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THE EFFECT OF LYSINE FORTIFICATION IN SELF-FORMULATED FEED ON THE GROWTH OF BARRAMUNDI (*Lates calcarifer*)

Pengaruh Fortifikasi Lisin pada Pakan Mandiri untuk Pertumbuhan Kakap Putih (*Lates calcarifer*)

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ABSTRACT

Fortification of essential amino acids in self-formulated feed is a strategic approach to improve nutrient efficiency and reduce production costs in barramundi (*Lates calcarifer*) aquaculture. This study aimed to evaluate the effect of dietary lysine supplementation at 0.5% in self-formulated feed on growth performance and feed utilization efficiency. The experiment was conducted from March to June 2023 using a completely randomized design with two treatments: commercial feed as control and self-formulated feed supplemented with lysine, each with three replicates. Fish were reared under controlled conditions and fed to satiation. Observed parameters included weight gain, length increment, specific growth rate (SGR), feed conversion ratio (FCR), feed efficiency (FE), and water quality. The results demonstrated that lysine supplementation significantly improved growth performance and feed utilization. Fish fed lysine-supplemented feed showed higher weight gain (13.87±0.37 g) compared to the control (11.99±0.31 g), as well as lower FCR (1.76±0.10) than commercial feed (2.70±0.10). Feed efficiency was also significantly higher in the lysine treatment (56.8±3.17%) compared to the control (37.1±1.31%). However, no significant difference was observed in SGR between treatments. In conclusion, lysine fortification in self-formulated feed enhances growth performance and feed efficiency of barramundi, indicating its potential as a cost-effective and sustainable feeding strategy in aquaculture practices.

Keywords: Barramundi, Feed Efficiency, Growth Performance, Lysine, Self-Formulated Feed

ABSTRAK

Fortifikasi asam amino esensial dalam pakan mandiri merupakan strategi untuk meningkatkan efisiensi nutrisi dan menekan biaya produksi dalam budidaya ikan kakap putih (*Lates calcarifer*). Penelitian ini bertujuan untuk mengevaluasi pengaruh penambahan lisin sebesar 0,5% dalam pakan mandiri terhadap kinerja pertumbuhan dan efisiensi pemanfaatan pakan. Penelitian dilaksanakan pada Maret–Juni 2023 menggunakan rancangan acak lengkap dengan dua perlakuan, yaitu pakan komersial sebagai kontrol dan pakan mandiri terfortifikasi lisin, masing-masing dengan tiga ulangan. Ikan uji dipelihara dalam wadah terkontrol dan diberi pakan secara ad satiation. Parameter yang diamati meliputi pertumbuhan bobot dan panjang mutlak, laju pertumbuhan spesifik (SGR), rasio konversi pakan (FCR), efisiensi pemanfaatan pakan (EPP), serta kualitas air. Hasil penelitian menunjukkan bahwa fortifikasi lisin secara signifikan meningkatkan kinerja pertumbuhan dan efisiensi pakan. Perlakuan pakan mandiri dengan lisin menghasilkan bobot mutlak yang lebih tinggi (13,87±0,37 g) dibandingkan kontrol (11,99±0,31 g), serta nilai FCR yang lebih rendah (1,76±0,10) dibandingkan pakan komersial (2,70±0,10). Efisiensi pemanfaatan pakan juga meningkat secara nyata pada perlakuan lisin (56,8±3,17%) dibandingkan kontrol (37,1±1,31%). Sementara itu, nilai SGR tidak menunjukkan perbedaan yang signifikan antar perlakuan. Temuan ini menunjukkan bahwa suplementasi lisin dalam pakan mandiri berpotensi meningkatkan efisiensi produksi melalui perbaikan pemanfaatan nutrisi dan performa pertumbuhan ikan kakap putih, sehingga dapat menjadi alternatif formulasi pakan yang lebih ekonomis dan berkelanjutan.

