Jurnal Sains Akuakultur Tropis
D e p a r t e m e n A k u a k u l t u r
kultas Perikanan dan Ilmu Kelautan – Universitas Diponegoro
Jl. Prof. Soedarto, SH, Tembalang,Semarang 50275
Telp. (024) 7474698, Fax.: (024) 7474698
Email: sainsakuakulturtropis@gmail.com, sainsakuakulturtropis@undip.ac.id

The Effect of Fermented Monosodium Glutamate Waste as a Feed Supplement on Feed Efficiency, Growth and Survival of Tilapia Fingerlings *(Oreochromis niloticus)*

Subandiyono Subandiyono[1], Novia Dwi Pangestuti[1], Sri Hastuti[1*]

[1]Department of Aquaculture. Faculty of Fisheries and Marine Sciene. Diponegoro University.
Jl. ProfJacub Rais. Tembalang. Semarang. Central Java-50275. Indonesia. Telp/Fax.+6224 7474698
* Corresponding author: email: hastuti_hastuti@yahoo.com

ABSTRACT

Tilapia (*Oreochromis niloticus*) is a freshwater commodity with high economic value; however. its growth performance is often constrained by low feed efficiency. One potential approach to improve feed utilization is the supplementation of fermented monosodium glutamate (MSG) waste. which contains protein and amino acids and can be classified as a single-cell protein (SCP) source. This study aimed to evaluate the effect of fermented MSG waste supplementation on feed utilization efficiency and growth rate of tilapia fingerlings. The experiment was conducted at the Quarantine Laboratory for 42 days. from May to June 2025. using a Completely Randomized Design (CRD) with four treatments and five replicates. consisting of supplementation levels of 0%. 5%. 10%. and 15%. The experimental fish were tilapia fingerlings measuring 5–7 cm in length and weighing 3.05±0.18 g. stocked at a density of 13 fish per aquarium. Observed parameters included total feed consumption (TFC). feed conversion ratio (FCR). feed utilization efficiency (FUE). protein efficiency ratio (PER). relative growth rate (RGR). survival rate (SR). and water quality. The results indicated that fermented MSG waste supplementation had no significant effect (P>0.05) on all measured variables. The highest feed consumption was observed at 5% supplementation (69.90±2.57). while the best performance values of lowest FCR (1.20±0.06). highest FUE (72.46±11.35). PER (1.68±0.26). and RGR (3.02±0.48) were recorded at 10% supplementation. Survival rates ranged from 76.92% to 90.77%. and water quality remained within optimal ranges. Overall. supplementation up to 15% did not significantly enhance feed efficiency or growth performance.

KEYWORDS: Single-cell protein. Feed conversion ratio. Protein efficiency ratio. Relative growth rate

INTRODUCTION

Tilapia (*Oreochromis niloticus*) is one of the most widely cultivated freshwater fish species (Hastuti and Subandiyono. 2020a; Nurkholifah. et al.. 2022; Subandiyono et al., 2026a) and represents a commodity of considerable economic importance. This species possesses several advantages that support its intensive culture. including adaptability to diverse rearing environments. rapid growth rate. tolerance to suboptimal conditions. and high nutritional value (Hastuti and Subandiyono. 2020b; Subandiyono and Hastuti. 2020; Susantie and Manurung. 2021). In addition. feed management plays a crucial role in determining production performance. as adequate nutrition is essential to support optimal growth and survival (Subandiyono and Hastuti. 2020; Setiyowati et al.. 2022; Subandiyono et al., 2026a).

Feed constitutes the largest operational cost in aquaculture. accounting for approximately 60–70% of total production expenses (Subandiyono. et al.. 2018; Hidayati et al.. 2020). However. the increasing cost of feed is often not accompanied by improved feed utilization efficiency. thereby reducing overall production profitability. Efficient nutrient utilization is therefore a key factor in enhancing fish growth performance. High-quality feed is characterized not only by its nutrient composition but also by its digestibility and bioavailability to fish (Subandiyono and Hastuti. 2020; Surianti et al.. 2024). One potential strategy to address this issue is the

incorporation of functional feed additives. such as vitamins. minerals. enzymes. or alternative protein sources. to improve feed efficiency.

Fermented monosodium glutamate (MSG) waste. commercially known as Ajitein. has emerged as a promising alternative protein supplement. Ajitein is a single-cell protein (SCP) derived from fermented mother liquor (FML). a by-product of MSG production through molasses fermentation by *Brevibacterium* sp. (Sunu.et al.. 2013). Its application in aquafeeds is expected to enhance the availability of protein and essential amino acids. thereby improving feed utilization efficiency in tilapia culture. Moreover. the use of Ajitein contributes to sustainable aquaculture practices by valorizing industrial waste into cost-effective feed ingredients.

