Fisheries Journal, 15 (5), 2999-3009 (2025)
http://doi.org/10.29303/jp.v15i5.1956

TECHNIQUES FOR MAKING ARTIFICIAL FEED ON A HOUSEHOLD AND INDUSTRIAL SCALE

Teknik Pembuatan Pakan Buatan Skala Rumah Tangga dan Skala Industri

Khazelilah Rahmi, Riris Roiska*

Fisheries Resource Utilization Study Program, University of Jambi

Jambi – Muara Bulian KM 15 Mendalo Darat, Jambi, 36361, Indonesia

*Corresponding author: ririsroiska@unja.ac.id

(Received November 13th 2025; Accepted December 9th 2025)

ABSTRACT

This researchwas conducted at the Sungai Gelam Freshwater Aquaculture Center (BPBAT) in Jambi, with the aim of studying and understanding the process of makingartificial feed for catfish (*Pangasianodon hypophthalmus*) through two production techniques, namely household scale and industrial scale. This studyused qualitative methods with direct involvement in all stages ofproduction, from the preparation of raw materials to packaging. Nine types of raw materials wereused, namely fish meal, rice bran, fine bran, soybean meal, wheat flour, aminoliquid, multivitamins, phytase enzymes, and antifungal agents. The household-scale feed production process is carried out using a simple machine with a capacity of 100 kg per hour, while the industrial-scaleprocess uses an automated system with a capacity of up to one ton per hour. The results of proximate analysis show that the feed produced has a protein contentof 30.01%, fat 7.26%, water 10.12%, crude fiber 3.35%, and ash8.85%, all of which meet the SNI 9043-12:2024 standard. These resultsshow that both household-scale and industrial-scale feed havegood nutritional quality and are suitable for use in catfish farming. The physical quality ofthe feed produced on a household scale is crumbly in texture, uneven in size, and yellowish-brown in color, in contrast to industrial-scale feed, which is dense in texture, uniform in size, and dark brown in color.

Keywords: Catfish, Artificial Feed, Household Scale, Industrial Scale

ABSTRAK

Penelitian ini dilaksanakan di Balai Perikanan Budidaya Air Tawar (BPBAT) Sungai Gelam, Jambi, dengan tujuan untuk mempelajari dan memahami proses pembuatan pakan buatan ikan patin (*Pangasianodon hypophthalmus*) melalui dua teknik produksi, yaitu skala rumah tangga dan skala industri. Penelitian ini menggunakan metode kualitatif dengan terlibat langsung dalam seluruh tahapan produksi, mulai dari persiapan bahan baku hingga pengemasan. Bahan baku yang digunakan terdiri dari sembilan jenis, yaitu tepung ikan, dedak poles, dedak halus, bungkil kedelai, tepung terigu, aminoliquid, multivitamin, enzym phytase, dan anti jamur. Proses pembuatan pakan skala rumah tangga dilakukan dengan mesin sederhana berkapasitas 100 kg per jam, sedangkan skala industri menggunakan sistem otomatis dengan kapasitas hingga satu ton per jam. Hasil analisis proksimat menunjukkan bahwa pakan yang dihasilkan memiliki kadar protein sebesar 30,01%, lemak 7,26%, air 10,12%, serat kasar 3,35%, dan abu 8,85%, yang semuanya memenuhi standar SNI 9043-12:2024. Hasil tersebut menunjukkan bahwa baik pakan skala rumah tangga maupun skala industri memiliki mutu gizi yang baik dan layak digunakan dalam pembesaran ikan patin. Kualitas fisik pakan yang dihasilkan skala rumah tangga teksturnya mudah hancur, ukuran tidak seragam, warna coklat kekuningan berbeda dengan skala industri yaitu teksturnya padat, ukuran seragam, warna coklat tua.

