IJCMS: Indonesian Journal of Coastal and Marine Studies
e-ISSN: 3124-1247 - Volume 2, Issue 2, 2026 - Pages 72-79
https://ejurnal.itbm.ac.id/ijcms

Proximate Composition of Fish Feed Formulated with Yellowtail Fusilier (*Caesio cuning*) Skin Flour from Filleting By-products

Jumriana[1], Husni Angreni[1]*, Awaluddin[1], Muh. Ayusal Salam[1]
[1] Institut Teknologi dan Bisnis Maritim Balik Diwa, Makassar City, Indonesia
*Correspondent Author**: husniangreni05@gmail.com

ARTICLEINFO

Received: 5 June 2026
Revised: 25 June 2026
Accepted: 20 July 2026
Published: 22 August 2026

Keywords:
aquafeed; Caesio cuning; fish processing by-products; fish skin; proximate composition; rice bran

ABSTRACT

Filleting of yellowtail fusilier (Caesio cuning) generates large quantities of by-products, including skin, that are usually discarded despite their high protein content. This study evaluated the use of yellowtail fusilier skin flour as a partial replacement for rice bran in fish feed and its effect on the proximate composition of the resulting pellets. Three formulations were prepared with 0% (A), 10% (B) and 20% (C) skin flour, while fish meal (35%), maize (25%) and the vitamin–mineral premix were kept constant and rice bran was reduced from 30% to 10%. Moisture, ash, crude protein, crude lipid and crude fibre were determined by standard proximate methods and analysed by one-way ANOVA followed by Tukey's HSD test ($\alpha = 0.05$). All parameters differed significantly among formulations ($p < 0.05$). Increasing the level of skin flour raised crude protein from 32.45% to 38.06% and 40.30%, and crude lipid from 7.24% to 7.65% and 7.83%, whereas moisture decreased from 14.55% to 9.58% and 8.43%, crude fibre from 5.26% to 3.64% and 3.27%, and ash from 9.56% to about 8.65%. Formulations B and C met the Indonesian national standard requirements for fish feed moisture, ash, lipid and fibre, whereas the control exceeded the recommended moisture limit. Formulation C produced the most nutrient-dense feed, with the highest protein and lipid and the lowest moisture and fibre. Yellowtail fusilier skin flour is therefore a promising protein source for low-cost fish feed and a practical route for adding value to filleting by-products.

DOI: *https://doi.org/10.63249/ijcms.v2i2.181*

INTRODUCTION

Indonesia is one of the world's largest fishing nations, and its coral reef ecosystems support a diverse group of reef-associated fishes that are important to coastal economies. Among these, the yellowtail fusilier (*Caesio cuning*, family Caesionidae) is a schooling planktivore that is widely caught by small-scale fishers and highly valued in local markets. Increasingly, yellowtail fusilier is processed into fillets for retail and restaurant supply, and this processing step generates a substantial volume of by-products in the form of heads, frames, viscera, fins, scales and skin. Globally, fish processing is estimated to discard about two-thirds of the total amount of fish as waste, which creates serious economic and environmental concerns, and much of this material is still disposed of with little or no value recovery (Coppola et al., 2021). The fish processing industry produces by-products amounting to between 25% and 70% of the raw material, and their disposal strongly affects the economic balance of processing companies (Caruso et al., 2020). In Indonesia, where much of the processing takes place in small and medium enterprises, filleting residues are frequently dumped in waterways or open land, where they decompose rapidly and contribute to odour, nutrient pollution and public health problems.

The valorisation of fishery by-products has therefore become a central theme of the circular bioeconomy. Fishery by-products are rich in proteins, collagen, polyunsaturated fatty acids, minerals and other bioactive compounds, but their potential remains largely

underutilised (Caruso et al., 2020). Recent reviews have documented a wide range of recovery routes, from high-value extraction of collagen, peptides, enzymes and oils to lower-technology applications such as fertilisers and animal feed (Coppola et al., 2021; Roy et al., 2023). For small-scale processors in developing countries, high-value extraction is often technically and economically out of reach, whereas conversion into feed ingredients can be achieved with simple equipment. Fish silage, for example, is produced by adding acids or lactic acid bacteria to homogenised fish waste and yields a mixture rich in peptides and free amino acids that is well suited to aquafeeds (Maksimenko et al., 2024). Reviews of fish waste ensiling likewise describe it as a low-cost, environmentally friendly process that is suitable for locations with limited feedstock availability (Libonatti et al., 2023). Drying and milling the by-products into a meal is an even simpler alternative that suits household and village-scale producers.

