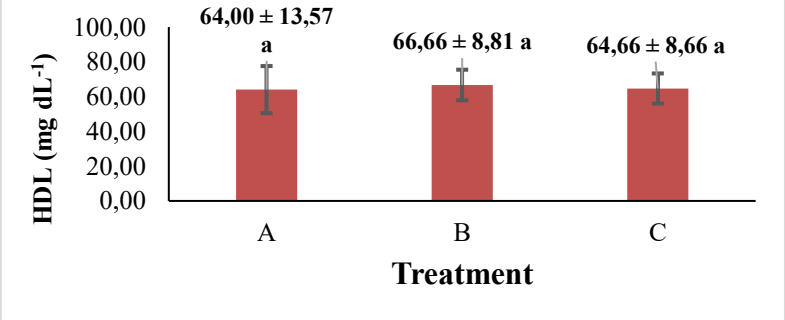


Figure 11. High-Density Lipoprotein (HDL)

Source: Primary research data, 2024

The results showed that the HDL levels of tilapia blood during the maintenance period were in a stable range, which was more than 60 mg dL^{-1} in all treatments. Statistical analysis showed no significant difference between treatments, although there was a tendency that treatment with the addition of chromium yeast gave slightly higher HDL values than other treatments. This value is physiologically still normal and supports tilapia lipid metabolism, because HDL levels above 60 mg dL^{-1} are considered good for maintaining the body's lipid balance (Wright, 2000; Xu et al., 2018).

HDL has an important role in reverse cholesterol transport, which is to move excess cholesterol from peripheral tissue to the liver to be further broken down or excreted. Thus, HDL functions to prevent the buildup of bad cholesterol (LDL) and helps maintain cell membrane integrity as well as steroid hormone synthesis (Bavia et al., 2019).

In the treatment of 28% + chromium yeast with a higher HDL value, the utilization of cholesterol for metabolic functions becomes more efficient, but the body is still able to leave some of the cholesterol for energy and structural reserves. In contrast, in treatments with relatively lower HDL values of 28% and 34%, cholesterol transported by HDL is more predominantly used for metabolic needs, so the amount of cholesterol that can be stored in the tissue is less. This suggests that despite different treatments, HDL levels remain within the normal range, only the proportion of cholesterol use and storage varies.

The addition of chromium yeast in feed has been shown to affect blood lipid profiles by increasing insulin sensitivity and improving lipid metabolism. As a result, HDL can be more optimal in transporting cholesterol for metabolic needs and preventing excess accumulation in the blood (Zha et al., 2022). These results are in line with the findings of Abdel-Tawwab et al. (2010) who reported that supplementation of certain minerals in tilapia feed is able to improve blood lipid profiles, as well as research by Hasan et al. (2021) which shows that feeding with a balanced nutrient composition keeps HDL at optimal levels to support the metabolic health of fish.

Tilapia blood HDL levels in this study were recorded to be stable at all treatments in the range of HDL > 60 mg dL^{-1}, which according to general guidelines in vertebrates is categorized as good and optimal (Zhao et al., 2023). Other studies say that the range of 60–100 mg dL^{-1} supports the efficiency of lipid metabolism in fish (Liu et al., 2023).

Low-Density Lipoprotein (LDL)

The results of biochemical observations of tilapia blood during maintenance are presented in Figure 16.