MATERIALS AND METHODS

Experimental Fish and Rearing Conditions

The experiment was conducted at the Quarantine Laboratory, Faculty of Fisheries and Marine Sciences, Diponegoro University. Nile tilapia (*Oreochromis niloticus*) fingerlings, with an average initial body weight of 3.05 ± 0.18 g and a total length of 5–7 cm, were used as experimental animals. The fish were obtained from Rowo Jombor Reservoir, Klaten, and acclimated to laboratory conditions prior to the experiment.

Experimental Diets and Feeding Procedure

A commercial diet (PF 1000) was used as the basal feed and supplemented with fermented monosodium glutamate (MSG) by-product, commercially known as "Ajitein." The experimental diets were prepared using a coating method, in which Ajitein was mixed with egg white as a binder, followed by the addition of water to ensure uniform coating onto the feed pellets. Fish were fed to apparent satiation three times daily at 08:00, 12:00, and 16:00 (WIB) throughout the 42-day experimental period.

Experimental Design

The experiment was arranged in a completely randomized design (CRD) consisting of four treatments and five replicates. The treatments were as follows: (A) basal diet without Ajitein (0%, control); (B) basal diet supplemented with 5% Ajitein; (C) basal diet supplemented with 10% Ajitein; and (D) basal diet supplemented with 15% Ajitein. The inclusion levels were adapted from Setiawan (2016), who evaluated Ajitein supplementation up to 16%. The proximate composition of the experimental diets is presented in Table 1.

Table 1. Proximate Composition of Experimental Diets

Proximate Composition	Experimental Diet (% Ajitein Level)			
	A(0)	B(5)	C(10)	D(15)
Protein*	39.200	41.997	43.031	45.033
Carbohydrates*	33.263	27.876	27.710	26.724
Fat*	4.619	4.442	4.200	4.109
Ash*	11.650	11.624	11.278	11.058
Water*	11.268	14.061	13.782	13.076
Total	100	100	100	100

Note:
Proximate composition analysis was performed at the Laboratory of Fishery Product Technology, Diponegoro University.

Growth Performance and Feed Utilization Parameters

The parameters evaluated in this study included total feed consumption, feed conversion ratio (FCR), feed utilization efficiency, protein efficiency ratio (PER), relative growth rate (RGR), and survival rate (SR).

Total feed consumption (TFC) was calculated as the difference between the total feed provided and the remaining feed (Pereira et al., 2007; Pangestyastuti et al., 2017; Subandiyono et al., 2026b). The feed conversion ratio (FCR) was determined based on Tacon (1987) as cited in Setyawan and Helmiati (2021), taking into account total feed intake, biomass gain, and mortality. Feed utilization efficiency (EPP) was calculated as the percentage ratio of biomass gain to total feed consumption (Tacon, 1987; Lukman et al., 2022).

The protein efficiency ratio (PER) was calculated as the ratio of biomass gain to protein intake, where protein intake was derived from feed consumption and dietary protein content (Tacon, 1987; Pangestyastuti et al., 2017). Relative growth rate (RGR) was calculated based on weight gain over time according to Subandiyono and Hastuti (2014). Survival rate (SR) was calculated as the percentage of fish remaining at the end of the experiment relative to the initial stocking density (Subandiyono and Hastuti, 2016).

Water Quality Monitoring

Water quality parameters, including temperature, pH, dissolved oxygen (DO), and ammonia (NH_3), were monitored throughout the experimental period. Temperature, pH, and DO were measured daily in the morning

and afternoon using a water quality meter. The probe was immersed in the water until stable readings were obtained. Ammonia levels were measured weekly and analyzed at the Laboratory of Environmental Engineering, Diponegoro University.

Data Analysis

All data are presented as mean ± standard deviation (SD), with five replicates per treatment (n = 5). Prior to statistical analysis, the data were tested for normality (Shapiro–Wilk test), homogeneity of variance (Levene's test), and additivity to ensure that the assumptions for parametric analysis were met.

Growth performance parameters, feed utilization efficiency and Feed conversion ratio (FCR) were analyzed using one-way analysis of variance (ANOVA) to evaluate the effects of dietary supplementation with fermented monosodium glutamate by-product ("Ajitein") on Nile tilapia (*Oreochromis niloticus*) fingerlings. When significant differences were detected ($P < 0.05$), Duncan's multiple range test was performed as a post hoc test to determine significant differences among treatment means.

All statistical analyses were conducted using SPSS software (IBM SPSS Statistics, version 22) or an equivalent statistical package.

Water quality parameters were analyzed descriptively and are presented as mean ± SD. These values were subsequently compared with established optimal ranges for Nile tilapia culture to assess the suitability of the rearing conditions.

RESULTS AND DISCUSSION

Results

a. Total Feed Consumption

Total feed consumption (TFC) is presented in Figure 1. No significant differences were observed among treatments ($P>0.05$), with values ranging from 66.33 ± 1.54 g to 69.90 ± 2.57 g. This indicates that dietary inclusion of fermented monosodium glutamate by-product ('Ajitein') did not affect feed intake or palatability in tilapia fingerlings.