The motivation for using fish by-products in feed is reinforced by the economics of aquaculture. Feed typically accounts for the largest share of production costs in fish farming, and fish meal remains the preferred protein source because of its balanced amino acid profile, palatability and digestibility. However, the supply of fish meal is limited by the availability of wild forage fish, and its price has risen steadily, prompting a global search for alternative protein sources. A recent review of fishmeal alternatives in Bangladesh evaluated plant proteins, insect meals, agricultural by-products and single-cell proteins and emphasised that locally available ingredients are essential for making aquafeeds affordable to small-scale farmers (Mahmud et al., 2025). Fish processing by-products are among the most nutritionally similar alternatives to fish meal. Hydrolysed protein derived from tilapia processing by-products, for instance, has been used to replace part of the fish meal in diets for white shrimp, with positive effects on growth performance and metabolism (Nguyen et al., 2025). Using by-products from the same supply chain also reduces the environmental footprint of feed production and keeps value within the local economy.

Fish skin is a particularly interesting by-product. It is composed mainly of a dermal layer with dense collagen fibres and contains relatively little carbohydrate or fibre. Proximate analyses of catfish processing waste showed that skin yields high amounts of protein, and collagen extracted from it consisted of type I collagen with molecular weights of 97–200 kDa (Abbas et al., 2022). The skin of purple-spotted bigeye snapper (*Priacanthus tayenus*), a reef-associated species processed for surimi in Southeast Asia, contains 31.14% protein, and its collagen can be extracted for diverse food applications (Oslan et al., 2022). These findings show that fish skin is a concentrated source of protein that could be incorporated directly into feeds after drying and grinding, without the need for purification. Although collagen is not as rich in some essential amino acids as muscle protein, it contributes nitrogen and binding properties that may improve pellet integrity, and when combined with fish meal it can increase the overall protein content of the diet.

In small-scale feed production in Indonesia, rice bran is one of the most widely used filler ingredients because it is cheap and abundant. Rice bran is a by-product of rice milling that contains protein, oil, dietary fibre, minerals and bioactive compounds, but its main use is still in feed formulation, often without consideration of its nutritional limitations (Spaggiari et al., 2021). It is rich in dietary fibre and phytochemicals and is valued as a functional ingredient in human foods (Sapwarobol et al., 2021), yet its high fibre and ash contents can reduce the digestibility and nutrient density of fish diets. In juvenile largemouth bass, dietary non-starch polysaccharides above 9% reduced weight

gain, protein efficiency and digestive enzyme activity, and the recommended inclusion was no more than about 5.5% of the diet (Liu et al., 2022). Partially replacing rice bran with a protein-rich animal by-product could therefore improve the nutritional profile of farm-made feeds while making use of a material that would otherwise be wasted.

The protein and energy content of a diet are the primary determinants of fish growth and feed efficiency. A meta-analysis of protein and energy balance in Nile tilapia feeds showed that protein retention efficiency and fillet yield respond in opposite ways to changes in the dietary protein-to-energy ratio and that the optimal ratio depends on context (Konnert et al., 2022). Experimental work with Nile tilapia juveniles found that maximum growth performance was achieved at a digestible protein to digestible energy ratio of 16.5–17.2 mg kJ^{-1}, while digestibility of dry matter and protein declined at higher ratios (Peres et al., 2022). Beyond protein and energy, the physical and chemical stability of the feed is critical. Even short periods of unsuitable storage can lead to colonisation of fish feed by fungi and contamination with ochratoxin A when the feed is kept warm and humid (Pietsch et al., 2020). Moisture content is therefore a key quality parameter for farm-made pellets, which are usually dried under variable conditions and stored without climate control.

Despite the clear potential of fish skin as a feed ingredient, information on the use of yellowtail fusilier skin in fish feed formulations is lacking. Most local studies on fish waste-based feeds have used mixed by-products such as heads, bones and viscera, and few have quantified the effect of replacing a plant filler with a single, well-defined animal by-product on the proximate composition of the final pellets. Such information is needed to determine whether the substitution meets national feed quality standards and to guide small-scale producers in formulating feeds from locally available materials.