Kata Kunci: Lisin, Pakan Mandiri, Kakap Putih, Pertumbuhan, Efisiensi Pakan

INTRODUCTION

White snapper (*Lates calcarifer*) or barramundi, is an aquaculture species with high economic value in tropical and subtropical regions. Its commercial value is demonstrated by high market demand, reaching 98.86 tons per year with a price range of IDR 60,000–70,000 per kilogram (Widianti & Ariasari, 2025). To meet this demand, intensive cultivation is a sustainable solution. However, in intensive cultivation systems, feed costs contribute 60–70% of total operational costs (Mahmud & Ritu, 2025). Therefore, feed efficiency is the main key to business sustainability.

Commercial feeds are generally formulated with complete and balanced nutritional content, ensuring optimal fish growth. However, the high price of commercial feed is often a major limiting factor for small and medium-scale farmers (Kleih et al., 2013). As an alternative, the development of more affordable self-formulated feeds continues to be encouraged, such as efforts undertaken by the Lampung Center for Marine Aquaculture. Although these self-formulated feeds meet crude protein standards (28–30%), several reports indicate a lower growth rate for white snapper compared to commercial feeds. (Windarto, et al. (2019). This indicates a nutritional imbalance, particularly essential amino acids, in the formulation of independent feeds (Putri, et al. 2018).

Protein is the most critical nutritional component in fish feed, serving as the primary source of amino acids for tissue synthesis, growth, and cell repair (Salamanca & Herrera, 2025). Protein quality is determined not only by its quantity, but also by the composition and balance of essential amino acids. Lysine is one of the essential amino acids that is most often a limiting factor in plant-based feeds. (Hossain et al., 2026). Lysine deficiency can cause decreased feed efficiency, stunted growth rates, and metabolic disorders (Ruby et al., 2022). Previous studies on white snapper have shown that lysine supplementation significantly improves growth and feed efficiency (Imani, et al., 2021). Therefore, fortification of certain amino acids, such as lysine, is an effective nutritional strategy to improve the protein quality of locally sourced feeds (Malik et al., 2017).

Based on this background, this study aims to evaluate the effect of lysine addition to a self-feed on growth performance and cost efficiency in white snapper. A multivariate analysis approach will be used to understand the interactions between nutritional parameters and growth. The results of this study are expected to provide recommendations for optimal, cost-effective, and sustainable self-feed formulations, thus providing a practical solution for the white snapper aquaculture industry in Indonesia.

RESEARCH METHODS

The research was conducted from March to June 2023 at the Lampung Maritime Aquaculture Center (BBPBL) and the Pangandaran Marine and Fisheries Polytechnic laboratory. The equipment used included tanks, aeration tanks, digital scales, scoop nets, basins, sieves, brushes, cloths, a water quality taster, and a feed press. Materials used: Snapper, commercial feed No. 3, fresh water, sea water, chlorine, and lysine.

Feed Preparation

The feed used in this study consisted of commercial feed (PK) and self-prepared feed (PM). Both types of feed have compositions appropriate to the needs of white snapper. Making independent feed is done by mixing raw materials in the form of Fish Meal (27.93%), Soybean meal (59.84%) Bran (2.99% gr) Corn flour (2.49%), Wheat flour (2.71%), Lysine (0.5% gr) Vit C (0.06%), Taurine (0.02%), Methionine (0.26%), Pytase (0.06%), Dicalcium Phosphate/DCP (0.50%), Mineral mix (0.10%), Amino nutricall (0.01%), Vit. premix (0.01%) into a mixer machine until homogeneous. During mixing, 2 L/10 kg of water is added little by little. Then the pellets are molded, using a mold size No. 3, sieved and dried using an oven. After leaving the oven, they were treated with fish oil (1.44%), and cooled.

Research Design

The study used a Completely Randomized Design (CRD) method, divided into two treatment groups with three replications: fish fed commercial feed (CP) and fish fed self-feed supplemented with 0.5% lysine (PM). Ten white snapper fingerlings measuring 6-7 cm in length and weighing an average of 3.5 grams were stocked into 12 100-L containers from the Lampung Center for Marine Aquaculture (SNI 6145.3.2014). The fish were reared for 45 days and fed using the at-satiation method three times a day. During the maintenance process, observations and water changes were carried out (Rayes et al. (2013).