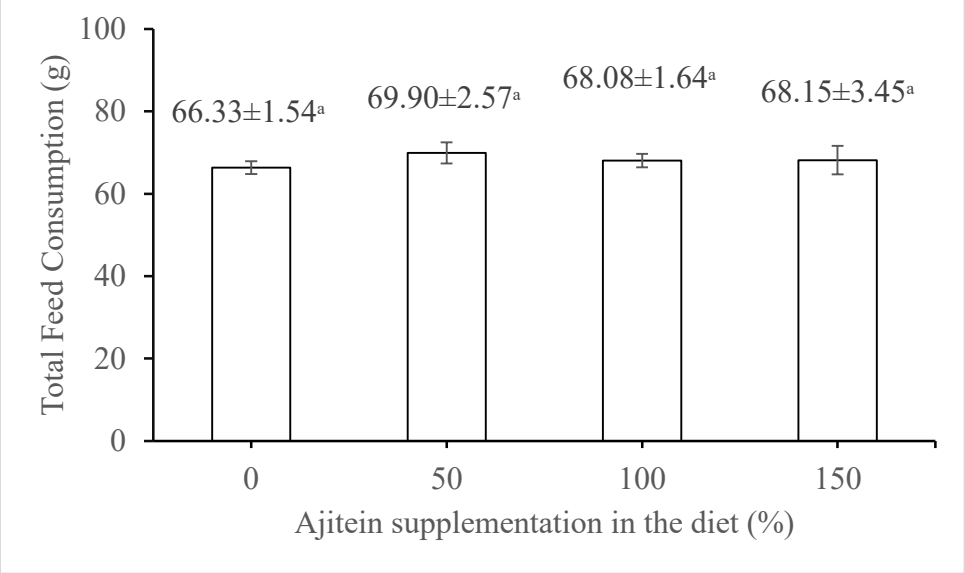


Figure 1. Total feed consumption (TFC) of tilapia fry across treatments

The relatively uniform TFC across treatments suggests that the basal diet already possessed adequate nutritional quality and acceptability. Feed additives generally enhance intake only when baseline palatability is suboptimal. Higher TFC values compared to those reported in gourami (Setiawan, 2016) likely reflect species-specific differences in metabolic rate and growth performance, as tilapia exhibit faster growth and higher feed demand (Malau et al., 2021).

b. Feed Conversion Ratio

Feed conversion ratio (FCR) values (Figure 2) ranged from 1.20 to 1.33 and were not significantly affected by Ajitein supplementation ($P>0.05$). These values fall within the efficient range reported for tilapia culture (Poot-Lopez et al., 2020), indicating effective feed utilization across treatments.

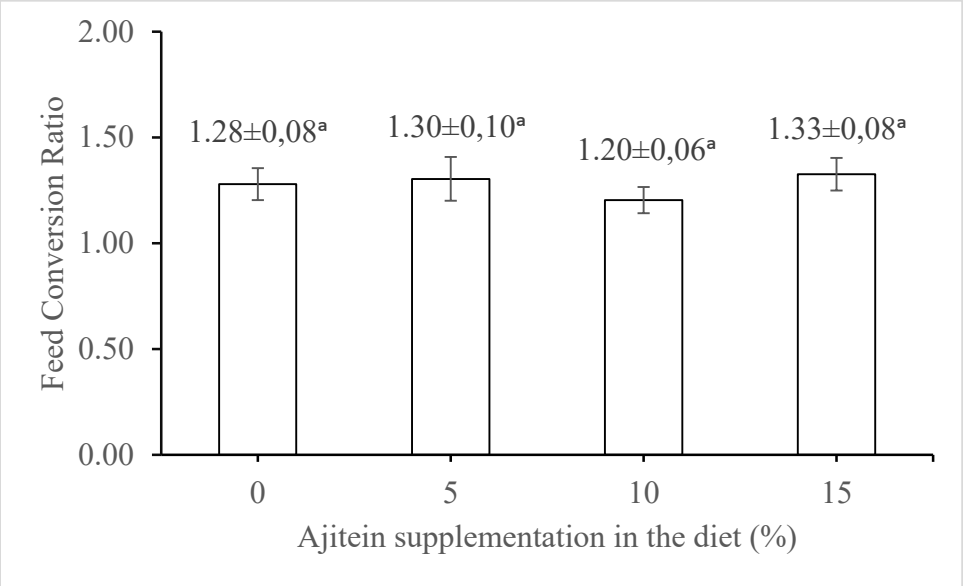


Figure 2. Feed conversion ratio (FCR) of tilapia fingerlings across treatments

The absence of treatment effects suggests that the basal diet already met the nutritional requirements for optimal growth. Under such conditions, additional supplementation does not necessarily improve feed efficiency. Variability in FCR is therefore more likely associated with individual physiological differences rather than dietary treatment.

c. Feed Utilization Efficiency

Feed utilization efficiency (FUE) values (Figure 3) ranged from 62.11 ± 14.33% to 72.46 ± 11.33%, with no significant differences among treatments (P>0.05). These values indicate efficient conversion of feed into biomass and exceed the commonly accepted threshold of 50% for aquaculture species.