Kata Kunci: Ikan Patin, Pakan Buatan, Skala Rumah Tangga, Skala Industri

INTRODUCTION

The Province of Jambi is one of the regions in Indonesia that has great potential in the freshwater fisheries sector. Geographical conditions and supporting natural resources, such as the Batanghari River and its various tributaries, make Jambi a strategic area in the development of fish farming enterprises. The Batanghari River not only serves as an economic route but also as the main water source for aquaculture activities and surrounding communities. The availability of extensive aquatic land and sufficiently good water quality makes the fisheries sector have great potential to support food security and regional economic improvement (Aryani *et al.,*2014). In recent years, the local government through the Marine and Fisheries Service of Jambi Province has continued to encourage the increase of freshwater fish production, both through the development of aquaculture technology and empowerment of fish-farming communities.

One of the leading commodities that has high economic value and broad development prospects in the Province of Jambi is the catfish (*Pangasianodon hypophthalmus*). Catfish have physiological characteristics that support rapid growth, environmental adaptability, and a flesh flavor preferred by consumers. Based on data from the Marine and Fisheries Service of Jambi (2023), catfish production has increased significantly from year to year, making it one of the main commodities in the freshwater aquaculture sector in this region. Increasing domestic and export market demand requires improvements in efficiency in cultivation processes, especially in terms of availability and management of fish feed.

In fish farming activities, feed is the largest cost component, reaching 60–70% of total production costs (Amri & Hasan, 2017). The high dependence of farmers on commercial feed directly affects the decline in profit margins, especially when global raw material prices rise. In addition, the quality of commercial feed, which does not always match the nutritional needs of fish, can hinder growth and feed conversion efficiency. Therefore, the development of artificial feed based on local ingredients becomes a strategic solution to reduce production costs, increase farmer independence, and maintain the sustainability of freshwater aquaculture enterprises (Kurniawan & Pratiwi, 2018).

The Freshwater Aquaculture Development Center (BPBAT) of Sungai Gelam, Jambi, is one of the technical implementation units under the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia that has an important role in research, training, and development of aquaculture technology. BPBAT Sungai Gelam functions as an innovation center in the application of appropriate technology, including in the production of independent artificial fish feed.

Based on the above data, it is necessary to conduct research related to the method of making feed at the household scale and industrial scale to determine whether there are differences in the quality of feed produced by the household scale and industrial scale. This research is also expected to provide an overview of which feed production process is better.

METHODS

Time and Place

The implementation time of this research was carried out for 2 months, from June 30 to August 30 of the year 2025. The location of this research was conducted at the Freshwater Aquaculture Fisheries Center. Sungai Gelam Village, which is located on Bumi Perkemahan Pramuka Street, Sungai Gelam Village, Sungai Gelam District, Muaro Regency, Jambi Province.

Tools and Materials

The tools and materials used in the activity of producing sinking fish feed in the independent fish feed production unit (UPPIM) at the Freshwater Aquaculture Fisheries Center Sungai Gelam were as follows: Digital scales, shovels, forklifts, wheelbarrows, basins, Hummer mill machines, discmill machines, tarpaulins, wooden pallets, sewing machines, sacks and inner plastic, boat shoes, masks, safety helmets, and gloves. The raw materials used in the production of sinking fish feed in the independent fish feed production unit (UPPIM) at the Freshwater Aquaculture Fisheries Center Sungai Gelam consisted of plant-based proteins such as soybean meal, fine bran, polished bran, wheat flour and animal-based protein in the form of fish meal, as well as additive substances such as multivitamins, phytase enzymes, aminoliquid, and antifungal agents.

Research Method

This research was conducted qualitatively by carrying out direct feed production at both household-scale and industrial-scale levels at the Freshwater Aquaculture Fisheries Center (BPBAT) Sungai Gelam. Observations were conducted for 2 months, and physical quality examinations were performed on the feed produced at both household and industrial scales, and finally, proximate analysis testing of industrial-scale feed was conducted by the nutritional laboratory analyst team of BPBAT Sungai Gelam.

Data Analysis

The preparation of feed formulations was processed using Microsoft Excel, and the analysis of the feed production stages at both household and industrial scales was conducted descriptively.

RESULTS

The research at the Freshwater Aquaculture Fisheries Center (BPBAT) Sungai Gelam provided direct experience to understand the process of producing catfish feed (*Pangasianodon hypophthalmus*) through two approaches, namely household-scale production and industrial-scale production. This activity was carried out to observe, compare, and analyze the efficiency and quality of the feed produced from both production systems.