Growth Observations

During the research process, observations were made regarding growth, FCR, and EPP. Absolute length gain is the difference between the length of the fish from the tip of the head to the tip of the tail at the end of the observation and the initial body length (Sahusilawane et al., 2025). Measurements of absolute weight gain and absolute length gain were calculated at the end of the observation using the following formula (Perdana et al., 2022):

1) Absolute Weight Gain:

$$W = Wt - Wo$$

Where:
W = Absolute weight gain (g)
Wt = Average final weight (g)
Wo = Average initial weight (g)

2) Absolute Length Growth:

$$P = Pt - Po$$

Where:
P = Absolute length gain (cm)
Pt = Fish length at the end of maintenance (cm)
Po = Fish length at the beginning of maintenance (cm)

3) Specific Growth Rate (SGR)

The specific growth rate is the percentage difference between the final and initial weights, divided by the length of the rearing period. The daily growth rate is obtained using the following formula (Imani et al., 2021):

$$SGR = \frac{\mathrm{InW_t - InW_o}}{T} \text{ x } 100\%$$

Where:
SGR = Daily growth rate (%/day)
Wt = Average fish weight at the end of cultivation (fish)
Wo = Average fish weight at the beginning of cultivation (fish)
T = Length of cultivation (days)

4) Feed Conversion Ratio (FCR)

FCR can be calculated using the following formula (Santika et al., 2021):

$$FCR = \frac{\mathrm{F}}{\mathrm{(Wt + D) - Wo}}$$

Where:
F = Amount of feed consumed
Wt = Fish weight at the end of cultivation
D = Number of fish that died
Wo = Fish weight at the beginning of cultivation

5) Feed Utilization Efficiency (FEE)

FEE can be calculated according to (Windarto et al., 2019) using the following formula:

$$\mathrm{EPP = (Wt - Wo / F \text{ x } 100\%)}$$

Where:
EPP = Feed Utilization Efficiency
Wt = Weight of test fish at the end of cultivation (g)
Wo = Weight of test fish at the beginning of cultivation (g)
F = Amount of feed consumed (g)

Water Quality Observations

During the research process, in-situ water quality observations were conducted. Parameters observed included temperature, pH, DO, and salinity. The method used in water quality observations complies with SNI (Table 1).

Table 1. Water Quality Parameters

Parameter	Unit	Methods
Temperature	(^{0}C)	Thermometric
pH	-	pH meter
DO	(mg/L)	Electrochemical
Salinity	(g/L)	Refractometry

Statistical Analysis

The data analysis methods used were divided into two: quantitative descriptive analysis and qualitative descriptive analysis. The data obtained were first processed using quantitative descriptive analysis, then presented in tables, graphs, and figures. The quantitative descriptive analysis included observations of specific growth (SGR), absolute length growth, absolute weight growth, survival rate (SR), FCR, EPP, and water quality measurements.

RESULT

The quality of the feed provided was analyzed using proximate analysis. The analysis was conducted at the Fish Health and Environmental Testing Laboratory, Serang. The parameters tested included protein, fat, ash, and moisture content (Table 2).

Table 2. Composition of Commercial and Self-Prepared Feed Based on Proximate Analysis

Feed Type	Protein	Fat	Ash Content	Moisture Content
Commercial feed	40%	6%	12%	10%
Self-Prepared feed + 0.5% lysine	40%	8.3%	19.5%	5.5%

The results of the proximate analysis showed that the self-prepared feed supplemented with lysine contained 40% protein, 8.3% fat, 19.5% ash, and 5.5% moisture.

During the maintenance period, sampling was carried out to determine the growth rate and efficiency of feed use of white snapper, which is presented in Table 3.

Table 3. White Snapper Growth Results

Growth Parameters	Self-Prepared Feed + 0.5%	Commercial Feed
Average Absolute Weight (g/fish)	13.87 ± 0.37^a	11.99 ± 0.31^b
Average Absolute Length (cm/fish)	3.51 ± 0.50^a	3.45 ± 0.20^b
SGR (%)	0.045 ± 0.001^a	0.042 ± 0.001^a
FCR	1.76 ± 0.10^a	2.70 ± 0.10^b
EPP (%)	56.8 ± 3.17^a	37.1 ± 1.31^b
SR (%)	100^a	100^a