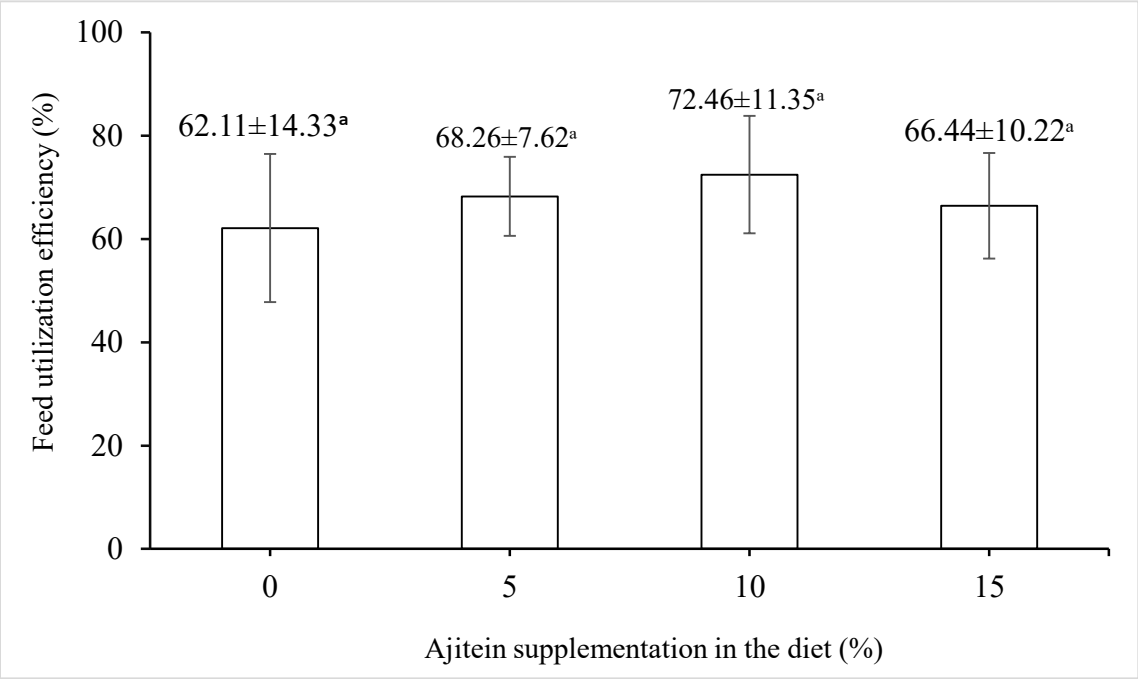


Figure 3. Feed utilization efficiency of Tilapia fingerlings across treatments

The lack of response to Ajitein supplementation suggests that dietary energy was sufficient to support metabolic processes, allowing protein to be primarily allocated for growth rather than catabolism. Thus, improvements in feed efficiency were limited by the already optimal nutritional composition of the basal diet.

d. Protein Efficiency Ratio

Protein efficiency ratio (PER) values (Figure 4) ranged from 1.47 ± 0.23 to 1.68 ± 0.26 and were not significantly influenced by Ajitein inclusion (P>0.05). These values indicate effective protein utilization but suggest no additional benefit from supplementation.

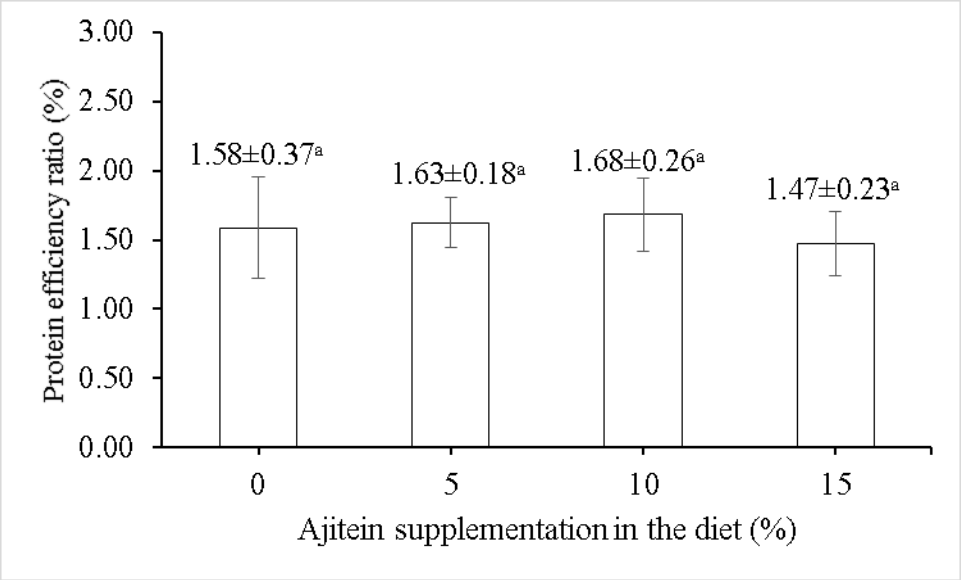


Figure 4. Histogram of Protein Efficiency Ratio (PER) of Tilapia fingerlings across treatments