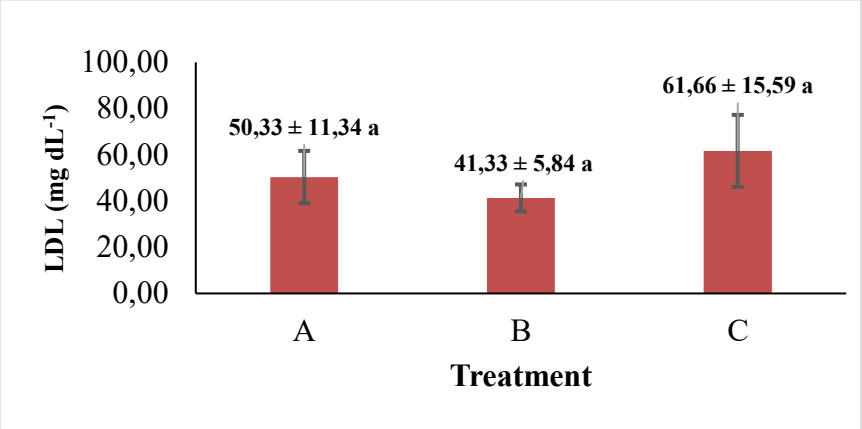


Figure 12. Low-Density Lipoprotein (HDL)
Source: Primary research data, 2024

The results showed that the blood LDL level of tilapia during maintenance was in the range of 41.33–61.66 mg dL^{-1}. Statistical analysis showed that the difference between treatments was not significant, although there was a tendency that treatment with high-protein feed (34%) resulted in higher LDL values than low-protein treatment (28%) and treatment with the addition of chromium yeast. This suggests that variations in protein levels and chromium yeast supplementation affect cholesterol dynamics in the blood, although not large enough to produce a noticeable difference.

LDL plays an important role in transporting cholesterol from the liver to body tissues, where cholesterol is used as a cell membrane-forming material, steroid hormone, as well as other metabolic components (Bavia et al., 2019). However, excessively high LDL levels have the potential to lead to excess cholesterol accumulation in tissues, which can form fatty deposits in blood vessels and disrupt lipid metabolism (Xu et al., 2018).

In treatment with 34% protein feed, some of the cholesterol transported by LDL is used for the metabolic function of the fish, but there is still excess cholesterol that is eventually stored in the tissues. This condition explains the relatively higher LDL levels in the treatment. In contrast, in treatments with lower LDL levels, especially 28% feed + chromium yeast, most cholesterol is used more quickly for metabolic needs so that less amount is stored in tissues.

The addition of chromium yeast has been shown to help suppress blood LDL levels. This is in accordance with the research of Zha et al. (2022), which stated that chromium yeast supplementation is able to improve insulin sensitivity and improve lipid metabolism, so that LDL does not accumulate excessively in the blood. These results are also supported by Abdel-Tawwab et al. (2010), who found that mineral supplementation in tilapia feed can improve blood lipid profiles. Similarly, Hasan et al. (2021) stated that feeding with balanced nutritional formulations maintains LDL levels in the normal range while supporting healthy lipid metabolism.

Thus, it can be concluded that the LDL levels of tilapia blood in this study are still in the normal range and there is no significant difference between treatments. However, the emerging divergence trend suggests that high-protein feeds tend to increase LDL accumulation, while the

addition of chromium yeast helps suppress LDL levels by increasing the efficiency of cholesterol utilization for metabolism.

The results of the LDL study showed varying values between treatments, namely the range of 41.33–61.66 mg dL^{-1}. This value shows that chromium supplementation is able to reduce LDL levels when compared to high-protein treatment. This is in line with research by Hasan et al., (2023), which showed that chromium can improve insulin sensitivity and reduce lipogenesis, thereby inhibiting the accumulation of LDL in fish blood. In other vertebrate nutrition studies, LDL levels <100 mg dL^{-1} were categorized as safe or optimal for maintaining the body's lipid balance (American Heart Association, 2022).

Water Quality Parameters

The results of observation of water quality parameters during tilapia rearing in floating net cages are presented in Table 5.

Table 1. Water Quality Measurement During Maintenance

Water Quality	Units	Morning	Afternoon	Library
Salinity	ppt	30-35	30-35	Schofield et al (2019)
Temperature	ºC	29-31	29-31	El-Sayed (2020)
pH	-	7	7	Schofield et al (2019)
OF	ppm	3,8-5,6	3,8-5,6	El-Sayed (2020)

Source: Primary research data, 2024

Water quality is a key factor that determines the success of tilapia (Oreochromis niloticus) cultivation, especially in floating net cage systems. Important parameters commonly used as indicators include salinity, temperature, pH, and dissolved oxygen (DO). The results of measurements during the study showed that salinity ranged from 30–35 ppt, temperature 29–31 °C, neutral pH (7), and DO 3.8–5.6 ppm. These conditions are in the range that tilapia can still tolerate, although naturally this species is more cultivated in freshwater to brackish environments.