The present study therefore aimed to evaluate the effect of replacing rice bran with yellowtail fusilier (*C. cuning*) skin flour at 0%, 10% and 20% of the formulation on the moisture, ash, crude protein, crude lipid and crude fibre contents of fish feed pellets, and to compare the results with Indonesian national standards for fish feed. The findings are expected to support the development of low-cost, locally produced aquafeeds and to provide a practical outlet for filleting by-products in South Sulawesi.

METHODS

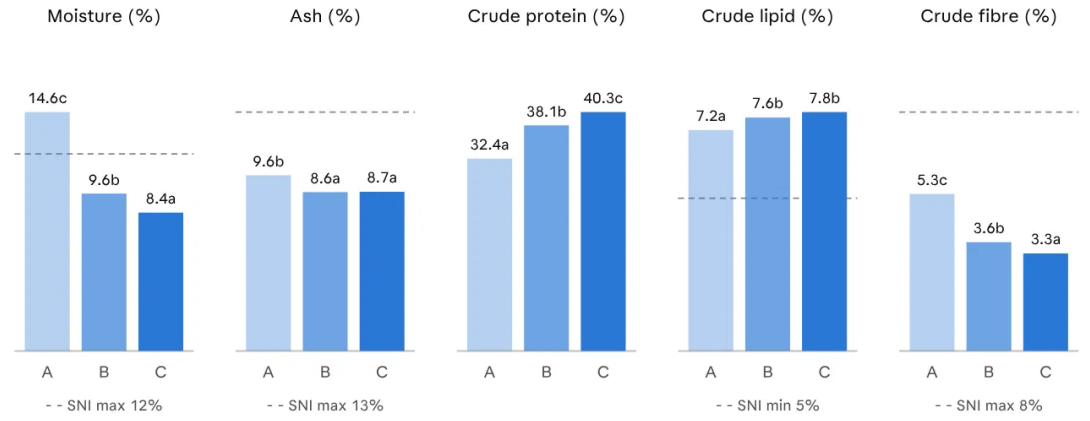
The study was conducted from June to July 2025. Feed was produced in Tokka Hamlet, Bontomarannu Village, Moncongloe District, Maros Regency, South Sulawesi, and proximate analyses were carried out at the laboratory of Politeknik Pertanian Negeri Pangkep. Skin collected from yellowtail fusilier filleting was cleaned, dried and ground into flour, following the general preparation of fish skin as a protein-rich by-product (Oslan et al., 2022; Abbas et al., 2022). Three formulations were prepared, modified from a local fish feed formula, in which skin flour replaced rice bran: formulation A contained 0% skin flour and 30% rice bran, formulation B 10% skin flour and 20% rice bran, and formulation C 20% skin flour and 10% rice bran, while fish meal (35%), maize (25%) and the vitamin–mineral premix (10%) were kept constant. Rice bran was chosen as the ingredient to be replaced because of its high fibre and ash contents and its widespread use as a low-cost filler in farm-made feeds (Spaggiari et al., 2021). This partial-replacement design, in which one protein-rich by-product substitutes for a conventional ingredient at graded levels, is commonly used to evaluate alternative feed ingredients (Nguyen et al., 2025). The ingredients were mixed, pelleted with a pelletiser and oven-dried.

Moisture content was determined by oven drying to constant weight, ash by incineration in a muffle furnace, crude protein by the Kjeldahl method, crude lipid by Soxhlet extraction with diethyl ether, and crude fibre by sequential acid and alkaline digestion, each in triplicate. These proximate parameters are the standard indicators used to assess the nutrient density and digestibility of fish diets (Peres et al., 2022; Liu et al., 2022), and moisture was given particular attention because it governs fungal growth and mycotoxin formation in stored feed (Pietsch et al., 2020). Data were analysed in SPSS by one-way analysis of variance at a significance level of 5% ($p < 0.05$). When significant differences were found, Tukey's honestly significant difference (HSD) test was used to identify which formulations differed. The results were compared with the quality requirements of the Indonesian national standard for fish feed.

RESULTS AND DISCUSSION

Replacing rice bran with yellowtail fusilier skin flour significantly altered every proximate component of the feed (one-way ANOVA, $p < 0.05$; moisture and protein $p = 0.000$, ash $p = 0.001$, lipid and fibre $p = 0.002$). As the proportion of skin flour increased from 0% to 20%, crude protein and crude lipid rose, whereas moisture, crude fibre and ash fell (Figure 1). Formulation C therefore produced the most nutrient-dense feed, with the highest protein and lipid contents and the lowest moisture and fibre contents, while the control formulation A had the lowest protein and the highest moisture, fibre and ash. These shifts follow directly from the composition of the two interchanged ingredients: fish skin is an animal tissue dominated by protein and containing little carbohydrate or fibre, whereas rice bran is a plant milling residue rich in fibre, ash and starch.