A. Feed Raw Materials

Raw materials are an important factor influencing the nutritional quality and physical performance of fish feed. Based on observations at the Independent Fish Feed Production Unit (UPPIM) BPBAT Sungai Gelam, the raw materials used in the production of catfish feed consisted of nine types, namely fish meal, polished bran, fine bran, soybean meal, wheat flour, aminoliquid, multivitamins, phytase enzymes, and antifungal agents. The selection of these materials was based on their market availability, nutrient content, and their ability to support the growth of catfish.

Fish meal functions as the main source of animal protein that is easily digested by fish, while soybean meal serves as a plant-based protein source that complements essential amino acid requirements. Fine bran and polished bran are used as fillers as well as sources of energy and fiber, while wheat flour functions to strengthen pellet structure and assist in the molding process. Aminoliquid serves to increase amino acid content and enhance fish appetite. Multivitamins contribute essential micronutrients, phytase enzymes assist the digestive process, and antifungal agents are used to maintain feed quality and prevent degradation during storage.

Table 1. Composition of Raw Materials

No	Material Name	Volume (kg)	Percentage (%)	Volume (Kg)
1	Soybean Meal	20	20	2
2	Fine Bran	25	25	2.5
3	Fish Meal	25	25	2.5
4	Polished Bran	15	15	1.5
5	Wheat Flour	12.5	12.5	1.25
6	Multivitamins	1	1	0.1
7	Phytase Enzyme	0.25	0.25	0.025
8	Antifungal Agent	0.25	0.25	0.025
9	Aminoliquid	1	1	0.1
	Total	100	100	10

Source: UPPIM Sungai Gelam

These ingredients are formulated to produce feed with a protein content of between 27 and 30 percent, meeting the needs of catfish during the grow-out phase. The use of local ingredients such as bran and soybean meal helps reduce production costs, ensuring the resulting homemade feed maintains high quality yet is more economical than commercial feed.

B. Stages of Making Household Scale Feed

Household-scale fish feed production at the Sungai Gelam Fish Farming and Aquaculture Agency (BPBAT) is carried out using machines with a capacity of approximately 100 kg per hour. This process utilizes simple machines such as disc mills, mixers, and vertical pelletizers, which are easy to operate and suitable for small-scale fish farmers. The stages of feed production include raw material preparation, flouring, weighing, mixing, molding, drying, and packaging.

During the raw material preparation stage, all dry ingredients are checked for moisture or mold. The flouring stage is carried out using a disc mill to finely grind coarse ingredients such as bran and soybean meal. The ingredients are then weighed according to the formulation and fed into a mixer for 15–20 minutes until the mixture is homogeneous. Liquid ingredients such as amino liquids and multivitamins are added gradually to ensure even mixing.

The mixed mixture is then molded using a vertical pelletizer, producing sinking pellets approximately 4 mm in diameter. After the molding process, the pellets are dried in a dryer for approximately three hours at 60°C until the moisture content reaches 10–12%. The final process is packaging, which is done by putting the dry pellets into plastic sacks with a capacity of 25–50 kg which are tightly sewn and labeled with a production label.

Figure 1. Feed Printing Machine (vertical)
Source: Personal documentation

Visually, the feed produced by the home-made pellet machine has a yellowish-brown color and a slightly coarse texture. The pellets are not completely uniform due to the relatively low pressure of the machine, but they remain dense and do not easily disintegrate in water. The advantages of this method are its low production costs, the use of readily available local materials, and the simplicity of the process, making it readily applicable to small-scale fish farmers in the area surrounding the Sungai Gelam BPBAT.

C. Stages of Industrial Scale Feed Production

Industrial-scale feed production is carried out at the Sungai Gelam BPBAT factory, which has a production capacity of up to one ton per hour. The work system at this scale is integrated, from raw material input to the final packaging process, and is controlled by an automated panel. The process includes flouring, mixing, molding, drying, sieving, and packaging.