The absence of significant differences may be attributed to a balanced amino acid profile and sufficient non-protein energy sources in the basal diet. When dietary energy is adequate, protein is efficiently utilized for growth, reducing the potential impact of additional protein or amino acid inputs.

e. Relative Growth Rate

Relative growth rate (RGR) values (Figure 5) ranged from 2.48 ± 0.69 to 3.02 ± 0.48, with no significant differences among treatments (P>0.05). This indicates that Ajitein supplementation did not enhance growth performance.

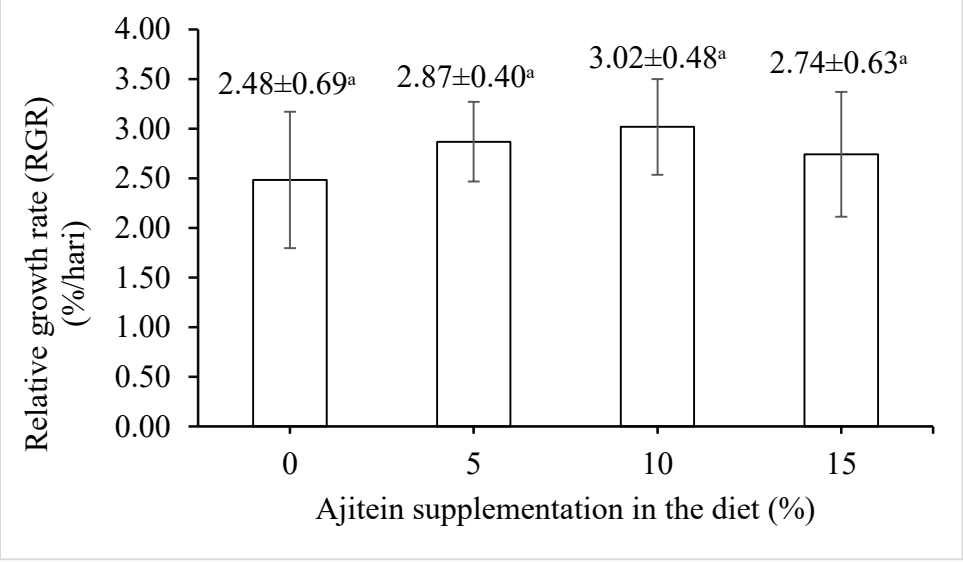


Figure 5. Histogram of Relative Growth Rate (RGR) of Tilapia fingerlings across treatments

The results suggest that growth was primarily driven by the adequacy of the basal diet rather than the additive. Once the dietary protein–energy balance reaches optimal levels, further supplementation typically does not result in additional growth gains.

f. Survival Rate

Survival rate (SR) ranged from 76.92% to 90.77% (Figure 6) and was not significantly affected by dietary treatments (P>0.05). This demonstrates that Ajitein inclusion up to 15% is safe and does not negatively impact fish survival.

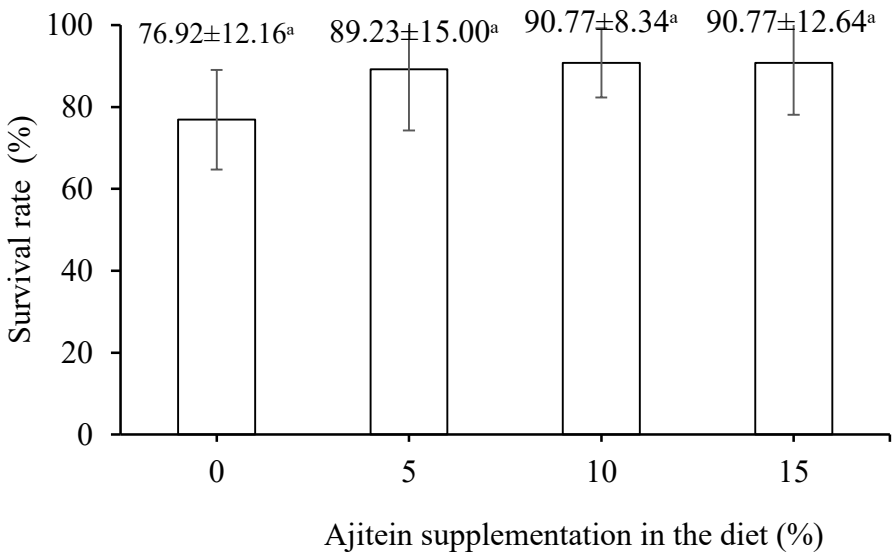


Figure 6. Histogram of Survival Rate of Tilapia fingerlings across treatments

The relatively high survival across treatments indicates favorable rearing conditions and the absence of toxic or stress-inducing effects from the diets. Survival is influenced by multiple factors, including environmental conditions and stress, which appear to have been well controlled in this study.

g. Water Quality

Water quality parameters remained within optimal ranges for tilapia culture throughout the study. Temperature (24–28 °C), pH (6.97–8.5), dissolved oxygen (3.4–4.7 mg/L), and ammonia (0.00003–0.13189 mg/L) were all within acceptable limits, indicating that environmental conditions did not constrain fish performance. These results confirm that the observed growth and survival outcomes were primarily influenced by dietary treatments rather than water quality limitations.