Figure 1. Proximate composition of feed (%), mean of 3 replicates; letters = Tukey HSD groups within each parameter



Feed A = 0%, B = 10%, C = 20% yellowtail fusilier skin flour (replacing rice bran); darker bars = more skin flour

Moisture content decreased from 14.55% in formulation A to 9.58% in B and 8.43% in C, and Tukey's test placed each formulation in a separate group. Only formulations B and C met the national requirement of a maximum of 12% moisture for fish feed, whereas the control exceeded it. The higher moisture in the control is attributed to the larger proportion of rice bran, which contains hygroscopic fibre and starch that bind water during mixing and steaming and release it slowly during drying. Rice bran is composed of protein, oil, dietary fibre and minerals in proportions that vary with the rice variety and milling process (Spaggiari et al., 2021), and its arabinoxylan-rich fibre

has a high water-holding capacity (Sapwarobol et al., 2021). By contrast, dried fish skin consists mainly of collagen fibres that hold less water once dehydrated (Oslan et al., 2022). The practical importance of this result is considerable, because farm-made pellets are commonly stored in warm and humid conditions. Storing fish feed for only one month at 25 °C and more than 60% relative humidity led to fungal colonisation and contamination with ochratoxin A, showing how quickly feed quality deteriorates when moisture is not controlled (Pietsch et al., 2020). The reduction of moisture by 4–6 percentage points in formulations B and C therefore substantially improves the storage stability of the feed.

Ash content was highest in formulation A (9.56%) and lower in formulations B (8.64%) and C (8.66%), which did not differ from each other. All formulations remained below the maximum ash content of 13% set by the national standard. The higher ash in the control reflects the mineral fraction of rice bran, which contains appreciable amounts of silica, phosphorus and other minerals derived from the outer layers of the rice grain (Spaggiari et al., 2021). Fish skin, in contrast, contains relatively little mineral matter compared with bone, scales or whole-fish by-products (Abbas et al., 2022). Fish processing by-products such as heads and frames are rich in calcium and phosphorus (Coppola et al., 2021), so feeds based on mixed by-products tend to have high ash, whereas the use of skin alone allowed the protein content to be increased without raising the ash content. Excessive ash dilutes the digestible energy of a diet and can increase phosphorus discharge, so keeping ash moderate is advantageous for both fish growth and water quality.

Crude protein increased markedly with skin flour inclusion, from 32.45% in formulation A to 38.06% in B and 40.30% in C, and all three formulations differed significantly. This increase confirms that yellowtail fusilier skin is a concentrated protein source. Fish skins from several species are reported to contain high protein contents dominated by type I collagen (Abbas et al., 2022; Oslan et al., 2022), and fishery by-products in general are recognised as a rich but underutilised source of proteins and peptides (Caruso et al., 2020; Roy et al., 2023). All formulations exceeded the minimum protein content of 28% required for grow-out fish feeds, and formulations B and C exceeded the upper value commonly recommended for omnivorous species. A higher protein content is not automatically beneficial, because protein is the most expensive dietary component and excess protein is catabolised for energy. Meta-analysis of Nile tilapia feeds has shown that protein retention efficiency declines as the dietary protein-to-energy ratio increases, so that the optimal ratio depends on whether the producer aims to maximise growth, fillet yield or protein efficiency (Konnert et al., 2022). In tilapia juveniles, maximum growth was obtained at a digestible protein to digestible energy ratio of 16.5–17.2 mg kJ^{-1}, and protein digestibility declined at higher ratios (Peres et al., 2022). The high-protein formulations produced here may therefore be best suited to carnivorous species or to early life stages with higher protein requirements, or they could be diluted with cheaper energy ingredients to optimise cost.

The quality of the protein supplied by fish skin should also be considered. Collagen is rich in glycine, proline and hydroxyproline but relatively poor in some indispensable amino acids such as tryptophan and methionine. In the present formulations, fish meal remained at 35% in all treatments and would have supplied a balanced amino acid profile, so skin flour acted as a supplement rather than a sole protein source. Studies on alternative proteins derived from fish processing by-products have shown that partial replacement of fish meal can maintain or even improve growth performance (Nguyen

et al., 2025), and reviews of fishmeal alternatives emphasise that locally available animal by-products are among the most suitable substitutes for small-scale aquafeeds (Mahmud et al., 2025). Processing fish waste into silage or hydrolysates can further increase protein digestibility by breaking proteins into peptides and free amino acids (Maksimenko et al., 2024; Libonatti et al., 2023), which suggests that hydrolysis of skin flour could be a useful next step.