The first stage is flouring the raw materials using a high-speed hammer mill to produce a large quantity of fine flour. The resulting flour is then transferred to a horizontal mixer to be mixed according to the nutritional formulation. Once the mixture is homogeneous, pellets are formed using a horizontal pelletizer, producing uniform-sized pellets. The resulting pellets are dried using a rotary dryer until the moisture content reaches 10–12%.

The next stage is sieving, which separates damaged or non-uniform pellets. The final process, packaging, is carried out automatically using a bagging machine into 50-kg sacks. Each package is labeled with the production date, date, and batch code to facilitate quality tracking.

Figure 2. Hammer mill machine (industrial scale)
Source: Personal documentation

Observations show that industrial feed has a denser texture, uniform shape, and a dark brown color. Its nutritional content is stable because the production process is controlled by an automated system that maintains temperature, pressure, and drying time. Industrial feed offers advantages in terms of efficiency and quality, although it requires a higher investment cost than household-scale feed.

D. Quality Analysis of Artificial Feed

Quality analysis is conducted to assess the conformity of the manufactured feed to national standards. Testing is conducted at the BPBAT Sungai Gelam Nutrition Laboratory using proximate analysis methods to determine protein, fat, water, crude fiber, and ash content.

Table 2. Results of Proximate Analysis of BPBAT Pangasius Feed, Sungai Gelam

No	Parameter	Unit	Test Result	SNI 9043-12:2024
1	Ash Content, Max	%	8.85	13
2	Moisture Content, Max	%	10.12	12
3	Fat Content, Min	%	7.26	5
4	Protein Content, Min	%	30.01	25
5	Crude Fiber Content, Max	%	3.35	8

Source: BPBAT Sungai Gelam Nutrition Laboratory

Based on Table 2 above, the results of the proximate analysis test conducted by the BPBAT Sungai Gelam nutrition laboratory analysis team show parameters such as ash content of 8.85%, moisture content of 10.12%, fat content of 7.26%, protein content of 30.01%, and crude fiber content of 3.35%, meeting the Indonesian National Standard (SNI 9043-12:2024) for catfish cultivation.

Based on the results of the research conducted, the physical quality characteristics of feed processed at the household and industrial scales can be seen in Figure 3 below.

(a) (b)
Figure 3. (a) Household-Scale Feed (b) Industrial-Scale Feed
Source: Personal documentation

Based on Figure 3 above, the visual differences in feed produced between the industrial-scale machine and the household-scale vertical feed extruder are clearly visible, especially in terms of shape, texture, smell, color, and the uniformity of the results. In industrial-scale machines, feed is generally processed with a large capacity of 1 ton/hour and is able to produce 200 kg of feed in a single production cycle. Using a chopping blade, it produces granules of more uniform size; the particles coming out of the machine appear even, so when observed, the shape tends to be uniform, without many large or coarse granules. The feed exhibits high density and homogeneity, is dark brown in color, has a pungent smell as typical feed, and a dense and uniform texture both in size and shape. Industrial feed is often coated with oil or binder, making it more durable in water, preventing rapid nutrient loss, and reducing clumping or broken particles due to stable machine pressure.

In contrast, feed produced from a household-scale vertical extruder is generally processed with a small machine that has a capacity of 100 kg/hour and produces 20 kg of feed per production cycle. This machine operates with limited capacity and relatively low pressure, so the feed output often appears less consistent. Feed granules appear coarser, the shapes may vary slightly from one another, the machine must not overheat during extrusion as it can damage vitamins in the pellets and cause protein loss due to voids, and sometimes there are cracks or breaks in certain parts. Nevertheless, this feed remains suitable for small to medium-scale fish farming. Its texture is less fine, gelatinization is incomplete and easily broken, the particle size is uneven, and the shapes vary, tending to be coarser and disintegrating more quickly in water, resulting in low water durability; the color is yellowish-brown, and the smell is stronger compared to industrial feed.

The extruded feed then undergoes proximate analysis conducted by the BPBATSG nutrition laboratory team. Proximate analysis is carried out to determine the nutrient percentages in the feed to evaluate the feed results according to the final production, including moisture, protein, fat, fiber, nitrogen-free extract, and ash content. The following data are the results of proximate analysis conducted at the BPBAT Sungai Gelam nutrition laboratory.