Discussion

The present study demonstrated that dietary supplementation of fermented monosodium glutamate by-product ('Ajitein') did not significantly affect feed utilization, growth performance, or survival of tilapia (*Oreochromis niloticus*) fry (P>0.05). Across all evaluated parameters—total feed consumption (TFC), feed conversion ratio (FCR), feed utilization efficiency (FUE), protein efficiency ratio (PER), relative growth rate (RGR), and survival rate (SR)—no statistical differences were observed among treatments. These findings indicate that Ajitein inclusion, at the tested levels, did not provide measurable benefits under the given experimental conditions.

The absence of significant effects on TFC suggests that Ajitein up to 15% in the experimental diet did not enhance feed palatability or feeding stimulation. Feed intake in fish is influenced by sensory properties such as taste and aroma, as well as physiological regulation (NRC, 2011, Subandiyono and Hastuti, 2022). The relatively uniform feed consumption across treatments implies that the basal diet already had sufficient palatability and nutritional adequacy. Similar findings have been reported by Satria et al. (2022), who stated that feed additives may not significantly influence consumption when the basal diet is already acceptable to fish. This supports the notion that the effectiveness of feed additives is context-dependent, particularly on the quality of the base diet.

Feed efficiency indicators further reinforce this interpretation. The FCR values obtained in this study (1.20–1.33) fall within the optimal range for tilapia culture, indicating efficient feed utilization (Poot-López et al., 2020). In parallel, FUE values exceeding 60% suggest that a large proportion of consumed feed was effectively converted into biomass. According to De Silva and Anderson (1995), feed efficiency is closely related to nutrient digestibility and metabolic utilization. When these processes operate efficiently, additional supplementation may not yield further improvements. The lack of significant differences in FCR among treatments therefore suggests that the basal diet already supported near-optimal nutrient utilization.

The PER results also showed no significant response to Ajitein supplementation, despite its potential contribution of protein and amino acids. Protein utilization in fish is strongly influenced by the balance between dietary protein and available energy sources (Wilson, 2002; Subandiyono and Hastuti, 2022). When sufficient non-protein energy (lipids and carbohydrates) is available, protein is preferentially used for growth rather than catabolized for energy. In this study, the stable PER values (1.47–1.68) indicate that protein was efficiently utilized across all treatments. The lack of improvement may also be related to the amino acid profile of the diet

(Subandiyono and Hastuti, 2022; Subandiyono et al., 2026a) where Ajitein supplementation did not significantly enhance the availability of limiting amino acids. Similar findings were reported by Fadilatirrohmah et al. (2023), who noted that protein efficiency increases only when amino acid balance and digestibility are improved.

Growth performance, as reflected by RGR, was also not significantly affected by dietary treatments. Fish growth is primarily driven by the adequacy of essential nutrients, especially digestible protein and energy (NRC, 2011). Once these requirements are met, growth responses tend to plateau, and further supplementation does not result in proportional gains (Taj et al., 2023). The uniform growth observed in this study suggests that the basal diet provided a balanced nutrient composition, thereby minimizing the potential impact of additional supplementation.

Survival rates ranging from 76.92% to 90.77% indicate that Ajitein inclusion up to 15% is safe for tilapia fry and does not induce adverse physiological effects. The absence of significant differences among treatments suggests that survival was not influenced by dietary factors but rather by environmental conditions and fish adaptability. Survival in aquaculture systems is known to be influenced by multiple factors, including water quality, stress, and husbandry practices (Boyd, 2015). Hastuti, et al. (2024) also reported that stress and environmental fluctuations are major contributors to fish mortality, often exceeding the impact of dietary treatments.

Water quality parameters measured during the study—including temperature, pH, dissolved oxygen, and ammonia—remained within optimal ranges for tilapia culture. Temperature (24–28 °C), pH (6.97–8.5), and dissolved oxygen (>3 mg/L) were all within recommended limits (Boyd, 2015; Hastuti, et al., 2024), while ammonia levels remained below harmful thresholds (Srithong et al., 2015). These stable conditions ensured that environmental stressors did not confound the effects of dietary treatments. Good water quality is essential for maintaining physiological homeostasis, supporting metabolic efficiency, and preventing stress-related growth suppression (Wedsuwan,et al., 2016).