Crude lipid increased slightly from 7.24% in formulation A to 7.65% in B and 7.83% in C; formulation A differed from B and C, which did not differ from each other. All formulations exceeded the national minimum of 5% lipid. The modest increase is consistent with the presence of subcutaneous fat in fish skin and with the replacement of rice bran, whose oil content is variable and partly lost during storage. Lipid is an important energy source and spares protein for growth, but higher lipid levels also increase the susceptibility of feed to oxidation during storage. Fishery by-products contain polyunsaturated fatty acids that are valuable nutritionally but are prone to rancidity (Caruso et al., 2020; Coppola et al., 2021). The combination of lower moisture and slightly higher lipid in formulations B and C suggests that these feeds would be less prone to microbial spoilage but should be stored in cool, dry and dark conditions, preferably with an antioxidant, to limit lipid oxidation.

Crude fibre declined from 5.26% in formulation A to 3.64% in B and 3.27% in C, and each formulation formed a separate group. All values were below the national maximum of 8%. The reduction is directly related to the decreasing proportion of rice bran, which is the main source of fibre in the formulations (Spaggiari et al., 2021; Sapwarobol et al., 2021). Fish have limited ability to digest structural carbohydrates, and high dietary fibre can impair digestive enzyme activity, nutrient digestibility and intestinal morphology. In largemouth bass, dietary non-starch polysaccharides above 9% reduced weight gain and protein efficiency, and the suggested upper limit was about 5.5% (Liu et al., 2022). The fibre content of the control formulation approached this level, whereas formulations B and C were well below it, indicating that replacing rice bran with skin flour should improve the digestibility of the feed.

Taken together, the results show that yellowtail fusilier skin flour can replace up to two-thirds of the rice bran in a farm-made fish feed and that this substitution simultaneously increases protein and lipid while reducing moisture, fibre and ash. Formulation C (20% skin flour) yielded the most nutrient-dense feed and met all the national standard requirements evaluated for moisture, ash, lipid and fibre. Converting filleting by-products into feed ingredients in this way supports the circular use of fishery resources and reduces the environmental burden associated with fish waste disposal (Coppola et al., 2021; Roy et al., 2023). However, proximate composition is only the first step in evaluating a new feed ingredient. Feeding trials are needed to determine the digestibility, growth performance and feed conversion of fish fed these diets, and amino acid analysis would clarify the contribution of skin collagen to the essential amino acid requirements of the target species.

CONCLUSION

Replacing rice bran with yellowtail fusilier (*Caesio cuning*) skin flour significantly changed the proximate composition of fish feed. As skin flour increased from 0% to 20% of the formulation, crude protein rose from 32.45% to 40.30% and crude lipid from 7.24% to 7.83%, while moisture fell from 14.55% to 8.43%, crude fibre from 5.26% to 3.27% and ash from 9.56% to about 8.66%. These changes reflect the protein-rich, low-fibre nature

of fish skin and the reduced contribution of fibrous, mineral-rich rice bran. The formulations containing skin flour met the national standard requirements evaluated for moisture, ash, lipid and fibre, whereas the control exceeded the recommended moisture limit, which would reduce its storage stability. Formulation C, containing 20% skin flour, produced the most nutrient-dense feed, with the highest protein and lipid and the lowest moisture and fibre contents. Yellowtail fusilier skin, a by-product of filleting that is usually discarded, can therefore be converted into a valuable protein ingredient for low-cost, farm-made aquafeeds, supporting both waste reduction and the economic sustainability of small-scale fish farming. Feeding trials are required to confirm the digestibility, growth performance and feed efficiency of fish fed these diets, and amino acid profiling and storage studies are recommended to evaluate protein quality and oxidative stability.