DISCUSSION

Fish feed quality is influenced by several factors, including type, ingredients, and processing techniques. One ingredient used for feed is fish meal. Fish meal quality can be assessed physically, chemically, and microbiologically. Physically, the criteria evaluated are the shape and uniformity of particle size. Chemically, protein, fat, moisture, and ash content are measured. Microbiologically, fish meal must be free of pathogenic bacteria such as

Salmonella and yeast molds. High-quality fish meal must have uniform granules and be free from bone fragments and other foreign materials (Manik & Arlesto, 2021).
Soybean meal is another ingredient used in feed production. According to Cheng *et al*. (2021), in addition to protein, soybean meal contains crude fiber, plant fat, vitamins, and minerals that play an important role in supporting fish health.

Amino liquid is an additive in feed production. Amino liquid also contains essential minerals and vitamins that promote fish growth (Krishnamoorthy *et al*., 2019). The addition of multivitamins in feed has been shown to improve fish growth performance and enhance resistance to stress and disease (Ali *et al*., 2020). According to Yilmaz *et al*. (2022), the addition of certain probiotics can help increase fish resistance to fungal infections by strengthening the natural immune system. The addition of phytase to feed has been proven to increase phosphorus availability, improve nutrient utilization, and support fish growth (Cao *et al*., 2007). In addition, wheat flour is also used as a binder in feed production. Wheat flour contains gluten, which functions as a natural binding agent, improving pellet compactness and stability in water (Gatlin *et al*., 2007).

Formulation of feed requires knowledge of nutritional content and the feeding habits of the fish, which will determine the type of feed to be produced according to the fish species. Feed formulation is performed using Microsoft Excel. This is consistent with the findings of Adepoju *et al*. (2017), who stated that Excel not only simplifies manual calculations but also improves accuracy in formulating balanced rations. Therefore, using Microsoft Excel is a practical, economical, and easily accessible solution to support livestock feed management, especially for small and medium-scale farmers who cannot afford specialized commercial feed formulation software.

The extrusion process uses a diesel machine powered by solar fuel. Diesel-powered machines are still widely applied, especially in areas with limited electricity access, due to their operational flexibility and suitability for small-scale operations (Antia, Assian, & Ukaru, 2021). Therefore, the development of fish feed extruders, particularly vertical diesel-powered machines, is continually aimed at improving energy efficiency, production capacity, and pellet quality.

Based on Figure 2 above, the hammer mill has two types of grinding tools: batch-type and continuous-type. Raw materials fed through the material input path pass through a conveyor into the grinding machine equipped with a hammer mill and a 2 mm sieve, producing better-quality material. Hammer mill performance is influenced by factors such as rotational speed, sieve size, moisture content, and hammer wear resistance. For example, using a hammer mill for plant-based raw materials such as peanut cake shows increased hammer wear at low moisture levels, with optimal conditions at a rotation speed of approximately 3,262 rpm, 2 mm sieve size, and 14% moisture content (Oduntan & Omitoyin, 2016). Additionally, modern hammer mill designs have been developed to increase energy and operational efficiency while producing particles that meet standard feed requirements (Desta & Oumer, 2022). Overall, using a hammer mill in fish feed grinding improves production efficiency and ensures particle quality.

Based on Table 2 above, the protein content of 30.01% indicates that the feed supports optimal growth of *Pangasianodon hypophthalmus*. The fat content of 7.26% serves as an energy source, while moisture content of 10.12% indicates proper drying. Low crude fiber facilitates digestion, and ash content indicates mineral levels within the ideal range according to SNI 9043-12:2024.

Based on Figure 3 above, industrial-scale feed has a finer, more uniform shape and better water durability compared to household-scale feed. However, household-scale feed remains efficient for farmers due to lower production costs and readily available raw materials. Both feed types have good quality and can serve as an alternative to commercial feed for catfish farmers in Jambi and surrounding areas. Uniform shape and dense texture facilitate fish feeding and digestion and reduce nutrient loss due to water dissolution (Suparjo & Kusdiarti, 2023).