Overall, the results of this study highlight that the effectiveness of Ajitein as a feed additive is highly dependent on the nutritional status of the basal diet. When the base diet is already well-formulated and meets the physiological requirements of fish, the addition of supplementary ingredients may not produce significant improvements in performance. This finding is consistent with previous studies in aquaculture nutrition, which emphasize that feed additives are most effective when used to correct specific nutritional deficiencies or enhance suboptimal diets (NRC, 2011; De Silva & Anderson, 1995).

CONCLUSIONS

In conclusion, dietary supplementation of fermented monosodium glutamate by-product (Ajitein) did not significantly influence feed utilization, growth performance, or survival of Nile tilapia (*Oreochromis niloticus*) fingerlings ($P>0.05$). The consistency observed across all measured parameters i.a. TFC, FCR, FUE, PER, RGR, and SR were indicates that the inclusion of Ajitein up to 15% in the experimental diet neither improved nor impaired fish performance under the present experimental conditions.

ACKNOWLEDGEMENTS

The authors wish to express their profound appreciation to the Head of the Quarantine Laboratory, Faculty of Fisheries and Marine Sciences, Diponegoro University, for their continuous support, expert guidance, and facilitation throughout the course of this study. The provision of laboratory facilities, along with invaluable technical assistance, played a pivotal role in ensuring the successful execution and completion of this research.

LITERATURE CITED

Boyd C.E. 2015. Water quality: An introduction. Springer. 374 pp.

De Silva, S.S. and Anderson, T.A. 1995. Fish Nutrition in Aquaculture. Aquaculture Series, 319, Chapman & Hall, London.

Fadlilatirrohmah, A. N., Subandiyono., Yuniarti, T. dan Rachmawati, D. 2023. The Impact of Dietary Phytase on the Protein Efficiency Ratio and Growth of Tilapia (*Oreochromis niloticus*). Journal of Advances in Food Science and Technology. 10(4): 95-101.

Hastuti, S. and Subandiyono, S., 2020a. Aminotransferase, hematological indices and growth of tilapia (*Oreochomis niloticus*) reared in various stocking densities in aquaponic systems. AACL Bioflux 13(2):813-824.

Hastuti, S. and Subandiyono, S., 2020b. Blood serum biochemistry responses and digestive enzyme activities of tilapia (*Oreochromis niloticus*) according to different dietary protein level consumption. AACL Bioflux 13(6):3566-3573.

Hastuti S., Yuniarti T., Harwanto D., Subandiyono S., 2024. Growth performance of Java barb, *Barbonymus gonionotus*, in relation with water temperature. AACL Bioflux 17(3):949-959.

Hidayati, B. N., Darsono, D., Barokah, U. 2020. Business Analysis of Tilapia Aquaculture Using Floating Net Cages (KJA) and Its Marketing in Sragen Regency. Buletin Ilmiah Marina Sosial Ekonomi Kelautan dan Perikanan, 6(2), 145-157.

Lukman, N. A., Hidayani, A. A., Malina, A. C., Alimuddin, A., dan Fuadi, M. 2022. Feed Conversion and Seed Survival of Nile Tilapia (*Oreochromis. niloticus* Linnaeus, 1758) Feed by Recombinant Growth Hormone Through Immersion and Feed. Jurnal Iktiologi Indonesia, 22(1):1-15.

Malau, E. Y., Bungas, K., and Suriansyah, S. 2021. Effectiveness of Different Feed Types on the Growth of Gourami (*Osphronemus goramy*) Fry (in Indonesan). Journal of Tropical Fisheries, 16(2):132-140.

NRC (National Research Council). 2011. Proteins and Amino Acids. Nutrient Requirements of Fish and Shrimp. National Academy Press, Washington, D.C., pp. 57-101.

Nurkholifah, S., Hastuti, S., Amalia, R., ; Subandiyono, S., 2022. Effect of eugenol on the survival rate and blood glucose levels of prospective broodstock of tilapia (*Oreochromis niloticus*) during closed-system transportation (in Indonesian). Sains Akuakultur Tropis: Indonesian Journal of Tropical Aquaculture. 6(1):24-35. https://doi.org/10.14710/sat.v6i1.12363.

Pangestyastuti, I., Suminto dan Pinandoyo. 2017. The Effect of Vitamin C and Probiotics in Feed on Feed Utilization Efficiency, Growth, and Survival Rate of Nile Tilapia (*Oreochromis niloticus*) (In Indonesian). Journal of Aquaculture Management and Technology, 6(3), 113-122.

Pereira, E. M. ; Santos, F. A. P. ; Bittar, C. M. M. ; Ramalho, T. R. ; Costa, D. F. A. ; Martinez, J. C., 2007. Substitution of corn grain by wheat middlings or corn gluten feed in the finishing bulls diet. Acta Scientiarum - Animal Sciences, 29 (1): 49-55

Poot-López, G. R., Gasca-Leyva, E., González-Salas, C., Guillen-Hernández, S., and Domínguez-May, R. 2020. Compensatory Growth in Nile Tilapia *Oreochromis niloticus*: Feed Conversion Ratio, Size Heterogeneity, And Proximal Composition. Latin American Journal of Aquatic Research, 48(3): 421–428.

