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Optimization of US Soybean Meal for Growth Performance of Tilapia (*Oreochromis niloticus*) Compared to Commercial Feed on Lake Toba, North Sumatera, Indonesia

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Abstract

Feed is the most important factor in supporting the growth of tilapia fish production. Soybean meal is recognized as a cost-effective alternative protein source to replace costly fish meal in aquaculture. This study aimed to evaluate and compare the growth performance of tilapia (*Oreochromis niloticus*) fed a diet optimized with US soybean meal compared to an available commercial tilapia diet in fish farming in Lake Toba, North Sumatra. Two experimental diets were used, including commercial feed as a control and feed with optimized US Soybean meal with three replications. The experimental diets were given two times a day. After 240 days of feeding, data from the study were analyzed using independent samples T-test on the Statistical Product and Service Solutions (SPSS) software version 25.0. The Survival Rate (SR), Average Body Weight (ABW), Feed Conversion Ratio (FCR), and the harvested biomass of tilapia on the feed with US Soy were 64.2%, 1262.2 g, 1.76, and 244.144 kg, respectively. There was no significant effect ($P > 0.05$) on the SR (Survival rate), Feed Conversion Ratio (FCR), ADG (Average Daily Growth), and final ABW (Average Body Weight) in both the experimental diets. However, the harvested biomass of tilapia fed with feed-optimized US soybean meal was better than the control. An important finding of this research is the potential of optimizing US soybean meal in aquafeed to increase the growth of tilapia farming.

INTRODUCTION

One of the most widely cultured species is tilapia (*Oreochromis niloticus*). Tilapia farming has become an important sector of the Indonesian aquaculture industry. Lake Toba is one of the main locations for this farming activity. Feed contributes the most to the cost of sustainable fish farming across all species. Fish meal has proven to be the largest source of protein. Many nutritionists have realized

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that fish meal, a significant source of protein in aquafeeds, would soon become unaffordable due to its rising demand, erratic supply, and high pricing, as well as aquaculture's ongoing growth (Dawood *et al.,* 2015).

Because of its greater protein content, balanced essential amino acids, accessibility to sources, and affordability, soybean meal is an excellent option among plant proteins to partially or completely replace fish meal protein in diets (Azarm and Lee, 2014). The utilization of soybean meal as an alternative for fishmeal in aquafeed has been recognized as one of the most effective due to its wide availability, sustainable supply chain, affordable cost, high protein content (45–50%), and suitable amino acid profile (Lin and Ding, 2011). Therefore, soybean meal is an appropriate candidate to replace fishmeal for farmed fish species (Wang *et al*., 2017).

Soybean meal has the most secure amino acid profile, sustainable supply, high protein content, and reasonably priced plant protein source (Meng *et al.,* 2020). Several studies reported that soybean meal replaced fish meal since soybean is a global source of high-quality protein in the diets of several fish species. Generally, omnivorous and herbivorous fish species utilize soybean meal more efficiently than carnivorous fish species (Liu *et al.,* 2021). Additionally, soybean meal may be a cost-effective and widely available alternative protein source to substitute high-cost fish meal in aquaculture. Consequently, the present study aimed to evaluate and compare the growth performance of tilapia (*O. niloticus)* fed a diet optimized with US soybean meal compared to an available commercial tilapia feed on Lake Toba, North Sumatra.

METHODOLOGY

Ethical Approval

During this research, no animals were harmed or subjected to improper treatment. The trial animals involved in the study were treated appropriately, ensuring an optimal environment, including water quality factors like temperature and availability of dissolved oxygen.

Place and Time

This research was conducted in the Growth out Toba Sirungkungon site PT. Aquafarm Nusantara, Toba District, Lake Toba, North Sumatera, Indonesia from June 2023 to February 2024.

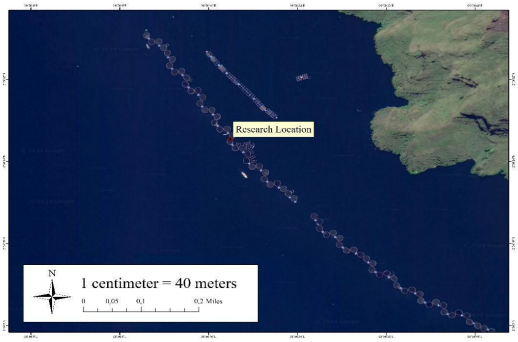

Figure 1. Research location at Lake Toba, North Sumatra, Indonesia.