Note:
PK : Commercial Feed
PM : 0.5% Lysine Formulated Feed

Table 4. Water Quality Observation Results

Parameter	PK1	PK2	PK3	PK4	Quality Standards
Temperature (°C)	29.5 ± 0.6	29.8 ± 0.5	29.5 ± 0.6	29.3 ± 0.5	28 - 32ºC
DO (mg/L)	5.17 ± 0.2	5.35 ± 0.4	5.49 ± 0.3	5.29 ± 0.3	> 4
Salinity (ppt)	30.5 ± 1.3	30.5 ± 1.3	30.5 ± 1.3	30.5 ± 1.3	0 - 28
pH (ppm)	8.10 – 8.28	8.07 – 8.16	7.95 – 8.36	7.99 – 8.21	7.0 – 8.5
	PM1	PM2	PM3	PM4	Quality Standards
Temperature (°C)	29.8 ± 0.5	29.5 ± 0.6	29.3 ± 0.5	29.8 ± 0.5	28 - 32ºC
DO (mg/L)	5.14 ± 0.3	5.18 ± 0.3	5.41 ± 0.2	5.34 ± 0.4	> 4
Salinity (ppt)	30.3 ± 1.26	30.5 ± 1.3	30.5 ± 1.3	30.5 ± 1.3	0 - 28
pH (ppm)	7.98 – 8.19	7.98 – 8.22	8.02 – 8.21	7.98 – 8.34	7.0 – 8.5

DISCUSSION

Absolute Weight Gain

The absolute weight gain of barramundi on the PM diet was 13.87 grams, while on the CP diet it only increased by 11.99 grams. The data indicates that barramundi supplemented with lysine exhibited faster growth compared to those fed without lysine. This finding aligns with research on lysine in barramundi (Murillo-Gurrea et al., 2001).

Lysine is an essential component, used to increase weight gain and plays a role in the digestive system (Zhang et al., 2024a). M. H. Li et al. (2019) also reported that lysine affects fish muscle tissue and increases size growth (Moura et al., 2016). Lysine contains a substrate used to synthesize carnitine, which is necessary for the transport of long-chain fatty acids from the cytosol to the mitochondria for oxidation (Chien et al., 2022). The addition of lysine to the feed can increase the formation of carnitine, which enhances the oxidation process (Rachmawati & Nurhayati, 2022).

Absolute Length Growth

The absolute length growth of white snapper in PM was 10.83 g, while in PK it only increased by 10.48 g. The data shows that snapper fed with lysine in the feed produced the highest absolute length compared to feed without lysine supplementation. This indicates that the addition of lysine to the feed significantly affects the absolute length of white snapper.

Falco et al. (2020) reported that essential amino acids are essential for supporting optimal growth in addition to serving as an energy source. Lysine deficiency directly inhibits length growth (Turano et al., 2002). Lysine plays a role in optimizing the utilization of other amino acids, thereby increasing the amount of protein utilized for length growth (Khalida, et al., (2017). Lysine is a limiting factor and determines protein retention for growth in length (Glencross, 2006).

Specific Growth Rate (SGR)

The specific growth rate (SGR) of white snapper fed with PM was 0.045 g/day, while that of CP only increased by 0.042 g/day. Data show that snapper fed with lysine supplementation did not significantly increase their specific growth rate.

This indicates that growth rate also depends on the balance of amino acid composition in the feed. Lysine is the first limiting amino acid; an imbalance between lysine and other amino acids can inhibit protein synthesis in the body (Dou et al., 2023). Poonnual et al. (2025) also stated that lysine did not accelerate relative growth efficiency per unit initial weight. SGR is highly influenced by formulation Crane (2020) and sensitivity to initial weight (Jobling, 1983).

Feed Conversion Ratio (FCR)

The FCR for PM was 1.76 compared to the commercial value of PK is 2.7. The feed conversion ratio (FCR) is defined as the ratio of total feed consumed to fish weight gain, reflecting the efficiency of the feed in producing biomass (Dou et al., 2023). A higher conversion value indicates poor feed utilization efficiency, indicating the feed is unable to support production.