CONCLUSION

Based on research conducted at the BPBAT Sungai Gelam floating feed factory, it can be concluded that the independent feed factory has two types of feed production machines: household-scale and industrial-scale.

1. The production process for household-scale floating feed includes preparation of raw materials, feed formulation, grinding, weighing raw materials, mixing, extrusion, drying, and packaging.
2. The production process for industrial-scale floating feed includes preparation of raw materials, feed formulation, panel installation, material input, grinding, mixing, extrusion, and packaging.

ACKNOWLEDGMENTS

We thank all parties at BPBAT Sungai Gelam, Jambi, for providing opportunities and facilities to conduct this research.

REFERENCE

Abdel-Wahab, A. A., El-Sayed, A. F. M., El-Tawil, N. E., & Shalaby, S. M. (2021). Effect of Feed Processing and Additives on Fish Feed Quality. *Bioresource Technology Reports*, *14*, 100722. https://doi.org/10.1016/j.birt.2021.100722

Adepoju, A. A., Olawoyin, O. O., & Abiola, S. S. (2017). Formulation of Broiler Starter Diets Using Linear Programming in Microsoft Excel. *Journal of Applied Sciences and Environmental Management*, *21*(2), 345–349. https://doi.org/10.4314/jasem.v21i2.15

Afrianto, E., & Liviawaty, E. (2005). *Pakan Ikan*. Kanisius.

Ai, Q., Mai, K., Tan, B., Xu, W., Zhang, W., & Ma, H. (2004). Effects of Dietary Vitamins on Growth of Caspian Salmon. *Aquaculture Nutrition*, *10*(5), 297–303. https://doi.org/10.1111/j.1365-2095.2004.00311.x

Alam, M. S., Faruq, A. N., & Haque, M. M. (2018). Development of Floating Fish Feed Extruder and Performance Evaluation of the Produced Feed. *Journal of Biosystems Engineering*, *43*(1), 58–67. https://doi.org/10.5307/JBE.2018.43.1.058

Alhotan, R. (2021). Commercial Poultry Feed Formulation: Current Status, Challenges, and Future Expectations. *World's Poultry Science Journal*, *77*(2), 279–299. https://doi.org/10.1080/00439339.2021.1878347

Ali, S., Hussain, R., Javid, A., Khan, M. N., Sultan, J. I., & Abbas, S. (2020). Effects of Multivitamins and Minerals Dietary Supplementation on Fish Growth and Health. *Aquaculture*, *520*, 734991. https://doi.org/10.1016/j.aquaculture.2020.734991

Aliyu-Paiko, M., Hashim, R., & Shu-Chien, A. C. (2010). Influence of Feeding Frequency on Nutrient Utilization, Growth and Body Composition of a Tropical Bagrid Catfish. *Aquaculture Research*, *41*(3), 370–381. https://doi.org/10.1111/j.1365-2109.2009.02347.x

Amal, M. N. A., Zamri-Saad, M., Iftikhar, A. R., & Siti-Zahrah, A. (2015). Feed and Feeding of Tropical Freshwater Fish: Sinking and Floating Pellets. *Aquaculture Research*, *46*(6), 1245–1256. https://doi.org/10.1111/are.12630

Amri, K., & Hasan, H. (2017). Pengaruh Pemberian Pakan Mandiri terhadap Pertumbuhan dan Kelangsungan Hidup Ikan Nila. *Jurnal Akuakultur Indonesia*, *16*(1), 45–52. https://doi.org/10.19027/jai.v16i1.5979

Antia, O., Assian, U., & Ukaru, Y. N. (2021). Design and Fabrication of a Modified Fish Feed Pelletizing Machine. *Global Journal of Engineering and Technology Advances*, *6*(2), 65–72. https://doi.org/10.30574/gjeta.2021.6.2.0016

Ariyanto, D., & Hartati, N. (2022). Pengaruh Formulasi Bahan Baku Lokal terhadap Kualitas Pakan Ikan Patin. *Jurnal Teknologi Perikanan dan Kelautan*, *13*(2), 85–93. https://doi.org/10.22146/jtpk.2022.1385

Aryani, N., Hidayati, N., & Syafrizal, A. (2014). Analisis Kualitas Air Sungai dan Dampaknya terhadap Produktivitas Ikan di Provinsi Jambi. *Jurnal Perikanan dan Kelautan*, *5*(2), 87–94.