Satria, D.M..R., D. Chilmawati, S. Hastuti, and S. Subandiyono, 2022. The Effect of Spirulina Platensis in Feed for Color Brightness, Growth, Feed Efficiency and Survival Rate of Rainbow Boesemani Fish (*Melanotaenia boesemani*). Sains Akuakultur Tropis : Indonesian Journal of Tropical Aquaculture, 6(1):10-23. https://doi.org/10.14710/sat.v6i1.12391

Setiawan, B. A. 2016. The Utilization of Ajitein Supplementation in Feed on Feed Efficiency and Feed Conversion Ratio (FCR) of Giant Gourami (*Osphronemus gouramy*) Fry (In indonesian. Undergraduate Thesis. Airlangga University. Surabaya, East Java, Indonesia.

Setyawan, G., and Helmiati, S. 2021. Effect of substitution of soybean flour with apu wood flour (*Pistia stratiotes*) fermented in feed on the performance of red tilapia (*Oreochromis* sp.). Journal of Fish Nutrition, 1(2), 108-126. https://doi.org/10.29303/jfn.v1i2.489

Srithong,C., Musig,Y., Areechon, N. and Taparhudee, W., 2015. Water Quality and Growth Performance of Hybrid Catfish (*Clarias macrocephalus* x *C. gariepinus*) Comparisons in Two Type of Water Recirculating System and a Water Exchange System. KASETSART UNIVERSITY FISHERIES RESEARCH BULLETIN.. 9(3):57-69.

Subandiyono and Hastuti, S. 2014. Rabbitfish and the Prospects of Marine Aquaculture in Indonesia. 1th Ed., UPT Undip Press, Semarang. 79 pp.

Subandiyono and Hastuti, S. 2016. Beronang. Badan Penerbit LP2MP Universitas Diponegoro, Semarang, 86 pp.

Subandiyono, S. and Hastuti, S. 2020. Dietary protein levels affected on the growth and body composition of Tilapia (*Oreochromis niloticus*). AACL Bioflux 13(5):2468-2476.

Subandiyono S., Hastuti S., 2022 Growth performances, feed utilization and hematological parameters of the carp (Cyprinus carpio), according to the dietary glutamate. AACL Bioflux 15(2):830-839.

Subandiyono; Hastuti, S.; Nugroho, R.A., 2018. Feed utilization efficiency and growth of java barb (*Puntius javanicus*) fed on dietary pineapple extract. AACL Bioflux 11(2):309-318.

Subandiyono S., Hastuti, S., and Harwanto, D., 2026a. The role of predigested plant protein in enhancing nutritional value, feed utilization efficiency, and growth performance of Nile tilapia, *Oreochromis niloticus*. Int. J. Aquat. Biol. 14(1): 104-116. https://doi.org/10.22034/ijab.v14i1.2716

Subandiyono S., Hastuti S., Nugroho R. A., Chilmawati D., Tyastanto H. B. D., 2026b Probiotics as feed additives to improve feed efficiency and growth in catfish (Clarias gariepinus) reared in probiotic-enriched media. AACL Bioflux 19(2):641-655.

Sunu, K. P. W., Hartutik and Hermanto. 2013. The Effect of Ajitein Use in Feed on the Production and Quality of Dairy Cow Milk (In Indonesian). Jurnal Ilmu-Ilmu Peternakan. 23(2): 42-51.

Surianti., Hasrianti., Damis., Gibran, M. H., Wahyudi., dan Mahfud, C. R. 2024. The Effect of Rice Bran Fermentation Using Different Fermenters on Tilapia Feed (In Indonesian). Jurnal Galung Tropika, 13 (3): 461-470.

Susantie, D., and Manurung, U. N. 2021. Potential of Mangosteen (*Garcinia mangostana* L.) Peel Meal to Improve Growth and Survival of Tilapia (*Oreochromis niloticus*) (In Indonesian). Jurnal Ilmiah Tindalung, 7(1): 19-27.

Tacon, A.G.J., 1987. The nutrition and feeding of farmed fish and shrimp - a training manual 1. the essential nutrients. Food and Agriculture Organization of the United Nations, Brasilia, Brazil. 106-109 pp.

Wedsuwan,T., Musig, W. and Musig, Y., 2016. Water Quality Control in Tilapia Closed Culture System Using Filter Feeding Freshwater Clam (*Pilsbryoconcha exilis compressa*). KASETSART UNIVERSITY FISHERIES RESEARCH BULLETIN. 40 (1): 52-63.

Wilson R.P. 2002. Amino acids and proteins. In: Fish Nutrition, 3rd edn, ed. by J.E. Halver & R.W. Hardy), pp. 143–179. Academic Press, New york.