Research Materials

The equipment used was floating net cages (KJA), Aquanetix probes, and a digital balance with an accuracy of 0.01 g. The material used was Tilapia fish obtained from Hatchery Lubuk Naga/conditioning pond nursery cages at Sirungkungon site PT Aqua Farm Nusantara/Regal Springs Indonesia. Commercial fish feed was used as a control, and another feed was fed optimized with US soybean meal from USSEC (US Soybean Export Council).

Research Design

The method used in this research is the experimental method with descriptive

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quantitative analysis. This study used two experimental diets with commercial feed as control and feed made by PT. Aquafarm Nusantara Feedmill. Each treatment will be replicated in three cages, with 75000 tested fish for each, and 6 cages (18 m x 6 m). Each replicate will be designated by a number (1, 2, and 3). The three replicates of each treatment will be designed to Code A1, A2, and A3 fed with commercial feed (32% crude protein and 6% fats). Codes B1, B2, and B3 were feed-optimized US soybean meal (32% crude protein and 6% fats). Sampling was carried out every 30 days with 300 fish samples. All fish from all treatments will be harvested on 240 days of feeding days and when the average size has reached 1.150 g on the last sampling day. The growth performance (ABW, ADG, and biomass), survival rate, and FCR are the primary parameters in this study, while supporting parameters were water quality measured using Aquanetix probes by INNOVASEA, UK.

Average body weight (ABW) is the fish's average weight calculated by the sample results (Prabu *et al.,* 2020). The formula is as follows:

$$\text{ABW} = \frac{\text{total weight of fish (g)}}{\text{number of fish (fish)}}$$

Average daily growth (ADG) is the fish's average daily weight gain during a specific period, which may be utilized to measure how quickly fish are growing. According to Prabu *et al.* (2020), the formula is as follows:

$$\text{ADG} = \frac{\text{final ABW (g)} - \text{initial ABW (g)}}{\text{time span (day)}}$$

The total weight of fish maintained in a pond or pond at a particular time is known as fish biomass. According to Anam *et al*. (2017), the formula is as follows:

$$\text{Biomass} = \text{Population (fish)} \times \text{ABW (g)}$$

Survival rate is a prediction of the survival of biota within a certain period. According to Prabu *et al*. (2020), the formula is as follows:

$$\text{SR} = \frac{\text{final number of fish (fish)}}{\text{initial number of fish (fish)}} \text{x}100\%$$

The ratio of the weight of fish feed given during a specific cycle time to the total weight (biomass) produced is known as the feed conversion ratio. According to Prabu *et al*. (2020), the formula is as follows:

$$\text{FCR} = \frac{\text{F}}{\text{Bt} + \text{D} - \text{Bo}}$$

Description:

F : Amount of feed given during the research (g)
Bt : Final biomass fish (g)
D : Weight of dead fish during the research (g)
Bo : Initial biomass fish (g)

Work Procedure

The research began with preparing nets and cages in the farming site, a total of ten cages of 18 meters in diameter and 6 meters deep and 1500 m^3 water density, located at the farm site on Lake Toba, North Sumatera. Fish will be approximately 25 g tilapia (*O. niloticus*) obtained from a nearby nursery cage and conditioned for a minimum of two weeks on site. Stocking tilapia fingerlings with a density of 75.000 fish/cage. Measurements were conducted every four weeks on growth parameters (ABW, ADG, FCR, and Biomass) from the first time stocking to harvest time and other parameters as well. Measuring water quality using aquatic probes and the data will be recorded as well every day as supporting data for this research.

Data Analysis

The data were analyzed with Excel 2016 described production data during the culture period and T-test data analysis used Statistical Package for the Social Sciences (SPSS) 25.0 software (SPSS Inc., Chicago, IL, USA) was used to conduct statistical analysis in this study. The comparison between the control feed and trial feed was conducted using two treatments and three replications.

RESULTS AND DISCUSSIONS

Average Body Weight (ABW)

Based on the results of the study, it was found that the overall average body weight of Nile tilapia with feed control and feed with US soybean meal can be seen in Figure 2.