Balai Perikanan Budidaya Air Tawar (BPBAT) Sungai Gelam. (2024). *Laporan Kegiatan Unit Pembuatan Pakan Ikan Mandiri (UPPIM) Tahun 2024*. Kementerian Kelautan dan Perikanan Republik Indonesia.

Cao, L., Wang, W., Yang, C., Bai, S., & Ma, H. (2007). Phytase Improves Growth Performance and Nutrient Digestibility in Fish. *Aquaculture Research*, *38*(1), 110–118. https://doi.org/10.1111/j.1365-2109.2006.01633.x

Cheng, K., Chen, Y., Yu, D., Wang, X., & Zhou, Z. (2021). Soybean Meal as an Alternative Protein Source for Aquafeed. *Aquaculture Nutrition*, *27*(1), 153–160. https://doi.org/10.1111/anu.13110

Desta, M. A., & Oumer, A. (2022). Design and Performance Evaluation of Grain Feed Grinding Machine. *Turkish Journal of Agricultural Engineering Research*, *7*(1), 104–115.

Fadillah, R., & Nuraini, S. (2021). Teknologi Pakan Mandiri untuk Meningkatkan Efisiensi Budidaya Ikan Air Tawar. *Jurnal Akuakultur Tropis*, *8*(3), 112–120. https://doi.org/10.32587/jakt.v8i3.1360

Fauzy, D., Putra, A. B., Gani, K., & Arifin, Z. (2024). Physical Properties of Sinking Fish Feed for Freshwater Aquaculture. *Jurnal Akuakultur Indonesia*, *23*(1), 11–19. https://doi.org/10.19027/jai.v23i1.36531

Gatlin, D. M., Barrows, F. T., Brown, P., Dabrowski, K., Gaylord, S. T., Hardy, R. W., Herman, E., Hu, G., Krogdahl, T., Nelson, R., Overturf, K., Rust, M., Sealey, W., Skonberg, D., Southerland, M., & Wilson, R. (2007). Expanding the Utilization of Sustainable Plant Products in Aquafeeds: A Review. *Aquaculture Research*, *38*(6), 551–579. https://doi.org/10.1111/j.1365-2109.2007.01704.x

Ghufron. (2016). *Budidaya Ikan Patin: Biologi, Pembenihan dan Pembesaran*. Yayasan Pustaka Nusantara.

Handajani, H., & Widodo, M. S. (2020). *Prinsip Nutrisi dan Formulasi Pakan Ikan Air Tawar*. Universitas Brawijaya Press.

Hardy, R. W. (2010). Utilization of Plant Proteins in Fish Diets: Effects of Global Demand and Supplies of Fishmeal. *Aquaculture Research*, *41*(5), 770–776. https://doi.org/10.1111/j.1365-2109.2009.02331.x

Hidayat, R., & Prakoso, V. A. (2020). The Use of Commercial Feed with Probiotics for Catfish Culture. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, *12*(1), 45–56. https://doi.org/10.29244/jitkt.v12i1.29854

Kementerian Kelautan dan Perikanan. (2024). SNI 9043-12:2024: *Standar Nasional Indonesia – Pakan ikan patin (Pangasianodon hypophthalmus)*. Badan Standardisasi Nasional (BSN).

Khairuman, & Sudenda, D. (2018). *Budidaya Ikan Patin*. Agro Media Pustaka.