According to Saputra & Samara (2022), a low FCR, but resulting in high growth rates, corresponds to the level of feed efficiency. Furthermore, food digestion is said to depend on the fish's absorption capacity. The correct amino acid ratio improves feed utilization by increasing the expression of genes regulating protein synthesis (Murillo-Gurrea et al., 2001). The use of feed with a balanced amino acid content, particularly meeting lysine requirements, has been shown to increase the efficiency of protein synthesis. This allows each gram of feed to be effectively converted into meat, resulting in a lower (more efficient) FCR in barramundi (Poonnual et al., 2025). According to Imani (2021), feed quality is influenced by the fish's absorption of the consumed feed. Essential amino acids in feed has a high absorption rate which means that the nutrients are easily absorbed and utilized for metabolism (Zhou et al., 2004).

Feed Utilization Efficiency (FUE)

Results obtained during observations revealed a feed efficiency value of 56.8% for the PM treatment (0.5% lysine formulation), while the feed efficiency value for the PK treatment (commercial control) was 37.1%. The feed utilization efficiency (FUE) value for barramundi with the addition of 0.5% lysine to the stand-alone feed is considered effective. According to Saputra & Samara (2022), a good EFE value indicates that the feed consumed is of good quality, easily digested and utilized efficiently by the fish. Pangentasari et al. (2025) stated that a feed can be considered good if the feed efficiency value is greater than 50% or even approaching 100%.

Optimal Lysine supplementation increases Feed Utilization Efficiency (FUE). This indicates that feed is used efficiently for growth, so that the use of feed protein for basal energy needs can be minimized and the remainder is allocated to body tissue synthesis (Poonnual et al., 2025). Lysine acts as a precursor in the formation of carnitine, a long-chain fatty acid carrier compound needed to penetrate the mitochondrial membrane for the fat oxidation process. This mechanism is important for efficient energy supply in white snapper maintenance (Harpaz, 2005). Optimal Lysine availability supports carnitine synthesis, so that long-chain fatty acid metabolism increases to supply energy. This results in a protein-sparing effect, where non-protein energy is met by lipids and energy from protein is optimally allocated for muscle growth (J. Li et al., 2017).

CONCLUSION

The results of research activities conducted at the Center for Marine Aquaculture (BBPBL) Lampung on the Effect of Adding Lysine Amino Acids to Independent Feed on the Growth of White Snapper (*Lates Calcarifer*) can be concluded that the Absolute Weight growth value in the PM treatment (0.5% lysine formulation) got a value of 13.87 gr and in the PK Treatment (commercial) got a value of 11.99 gr. Absolute Length Growth in the PM treatment got a value of 3.51 cm and in the PK treatment got a value of 3.45 cm. The SGR obtained in the PM treatment was 0.045% and in the PK treatment got a value of 0.042%. The FCR in the PM treatment was 1.76 and in the PK treatment 2.70. The EPP obtained in the PM treatment was 56.8% and in the PK Treatment was 37.1% and the Survival Rate (SR) of white snapper during maintenance had a Survival Rate (SR) of 100% (80 tails). It is necessary to provide treatment with lysine at different doses to determine the correct dose used in feed according to the phase of white snapper.

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REFERENCES

Chien, A., Chu, J., Hong, Y., Chien, A., & Sheen, S. (2022). Effects of Dietary Lipid , L-carnitine and L-lysine Supplementation on the Growth Performance and Body Composition of Epinephelus lanceolatus Larvae. 30(1). https://doi.org/10.51400/2709-6998.2561

Crane, D. P. (2020). *Use and misuse of a common growth metric : guidance for appropriately calculating and reporting specific growth rate*. 1542–1547. https://doi.org/10.1111/raq.12396

Dou, X., Liu, Y., Cao, Y., Zhang, Y., Fu, X., Deng, J., & Tan, B. (2023). Effects of Dietary Lysine Level on Growth Performance and Protein Metabolism in Juvenile Leopard Coral Grouper (Plectropomus leopardus). 2023.

Falco, F., Stincone, P., Cammarata, M., & Brandelli, A. (2020). Amino Acids as the Main Energy Source in Fish Tissues. 3(1).

Glencross, B. (2006). *The nutritional management of barramundi , Lates calcarifer – a review*. *1790*.