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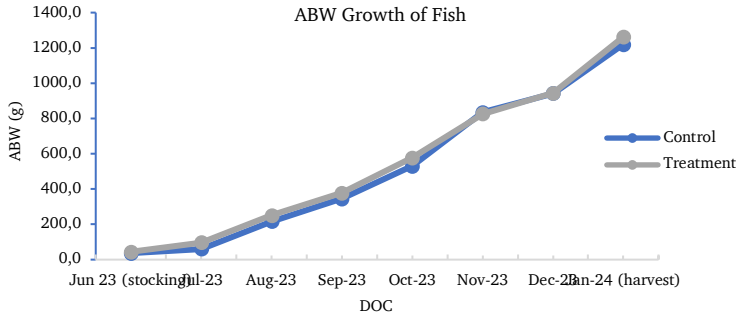

Figure 2. Comparability of overall ABW between control feed and feed optimized with the US soybean meal.

In this research, feed optimized with US soybean meal showed positive results compared to control/commercial feed. This can be seen in Figure 2. The average weight of the treatment using feed optimized with US soy is 1262.4 g, while the control feed is 1220 g. This shows that feed with a US soy formulation has good nutritional content for fish growth from fingerlings to market size. However, the final average of tilapia in all treatment diets was above 1200 g, and there were no significant differences (P> 0.05). Statistical analyses revealed no significant differences in the treatment, specifically between the control and trial feeds regarding the ABW (P>0.05). The ABW average calculated for the control feed was 523.68 436.60, whereas that trial feed (optimized with US soybean meal) was 547.45434.16. Previous studies by Ehsani *et al*. (2014) replaced fishmeal with fermented soybean meal on the average final weight of juvenile yellowfin showed no significance compared to the control group (P> 0.05). The final average weight from the control was 6.88 g, and the average final weight replaced with 10% fermented soybean meal was 6.87 g.

Previous studies (El-Saidy and Gaber, 2002) conducted a study that analyzed a commercial tilapia diet that contained 30% soybean meal and 20% fish meal with diets that had all of the protein originating from soybean meal, and the result after feeding for ten weeks, feed which containing 55% soybean meal outperformed the commercial tilapia diet concerning weight gain, final weight, protein efficiency ratio, feed conversion, and feed intake.

Average Daily Growth (ADG)

The results of this study found that the overall average daily growth of Nile tilapia with feed control and feed with US soybean meal can be seen in Figure 3.

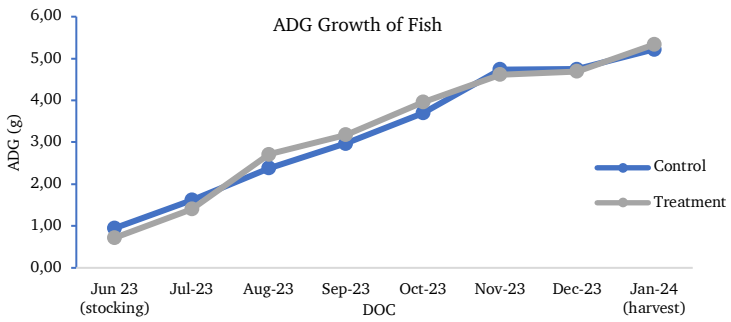

Figure 3. Comparability of overall ADG between control feed and feed optimized with the US soybean meal.

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The growth performance can be seen in Figure 3, where tilapia fish given control/commercial feed shows a significant increase in ADG with a value of 5.21 g, while compared to fish given feed with US soybean meal formulation had better ADG than control which is 5.34 g. However, statistical analyses using the T-test revealed no significant differences between this treatment of both the control feed and trial feed (P >0.05). The ADG average calculated for the control feed was 3.34 1.47, whereas that trial feed (optimized with US soybean meal) was 3.421.46. Based on the previous study by Ehsani *et al.* (2014), the ADG from the control feed was 4.40, while from feed replaced with 10% fermented soybean meal was 4.36.

Additionally, based on the result from this study proved that US soybean meal has a positive effect on tilapia growth due to treatment better than control. Soy product is utilized as livestock feed as they provide a benefit in growth performance, but this depends on the dosage that farmers use for feed manufacture (Sinha *et al.*, 2013). To identify a purpose for this by-product for freshwater aquaculture production, several studies have been conducted recently.

Biomass

Based on the results of the study, it was found that the overall biomass of Nile tilapia with feed control and feed with US soybean meal can be seen in Figure 4.