Krishnamoorthy, R., Kannappan, R., & Saranya, K. (2019). Impact of Farm-made Liquid Organic Nutrients on Growth and Nutritional Status of Fish. *Organic Agriculture*, *9*(1), 65–79. https://doi.org/10.1007/s40034-018-0287-3

Kurniawan, A., & Pratiwi, R. (2018). Inovasi Pakan Mandiri Berbahan Baku Lokal untuk Meningkatkan Kemandirian Pembudidaya Ikan. *Jurnal Teknologi Hasil Perikanan*, *7*(3), 122–130. https://doi.org/10.35816/jthp.v7i3.22152

Lacerda, C. F., Soares, L. D., & Lima, J. F. (2010). Rice Bran Utilization in Aquafeeds:

Nutritional Evaluation and Digestibility. *Aquaculture Nutrition*, *16*(1), 10–17. https://doi.org/10.1111/j.1365-2095.2009.00632.x

Manik, S. D., & Arleston, J. (2021). *Nutrisi dan Pakan Ikan*. Widina Bakti Prasada Bandung.

Mohammad, S., Supriatna, I., Agung, S. A., & Ernawati, S. (2021). Pelatihan Produksi Pakan Buatan Skala Rumah Tangga untuk Pembudidaya Ikan di Kota Sorong. *Jurnal Pengabdian kepada Masyarakat*, *1*(3), 117–126. https://doi.org/10.35911/abdimas.v1i3.117-126

NRC (National Research Council). (2011). *Nutrient Requirements of Fish and Shrimp*. The National Academies Press.

Nugraha, T., & Siregar, M. (2023). Analisis Efisiensi Energi dan Mutu Fisik Pakan Ikan Buatan pada Skala Industri Kecil dan Besar. *Jurnal Rekayasa Perikanan*, *11*(1), 45–56. https://doi.org/10.24198/jrp.v11i1.41165

Oduntan, O. B., & Omitoyin, B. O. (2016). Wear of Disc Mill Hammer in Wet Grinding Processes on Groundnut Cake for Fish Feed Production. *Research in Agricultural Engineering*, *61*(4), 162–169. https://doi.org/10.17221/36/2015-RAE

Putra, A. Y., & Sihombing, F. (2022). Pengaruh Kadar Protein Pakan terhadap Pertumbuhan Ikan Patin di Perairan Tawar. *Jurnal Ilmu Perikanan Indonesia*, *24*(1), 1–10. https://doi.org/10.29244/jipi.24.1.1-10

Rachman, A., Yochanan, E., Samanlangi, A. I., & Purnomo, H. (2024). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (pp. 105–137). CV Saba Jaya Publisher.

Saparinto, C. (2008). *Budidaya Ikan Air Tawar*. Penebar Swadaya.

Sukarni, D., & Hidayat, A. (2021). Penggunaan Enzim Phytase dalam Peningkatan Kecernaan Pakan Ikan Air Tawar. *Jurnal Bioteknologi Akuatik*, *6*(2), 57–64.

Suparjo, & Kusdiarti, D. (2023). Perbandingan Karakteristik Fisik dan Kimia Pakan Buatan Industri dan Pakan Lokal pada Budidaya Ikan Air Tawar. *Jurnal Akuatika Indonesia*, *8*(2), 45–53.

Syandri, H., Azrita, A., & Junaidi, J. (2021). The Production Performance of *Pangasius hypophthalmus* Fed Local-Based Feed. *IOP Conference Series: Earth and Environmental Science*, *709*(1), 012015. https://doi.org/10.1088/1755-1315/709/1/012015

Tacon, A. G. J., & Metian, M. (2008). Global Overview on the Use of Fish Meal and Fish Oil in Industrially Compounded Aquafeeds. *Aquaculture*, *285*(1–4), 146–158. https://doi.org/10.1016/j.aquaculture.2008.08.015

Widyaningsih, E., & Rahman, H. (2020). Pemanfaatan Bahan Baku Lokal dalam Produksi Pakan Ikan Hemat Biaya. *Jurnal Teknologi Hasil Perikanan*, *9*(2), 99–108. https://doi.org/10.35816/jthp.v9i2.33923

Yilmaz, E., Yilmaz, H., & El-Sayed, A. F. M. (2022). Probiotics as Feed Additives in Aquaculture. *Aquaculture Reports*, *22*, 100956. https://doi.org/10.1016/j.aqrep.2021.100956