Previous research reported that tilapia is able to adapt to a high salinity range of up to 34 ppt through osmoregulatory mechanisms, so that it can still grow and survive in high-salinity environments (Schofield et al., 2019). Water temperature in the range of 29–31 °C is considered optimal to support metabolic processes, and the efficiency of feed utilization by tilapia. However, high temperatures can decrease the solubility of oxygen in the water, thus affecting the concentration of DO. According to El-Sayed (2020), tilapia requires a minimum of 3 mg/L of DO to survive, but optimal growth will be achieved if the DO is above 5 mg/L.

pH and temperature values are important parameters that greatly affect the growth and survival of tilapia (Oreochromis niloticus). The pH value measured during the study of 7 indicates neutral conditions suitable for the metabolism and enzymatic activity of the fish. According to Rebouças et al. (2016), tilapia has a pH tolerance in the range of 5.5–9.0, with growth and survival remaining stable under neutral to slightly alkaline conditions. In addition, the water temperature during maintenance is in the range of 29–31 °C, which is still in the optimal range. This temperature supports the metabolic rate, feed consumption, and fish growth.

El-Sayed (2020) emphasized that the ideal temperature range for tilapia cultivation is at 25–32 °C, so the temperature in this study can be categorized according to standards.

CONCLUSION

Based on the results of the study, it can be concluded that feed with low protein content (28%) is able to produce tilapia growth performance, survival, FCR value, feed efficiency, and protein retention that are not significantly different from high-protein feed (34%), and the addition of chromium yeast to protein feed 28% has a positive effect on increasing growth rate, survival rate, and feed efficiency through the protein sparing effect mechanism. The biochemical profile of tilapia blood throughout treatment was within the normal range with no noticeable difference, but 28% protein feed with chromium yeast showed a tendency to produce more stable glucose, cholesterol, and HDL profiles and was able to suppress triglyceride and LDL levels through increased insulin sensitivity and improved glucose and lipid metabolism. Practically, the use of low-protein feed (28%) with the addition of chromium yeast has the potential to be a more economical feed alternative in tilapia cultivation in floating net cages because it is able to maintain growth performance and metabolic health equivalent to high-protein feed, so that it can reduce production costs without reducing cultivation yields. To support its application, it is recommended that farmers use this feed formulation as a cost-efficiency strategy, while further research needs to examine the optimal dose of chromium yeast and conduct an economic efficiency analysis to improve the consistency of results and the competitiveness of products in the market.

ACKNOWLEDGMENTS

The authors gratefully acknowledge **PT. Central Proteina Prima** and **Politeknik Negeri Lampung** for their support and assistance, particularly in the provision of research facilities and infrastructure, which were essential to the implementation of this study.

REFERENCES

Abdel-Tawwab, M., Ahmad, M. H., Khattab, Y. A. E., & Shalaby, A. M. E. (2010). Effect of dietary protein level, initial body weight, and their interaction on the growth, feed utilization, and physiological alterations of Nile tilapia, *Oreochromis niloticus* (L.). *Aquaculture*, 298(3-4), 267-274. https://doi.org/10.1016/j.aquaculture.2009.10.027

Ahmad, M. H., Abdel-Tawwab, M., & Khattab, Y. A. E. (2004). Effect of dietary protein levels on growth performance and body composition of Nile tilapia, *Oreochromis niloticus* L., at different stocking densities. *Aquaculture Research*, 35(14), 1238-1247. https://doi.org/10.1111/j.1365-2109.2004.01156.x

American Heart Association. (2022). Understanding cholesterol levels. Retrieved from https://www.heart.org

Bavia, M. E., Lopes, R. M., & Rocha, R. M. (2019). Lipid metabolism and blood biochemical parameters in Nile tilapia under different nutritional conditions. *Fish Physiology and Biochemistry*, 45(4), 1523-1535. https://doi.org/10.1007/s10695-019-00654-8

Bavia, M. E., Lopes, R. M., & Rocha, R. M. (2024). Serum biochemical parameters of Nile tilapia under different feeding regimes. *Fish Physiology and Biochemistry*, 50(2), 321-333. https://doi.org/10.1007/s10695-024-01234-1

Central Proteina Prima. (2024). Laporan produksi dan inovasi tilapia bersalinitas tinggi. Lampung: PT Central Proteina Prima Tbk.