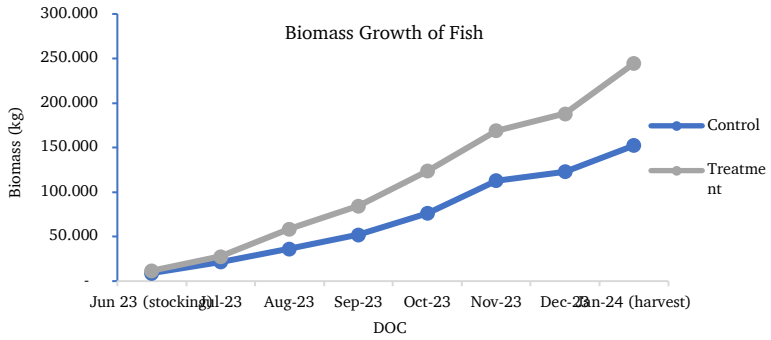

Figure 4. Comparability of biomass performance between control feed and feed optimized with US soy bean meal.

The total biomass of tilapia after post-stocking until harvest can be seen in Figure 4. The graph shows a significant difference in the increase of tilapia biomass every month. Both treatments showed positive results where the biomass increased significantly with the increase of day of culture (DOC) cultivation. However, there is a large difference in the total biomass at the end of the cultivation period. The fish fed with the treatment by optimizing the US soybean meal formulation had a greater biomass mass compared to the control/commercial feed, which was 244.144 kg, while the control feed was only 152.247 kg. From these data, it can be concluded that the effect of feed-given formulations using US soy has a positive impact on the amount of biomass in Tilapia fish. Similar to Nile tilapia in this study, omnivorous fish showed a high degree of acceptability towards the replacement of soybean meal for fishmeal.

However, favorable growth outcomes were preserved when fishmeal was replaced by 50% or more. Some authors suggest the soybean meal's production process may affect the digestibility performance for commercial fish like Nile tilapia (Tangendjaja, 2015).

Survival Rate (SR)

The results of the study show that the overall survival rate (SR) of Nile tilapia with feed control and feed with US soybean meal can be seen in Figure 5.

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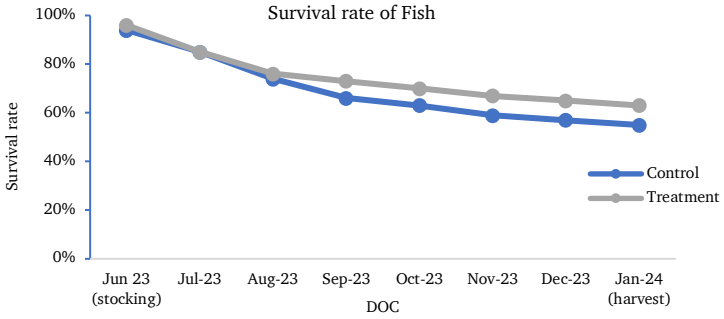

Figure 5. Comparability of overall survival rate between control feed and feed optimized with the US soybean meal.

SR (Survival Rate) is a determining factor in the success of fish farming activities. Based on the results of the study, the mortality rate was caused by several factors, such as water quality, fish health, weather conditions, etc. The main cause of reducing SR in this study was weather conditions, where in the rainy season it influences the water quality, especially in water temperature (decreased until 2°C), though the temperature is still safe for tilapia farming. However, sudden temperature changes caused the fish to become stressed and susceptible to diseases, which influenced the survival rate due to the high mortality occurrence at that time. The survival rate of tilapia in all treatment diets was above 50%, and there were no significant differences (P> 0.05). Previous studies by Ehsani *et al*. (2014) replaced fishmeal with fermented soybean meal on the survival rate of juvenile yellowfin showed no significance compared to the control group (P> 0.05). The survival rate from the control was 95%, and the survival rate by replacing with 10% fermented soybean meal was also 95%.

However, based on the result from this study, fish fed using the formulation with the US. Soy showed a percentage of the survival rate value until the end of the culture period of 64.2% while using the control feed of 55.1%. This showed that the fish given the treatment feed had a better survival rate than fish given control/commercial feed. It can be concluded that the content of nutrients in the feed can affect the health and survival of fish. According to a study by Kader *et al*. (2012), fermented soybean products can enhance blood biochemical parameters; nevertheless, determining the inclusion is necessary for improved fish health and growth.