Harpaz, S. (2005). l -Carnitine and its attributed functions in fish culture and nutrition — a review. 249, 3–21. https://doi.org/10.1016/j.aquaculture.2005.04.007

Hossain, M. S., Small, B. C., Kumar, V., & Hardy, R. (2024). Utilization of functional feed additives to produce cost‐effective, ecofriendly aquafeeds high in plant‐based ingredients. *Reviews in Aquaculture*, *16*(1), 121-153.

Imani, D. N., Santoso, L., & Supriya, S. (2021). PEFORMA PERTUMBUHAN IKAN KAKAP PUTIH (Lates calcarifer) PADA FASE PEMBESARAN YANG DIBERI PAKAN DENGAN PENAMBAHAN LISIN BERBEDA. *Journal of Aquatropica Asia*, *6*(1), 13-20

Jobling, M. (1983). Influence of body weight and temperature on growth rates of Arctic charr , Salvelinus alpinus (L .). 471–475.

Khalida, A., Agustono, N. I. D. N., & Lokapirnasari, W. P. (2017). Penambahan lisin pada pakan komersial terhadap retensi protein dan retensi energi ikan bawal air tawar (Colossoma Macropomum). *Jurnal Ilmiah Perikanan Dan Kelautan*, *9*(2), 98-106.

Kleih, U., Linton, J., Marr, A., Mactaggart, M., Naziri, D., & Orchard, J. E. (2013). Financial services for small and medium-scale aquaculture and fisheries producers. *Marine Policy*, *37*, 106–114. https://doi.org/10.1016/j.marpol.2012.04.006

Li, J., Li, L., Qin, X., Ning, L., Lu, D., Li, D., Zhang, M., Wang, X., & Du, Z. (2017). Systemic regulation of L-carnitine in nutritional metabolism in zebrafish , Danio rerio. Nature Publishing Group, September 2016, 1–14. https://doi.org/10.1038/srep40815

Li, M. H., Bosworth, B. G., & Lucas, P. M. (2019). Effects of available lysine concentrations in 28 and 32 % protein diets on growth , feed efficiency , processing yield , and fillet composition of pond-raised channel catfish , Ictalurus punctatus. 1013160, 1–9. https://doi.org/10.1111/jwas.12644

Mahmud, N., & Ritu, F. Y. (2025). *Review Article Exploring Protein-Based Fishmeal Alternatives for Aquaculture Feeds in Bangladesh*. *2025*.

Malik, M. F., Shah, S. H., & Azzam, A. (2017). Lysine Supplementation in Fish Feed. 1(2), 26–31.

Moura, M., de Oliveira Vidal, L. V., Xavier, T. O., de Moura, L. B., de Almeida, F. L. A., Pedrosa, V. B., ... & Furuya, W. M. (2016). Dietary lysine requirement to enhance muscle development and fillet yield of finishing Nile tilapia. *Aquaculture*, *457*, 124-130.

Murillo-gurrea, B. D. P., Coloso, R. M., Borlongan, I. G., & Serrano, A. E. (2001). Lysine and arginine requirements of juvenile Asian sea bass (Lates calcarifer). 17, 49–53..

Pangentasari, D., Harianto, E., Sumarsono, T., Putinur, P., Bareta, A. R., Purnamasari, T., ... & Lestari, S. Y. (2025). The Growth of Barramundi (Lates Calcarifer) at the Marine and Brackish Water Aquaculture Center (BPBALP) Teluk Buo, Padang City, West Sumatra. *Mantis Journal of Fisheries*, *2*(03), 141-149.

Perdana, A. W., Mellisa, S., Siahaan, J. Y. H., Arisa, I. I., & El, S. A. (2022). Effect of adding β-glucan in feed on the growth rate of White Snapper (Lates calcarifer) fingerling. *Depik Jurnal*, *11*(2), 161-166.

Poonnual, D., Tola, S., & Yuangsoi, B. (2025). Evaluation of Functional Marine Protein Hydrolysates as Fish Meal Replacements in Low-Fish-Meal Diets : Effects on Growth Performance , Feed Utilization , and Health Status of Asian Seabass (Lates calcarifer).

Poonnual, D., Tola, S., & Yuangsoi, B. (2025). *Evaluation of Functional Marine Protein Hydrolysates as Fish Meal Replacements in Low-Fish-Meal Diets : Effects on Growth Performance , Feed Utilization , and Health Status of Asian Seabass (Lates calcarifer)*.

