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EFFECT OF FERMENTED FIG FLOUR (*Ficus racemosa* L.) SUBSTITUTION ON PROTEIN AND LIPID RETENTION IN GIANT GOURAMI (*Osphronemus goramy* Lacepede, 1801)

Ramadani Fitra[1]*, Indra Junaidi Zakaria[2], Fuji Astuti Febria[2], Witri Winanda[1], and Mona Fathia[1]

[1]Biology Study Programme, Faculty of Health and Science, Batam International University, Riau Islands, 29426, Indonesia
[2]Biology Department, Faculty of Mathematics and Natural Sciences, Andalas University, Padang, 25163, Indonesia

*Corresponding author: ramadanifitra28@gmail.com

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ABSTRACT

Ficus racemosa has considerable potential as a plant-based alternative to partially replace soybean meal in giant gourami diets. Fermentation of fig flour using Effective Microorganisms 4 (EM-4) is expected to improve feed protein quality and nutrient utilization. This study evaluated the effects of substituting artificial feed with fermented fig flour on protein and lipid retention in giant gourami (*Osphronemus goramy*) cultured under aquaculture conditions. The experiment employed a completely randomized design with five dietary treatments containing 0%, 10%, 20%, 30%, and 40% fermented fig flour, each with five replicates. All diets were formulated to be isonitrogenous, with a crude protein level of 32%. Fig flour was aerobically fermented for 72 h using EM-4 prior to feed formulation. A total of 250 juvenile giant gourami (15–20 g initial body weight) were reared for 70 days and fed twice daily at a feeding rate of 3% of total biomass. Fish length and weight were recorded at 14-day intervals. Protein and lipid retention were determined based on proximate analyses conducted at the beginning and end of the experiment. The results showed that dietary inclusion of fermented fig flour significantly affected protein and lipid retention ($p < 0.05$). The highest protein retention (18.41 ± 0.86%) and lipid retention (36.03 ± 1.60%) were observed in fish fed the diet containing 30% fermented fig flour. These findings indicate that partial substitution of artificial feed with 30% fermented *F. racemosa* flour can enhance nutrient retention efficiency and represents a promising strategy for developing cost-effective and sustainable feeds for giant gourami aquaculture.

KEYWORDS: *Ficus racemosa*; retention; protein; lipid; fermentation; giant gourami

ABSTRAK*: Pengaruh Substitusi Tepung Buah Ara (Ficus racemosa* L.*) Fermentasi terhadap Retensi Protein dan Lemak Ikan Gurami (Osphronemus goramy Lacepede, 1801)*

Ficus racemosa memiliki potensi yang besar sebagai bahan nabati alternatif untuk menggantikan sebagian tepung kedelai dalam pakan ikan gurami. Fermentasi tepung buah ara menggunakan Effective Microorganisms 4 (EM-4) diharapkan dapat meningkatkan kualitas protein pakan dan pemanfaatan nutrien. Penelitian ini bertujuan untuk mengevaluasi pengaruh substitusi pakan buatan dengan tepung buah ara terfermentasi terhadap retensi protein dan lemak pada ikan gurami (Osphronemus goramy) yang dibudidayakan dalam sistem akuakultur. Penelitian ini menggunakan rancangan acak lengkap dengan lima perlakuan pakan yang mengandung 0%, 10%, 20%, 30%, dan 40% tepung buah ara terfermentasi, *masing-masing dengan lima ulangan. Seluruh pakan diformulasikan secara isonitrogen dengan kadar protein kasar sebesar 32%. Tepung buah ara difermentasi secara aerob selama 72 jam menggunakan EM-4 sebelum proses formulasi pakan. Sebanyak 250 ekor ikan gurami juvenil dengan bobot awal 15–20 g dipelihara selama 70 hari dan diberi pakan dua kali sehari dengan dosis 3% dari total biomassa. Pengukuran panjang dan bobot ikan dilakukan setiap 14 hari. Retensi protein dan lemak ditentukan berdasarkan analisis proksimat yang dilakukan pada awal dan akhir penelitian. Hasil penelitian menunjukkan bahwa penambahan tepung buah ara terfermentasi dalam pakan berpengaruh nyata terhadap retensi protein dan lemak (*$p < 0,05$*). Nilai retensi protein tertinggi (18,41 ± 0,86%) dan retensi lemak tertinggi (36,03 ± 1,60%) diperoleh pada perlakuan pakan dengan penambahan 30% tepung buah ara terfermentasi. Temuan ini menunjukkan bahwa substitusi parsial pakan buatan dengan 30% tepung F. racemosa terfermentasi mampu meningkatkan efisiensi retensi nutrien dan berpotensi dikembangkan sebagai strategi pakan yang efektif, ekonomis, dan berkelanjutan dalam budidaya ikan gurami.*