REFERENCE

Abbas, A. A., Shakir, K. A., & Walsh, M. K. (2022). Functional properties of collagen extracted from catfish (*Silurus triostegus*) waste. *Foods, 11*(5), 633. https://doi.org/10.3390/foods11050633

Caruso, G., Floris, R., Serangeli, C., & Di Paola, L. (2020). Fishery wastes as a yet undiscovered treasure from the sea: Biomolecules sources, extraction methods and valorization. *Marine Drugs, 18*(12), 622. https://doi.org/10.3390/md18120622

Coppola, D., Lauritano, C., Palma Esposito, F., Riccio, G., Rizzo, C., & de Pascale, D. (2021). Fish waste: From problem to valuable resource. *Marine Drugs, 19*(2), 116. https://doi.org/10.3390/md19020116

Konnert, G. D. P., Gerrits, W. J. J., Gussekloo, S. W. S., & Schrama, J. W. (2022). Balancing protein and energy in Nile tilapia feeds: A meta-analysis. *Reviews in Aquaculture, 14*(4), 1757–1778. https://doi.org/10.1111/raq.12671

Libonatti, C. C., Agüería, D. A., & Breccia, J. (2023). Fish waste silage, a green process for low feedstock availability: A review. *Agronomía Mesoamericana, 34*(2), 51077. https://doi.org/10.15517/am.v34i2.51077

Liu, Y., Fan, J., Huang, H., Zhou, H., Cao, Y., Zhang, Y., Jiang, W., Zhang, W., Deng, J., & Tan, B. (2022). High dietary non-starch polysaccharides detrimental to nutrient digestibility, digestive enzyme activity, growth performance, and intestinal morphology in largemouth bass, *Micropterus salmoides*. *Frontiers in Nutrition, 9*, 1015371. https://doi.org/10.3389/fnut.2022.1015371

Mahmud, M. N., Ritu, F. Y., Ansary, A. A., & Haque, M. M. (2025). Exploring protein-based fishmeal alternatives for aquaculture feeds in Bangladesh. *Aquaculture Nutrition, 2025*, 3198303. https://doi.org/10.1155/anu/3198303

Maksimenko, A., Belyi, L., Podvolotskaya, A., Son, O., & Tekutyeva, L. (2024). Exploring sustainable aquafeed alternatives with a specific focus on the ensilaging technology of fish waste. *Fermentation, 10*(5), 258. https://doi.org/10.3390/fermentation10050258

Nguyen, H.-T., Chu, Y.-T., Kuo, I.-P., Liao, Z.-H., Lin, Y.-R., Liao, C.-P., Ramadhana, A. W., Nan, F.-H., & Hu, Y.-F. (2025). Optimizing fishmeal replacement with tilapia

hydrolysate protein: Effects on growth, metabolism, and gene expression in white shrimp. *Aquaculture Reports, 44*, 103080. https://doi.org/10.1016/j.aqrep.2025.103080

Oslan, S. N. H., Shapawi, R., Mokhtar, R. A. M., Noordin, W. N. M., & Huda, N. (2022). Characterization of acid- and pepsin-soluble collagen extracted from the skin of purple-spotted bigeye snapper. *Gels, 8*(10), 665. https://doi.org/10.3390/gels8100665

Peres, H., Freitas, J. M. A., Carvalho, P. L. P., Furuya, W. M., Satori, M. M. P., Oliva-Teles, A., Pezzato, L. E., & Barros, M. M. (2022). Growth performance and metabolic responses of Nile tilapia fed diets with different protein to energy ratios. *Aquaculture, 547*, 737493. https://doi.org/10.1016/j.aquaculture.2021.737493

Pietsch, C., Müller, G., Mourabit, S., Carnal, S., & Bandara, K. (2020). Occurrence of fungi and fungal toxins in fish feed during storage. *Toxins, 12*(3), 171. https://doi.org/10.3390/toxins12030171

Roy, V. C., Islam, M. R., Sadia, S., Yeasmin, M., Park, J.-S., Lee, H.-J., & Chun, B.-S. (2023). Trash to treasure: An up-to-date understanding of the valorization of seafood by-products, targeting the major bioactive compounds. *Marine Drugs, 21*(9), 485. https://doi.org/10.3390/md21090485

Sapwarobol, S., Saphyakhajorn, W., & Astina, J. (2021). Biological functions and activities of rice bran as a functional ingredient: A review. *Nutrition and Metabolic Insights, 14*, 11786388211058559. https://doi.org/10.1177/11786388211058559

Spaggiari, M., Dall'Asta, C., Galaverna, G., & del Castillo Bilbao, M. D. (2021). Rice bran by-product: From valorization strategies to nutritional perspectives. *Foods, 10*(1), 85. https://doi.org/10.3390/foods10010085

.