Poonnual, D., Tola, S., & Yuangsoi, B. (2025). Evaluation of Functional Marine Protein Hydrolysates as Fish Meal Replacements in Low-Fish-Meal Diets : Effects on Growth Performance , Feed Utilization , and Health Status of Asian Seabass (Lates calcarifer).

Putri, D. F., Santoso, L., & Saputra, S. (2018). Effect Of Giving Feed With Different Protein Levels On Growth Of White Foot Fish (Lates calcarifer) Preserved In Controled Bak. *Berkala Perikanan Terubuk*, *46*(2), 89-96.

Rachmawati, D., & Nurhayati, D. (2022). Effect of dietary lysine on the growth performance of Pangasius hypophthalmus. *Depik*, *11*(2), 111-116.

Rayes RD, Sutresna IW, Dinniarti N, Supii AI. 2013. Pengaruh Perubahan Salinitas Terhadap Pertumbuhan Dan Sintasan Ikan Kakap Putih (*Lates calcarifer Bloch*). *Jurnal Kelautan* Vol. 6(1) : 47-56

Ruby, P., Ahilan, B., Antony, C., Manikandavelu, D., & Moses, T. L. S. S. (2022). *Effect of Dietary Lysine and Methionine Supplementation on the Growth and Physiological Responses of Pearlspot Fingerlings , Etroplus suratensis*. *56*(8), 945–958. https://doi.org/10.18805/IJAR.B-4897.Submitted

Sahusilawane, H. A., Beruatjaan, M. Y., & Erbabley, N. Y. G. F. (2025). BIOEDUPAT : Pattimura Journal of Biology and Learning Growth Performance of White Snapper (Lates calcarifer) With Different Stocking Density in Hapa at Hatchery Laboratory Tual State Fisheries Polytechnic. 5(2), 351–359.

Salamanca, N., Herrera, M., & de la Roca, E. (2025). Amino acids as dietary additives for enhancing fish welfare in aquaculture. *Animals*, *15*(9), 1293.

Santika, L., Diniarti, N., Astriana, B. H., Studi, P., Perairan, B., Pertanian, F., & Mataram, U. (2021). TERHADAP PERTUMBUHAN DAN EFISIENSI PEMANFAATAN PAKAN IKAN KAKAP PUTIH (Lates calcarifer). 14(1), 48–57.

Saputra, A. R. S. H., & Samara, S. H. (2022, July). Performance analysis of white snapper (Lates calcarifer) nursery at BBPBAP Jepara. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1036, No. 1, p. 012118). IOP Publishing.

Turano, M. J., Davis, D. A., & Arnold, C. R. (2002). Optimization of growout diets for red drum , Sciaenops ocellatus.

Widianti, R., & Ariasari, A. (2025, March). TEKNIK PEMBESARAN IKAN KAKAP PUTIH (LATES CALCARIFER) DENGAN METODE KERAMBA JARING APUNG DI BALAI BESAR PERIKANAN BUDIDAYA LAUT LAMPUNG. In *PROSIDING SEMINAR NASIONAL HASIL PENELITIAN KELAUTAN DAN PERIKANAN* (Vol. 3, pp. 124-143).

Windarto, S., Hastuti, S., Subandiyono, S., Nugroho, R. A., & Sarjito, S. (2019). Performa pertumbuhan ikan kakap putih (Lates Calcarifer Bloch, 1790) yang dibudidayakan dengan sistem keramba jaring apung (KJA).

Zhang, S., Liu, S., Wang, Y., Lu, S., Han, S., Jiang, H., Liu, H., & Yang, Y. (2024). Impact of dietary lysine on growth , nutrient utilization , and intestinal health in triploid rainbow trout (Oncorhynchus mykiss) fed low fish meal diets. Aquaculture Reports, 39(September), 102402. https://doi.org/10.1016/j.aqrep.2024.102402

Zhou, Q. C., Tan, B. P., Mai, K. S., & Liu, Y. J. (2004). Apparent digestibility of selected feed ingredients for juvenile cobia Rachycentron canadum. *Aquaculture*, *241*(1-4), 441-451.