Feed Conversion Ratio (FCR)

The results of the study showed that the overall feed conversion ratio (FCR) of Nile tilapia with feed control and feed with US soybean meal can be seen in Figure 6.

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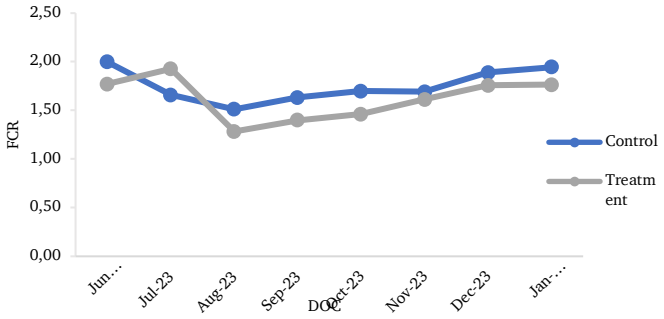

Figure 6. Comparability of overall FCR between control feed and feed optimized with the US soybean meal.

In this study, the FCR value can be seen in Figure 5. Fish given feed with US soybean meal formulations have a better FCR of 1.76 than fish given control/commercial feed of 1.94. The feed conversion ratio (FCR) was calculated to evaluate the feed utilization given to the fish. If the FCR value is lower, then the feed quality is good and effective for the growth of fish body weight. However, statistical analyses revealed no significant differences in the treatment, specifically between the control feed and trial feed regarding the FCR ($P>0.05$). The FCR average calculated for the control feed was 1.75 0.17, whereas that trial feed (optimized with US soybean meal) was 1.62 0.22. Based on the result from this study showed fluctuating results of FCR during the culture period, this case was caused by several factors such as weather and mortality rate, especially after 85 days post-stocking. When bad weather and high mortality occurred, most fish got a low fish appetite, which influenced the amount of feed per day and impacted the total of feed in the sampling period as well as the total biomass at the sampling time.

According to Wijayanti and Pebriani (2021), differences in FCR results depend on the protein contained in each feed ingredient, and environmental, quality, and quantity of feed affect the growth and conversion of the feed. Conversion of the feed. The lower the conversion value, the more efficiently the feed is converted into meat. The main components of soybean products include protein, lipids, fiber, and minerals. According to some studies, soybeans offer several functional qualities, including the capacity to serve as an antioxidant, the ability to prevent cardiovascular disease, the ability to reduce calorie consumption, and the potential to maintain a healthy hepatic lipid profile (Kim *et al*., 2016).

Water Quality

Water temperature is one of the most influencing environmental factors affecting the growth of fish. The better the water quality during the study, the better the growth and survival will be. The results from the observations show that the value of water quality is in optimal condition on Lake Toba. An average temperature value of 25 °C – 27 °C is in the good range for the growth and survival of Nile tilapia. This results from the following statement from Leonard and Skov (2022) that an optimal rearing temperature for Nile Tilapia of 25-30°C. Furthermore, the DO (dissolved oxygen) value shows the optimal DO for tilapia culture was in the optimal range of 5-7 mg/L. According to Indriati and Hafiludin (2022), dissolved oxygen (DO) concentration the more it is, the better it is for aquaculture, but the best is between 5 and 7 ppm. Low DO levels occur due to the pollution of toxic ammonia compounds from feces and metabolite waste of fish and feed residues.

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CONCLUSION

Based on the growth parameters in this research, the comparison between tilapia fish fed with US soybean meal optimized has better growth in average body weight (ABW) with the better value of 1262.4 g, average daily growth (ADG) with the better value of 5.34 g, biomass with the better value of 244.144 kg, survival rate (SR) with the better percentage of 64.2%, and feed conversion ratio (FCR) with the better value of 1.76. However, there was no significant effect ($P > 0.05$) on the SR (Survival rate), Feed Conversion Ratio (FCR), ADG (Average Daily Growth), and final ABW (Average Body Weight) in both the experimental diets.

CONFLICT OF INTEREST

None of the authors had any conflicts of interest upon writing and publishing this manuscript article.

AUTHOR CONTRIBUTION

Juanda: author correspondence, collecting data, researcher, sampling, Friska Setiawani Saragih: contributed to article writing and performed statistical, Hasim Djamil: contributed data analysis, Apryani Susanti: manuscript writing and analysis.

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