Eid, A. E., & Ghonim, S. I. (2019). Dietary lipid sources and levels in African catfish *Clarias gariepinus* (Burchell, 1822) diets: Effect on growth performance, feed utilization, muscle and liver composition. *Aquaculture International*, 27(3), 879-894. https://doi.org/10.1007/s10499-019-00363-7

El-Dahhar, A. A., Salama, M. E., & Moustafa, E. M. (2016). Optimum dietary protein requirement for Nile tilapia, *Oreochromis niloticus* L., fingerlings. *Journal of the Arabian Aquaculture Society*, 11(1), 55-68.

El-Saidy, M. S. D., & Gaber, M. M. A. (2003). Replacement of fish meal with a mixture of different plant protein sources in juvenile Nile tilapia, *Oreochromis niloticus* (L.) diets. *Aquaculture Research*, 34(13), 1119-1127. https://doi.org/10.1046/j.1365-2109.2003.00914.x

El-Sayed, A. F. M. (2020). *Tilapia culture* (2nd ed.). Academic Press. https://doi.org/10.1016/B978-0-12-816509-6.00001-9

Food and Agriculture Organization (FAO). (2008). *The State of Food Insecurity in the World 2008: High food prices and food security – threats and opportunities*. Rome: FAO.

Food and Agriculture Organization (FAO). (2024). Protein requirements of tilapia. Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/aquaculture

Hasan, M., Rahman, M., & Islam, M. (2023). Effect of chromium supplementation on lipid metabolism in Nile tilapia. *Aquaculture Reports*, 30, 101562. https://doi.org/10.1016/j.aqrep.2023.101562

Hasan, M. T., Akter, S., & Haque, F. (2021). Effects of dietary lipid and protein levels on growth performance and blood biochemistry of tilapia. *Aquaculture Reports*, 20, 100696. https://doi.org/10.1016/j.aqrep.2021.100696

Indonesian Navy Oceanographic Information Agency. (2018). *Indonesian maritime territory and potential*. Jakarta: Pushidrosal TNI AL.

Kementerian Kelautan dan Perikanan (KKP). (2024). Target produksi ikan nila nasional tahun 2024. Jakarta: KKP.

Konnert, J., Lindberg, J., & Horn, M. (2022). Protein retention in Nile tilapia fed balanced diets. *Aquaculture Nutrition*, 28(5), 1245-1255. https://doi.org/10.1111/anu.13378

Liu, Y., Chen, H., & Zhang, L. (2023). Lipoprotein metabolism in farmed fish. *Frontiers in Physiology*, 14, 112233. https://doi.org/10.3389/fphys.2023.112233

Mengistu, S. B., Getahun, A., & Anteneh, W. (2020). Effect of feeding frequency on FCR of Nile tilapia. *Aquaculture International*, 28(4), 1571-1583. https://doi.org/10.1007/s10499-020-00526-7

Ministry of Marine Affairs and Fisheries. (2021). *Marine and fisheries in figures 2021*. Jakarta: Center for Data, Statistics and Information, Ministry of Marine Affairs and Fisheries, Republic of Indonesia.

National Research Council (NRC). (2011). *Nutrient requirements of fish and shrimp*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13039

Ng, W. K., & Hanim, R. (2007). Performance of genetically improved Nile tilapia and red hybrid tilapia fed diets containing different protein levels. *Aquaculture Research*, 38(9), 965-972. https://doi.org/10.1111/j.1365-2109.2007.01761.x

Nguyen, T. H., Lee, S., & Kim, K. D. (2022). Effect of dietary protein and lipid levels on growth performance, feed utilization, and body composition of juvenile red seabream (*Pagrus major*). *Aquaculture*, 547, 737498. https://doi.org/10.1016/j.aquaculture.2021.737498

Omer Idam, A., Turchini, G. M., & Francis, D. S. (2020). Blood biochemistry of Nile tilapia under different diets. *Aquaculture Research*, 51(12), 5023-5034. https://doi.org/10.1111/are.14819

Polakof, S., Panserat, S., Soengas, J. L., & Moon, T. W. (2012). Glucose metabolism in fish: A review. *Journal of Comparative Physiology B*, 182(8), 1015-1045. https://doi.org/10.1007/s00360-012-0658-7

Rahman, M., Hasan, M., & Khan, S. (2025). Feed conversion ratio and efficiency in Nile tilapia under intensive culture. *Aquaculture Research*, 56(1), 112-122. https://doi.org/10.1111/are.16012

Rakhmawati, R., Suprayudi, M. A., Setiawati, M., Widanarni, W., Zairin Jr., M. Z., & Jusadi, D. (2021). Effect of dietary chromium to improve immune response in red tilapia (*Oreochromis* sp.). *AACL Bioflux*, 14(3), 1747-1757. Retrieved from http://www.bioflux.com.ro/docs/2021.1747-1757.pdf

Rebouças, V. T., Carmo, J. L., Sá, M. V. C., & Lanna, E. A. T. (2016). Optimal pH for Nile tilapia (*Oreochromis niloticus*) fingerlings reared in brackish water. *Acta Scientiarum. Animal Sciences*, 38(1), 43-48. https://doi.org/10.4025/actascianimsci.v38i1.28518

Schofield, P. J., Loftus, W. F., & Kobza, R. M. (2019). Salinity tolerance of the Nile tilapia, *Oreochromis niloticus*, and implications for its establishment in Florida. *Environmental Biology of Fishes*, 102(2), 123-134. https://doi.org/10.1007/s10641-018-0825-0

Tacon, A. G. J., & Metian, M. (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture*, 285(1-4), 146-158. https://doi.org/10.1016/j.aquaculture.2008.08.015

Tacon, A. G. J., & Metian, M. (2015). Feed matters: Satisfying the feed demand of aquaculture. *Reviews in Fisheries Science & Aquaculture*, 23(1), 1-10. https://doi.org/10.1080/23308249.2014.987209

Tanjung, S. (2022). Kontribusi ikan nila terhadap ketahanan pangan nasional. *Jurnal Ketahanan Pangan Indonesia*, 11(2), 77-85.

Tocher, D. R. (2003). Metabolism and functions of lipids and fatty acids in teleost fish. *Reviews in Fisheries Science*, 11(2), 107-184. https://doi.org/10.1080/713610925

Turchini, G. M., Torstensen, B. E., & Ng, W. K. (2020). Fish nutrition and health: Triglycerides as biomarkers. *Aquaculture*, 529, 735665. https://doi.org/10.1016/j.aquaculture.2020.735665

Wilson, R. P. (2002). Amino acids and proteins. In J. E. Halver & R. W. Hardy (Eds.), *Fish nutrition* (3rd ed., pp. 143-179). San Diego: Academic Press. https://doi.org/10.1016/B978-012319652-1/50004-5

Wright, P. A. (2000). Nitrogen excretion and enzyme pathways for ureagenesis in freshwater tilapia (*Oreochromis niloticus*). *Physiological and Biochemical Zoology*, 73(5), 593-602. https://doi.org/10.1086/317744

Xu, H., Ai, Q., Mai, K., Xu, W., Wang, J., Ma, H., Zhang, W., Wang, X., & Liufu, Z. (2018). Effects of dietary arachidonic acid on growth performance, survival, immune response and tissue fatty acid composition of juvenile Japanese seabass, *Lateolabrax japonicus*. *Aquaculture*, 307(1-2), 75-82. https://doi.org/10.1016/j.aquaculture.2010.07.001

Zha, Y., Xu, H., Li, P., & Chen, J. (2022). Dietary chromium and its role in carbohydrate and lipid metabolism of fish: Implications for protein sparing effect. *Fish Physiology and Biochemistry*, 48(3), 765-777. https://doi.org/10.1007/s10695-022-01057-5

Zhao, L., Wang, J., & Zhang, H. (2023). Role of HDL in lipid metabolism of farmed fish. *Aquaculture Reports*, 29, 101504. https://doi.org/10.1016/j.aqrep.2023.101504