KATA KUNCI*: Ficus racemosa; retensi; protein; lemak; fermentasi; ikan gurami*

INTRODUCTION

Aquaculture production in Indonesia continues to grow in line with increasing demand for fish protein as an animal protein source. The high cost of formulated feeds remains a significant constraint on the economic sustainability of commercial fish farming, which account for the most significant portion of total production costs (50–70%) (Fitra and Zakaria, 2022). Therefore, efforts to reduce feed costs by substituting conventional feed ingredients (e.g., fish meal or soybean meal) with low-cost local ingredients are crucial to improving the economic efficiency of aquaculture businesses (Chen *et al.*, 2019; Kim & Cho, 2024). Therefore, strategies to reduce feed costs without compromising fish performance are a key focus in modern aquaculture nutrition research.

Giant gourami (*Osphronemus goramy*) is a high value commodity in Indonesia, but often exhibits relatively slow growth and specific feeding requirements. Optimizing feed composition is necessary to improve feed conversion efficiency, growth rate, and protein and lipid retention in fish. Feed efficiency continues to be a limiting factor affecting the productivity of giant gourami farming, particularly in improving protein and lipid retention, which directly impacts fish growth and meat quality (Afriyanti *et al.*, 2020). The nutritional quality of dietary protein can be evaluated through protein retention in the fish body, which is strongly influenced by the source and quality of protein in the diet (Chen *et al*., 2019).

Giant gourami farming generally uses commercial feed, which can account for up to 60% of production costs, thereby reducing giant gourami production. Feed is a major factor affecting fish growth and survival (Sonavel *et al.*, 2020). One effort made to increase giant gourami is by using high-quality feed (Suwarsito & Susylowati, 2024). One of the nutritional factors required for fish growth is protein content and amino acid components (Fitra & Zakaria, 2022). Therefore, feed containing plant-based protein derived from fermented fig flour (*Ficus racemosa*) is applied as a dietary ingredient to enhance the growth performance of giant gourami

The use of fig flour has been proven in alternative feeding as a substitute for commercial feed for giant gourami to improve feed quality and fish growth (Zakaria *et al*., 2022). Substituting a portion of the feed with fig flour is hypothesized to improve digestive performance and increase feed utilization efficiency, thereby positively impacting protein retention and lipid retention in fish (Yonarta *et al*., 2023).

Conventional feed used in fish farming is generally based on imported raw materials such as fish meal and soybeans, which are expensive and limited in availability. The use of alternative raw materials in fish feed formulation is an increasingly interesting topic, especially for reducing dependence on conventional feed ingredients such as fish meal and soybeans. Therefore, economical local alternatives with high nutritional value are needed. One potential local ingredient is fig fruit (*F. racemosa*), which is the material contains high concentrations of bioactive constituents such as flavonoids, tannins, and saponins, along with adequate protein and fiber contents, supporting its use as an alternative feed ingredient. The nutrient profile of figs shows relatively high protein (28.125%) and carbohydrate (15.84%) contents, along with essential minerals (2%), calcium (30.5%), carotene (20%), ascorbic acid (5.3%), and notable amounts of phosphorus and iron (Kannan *et al*., 2024; Rasyid *et al*., 2017; Sharma *et al*., 2020).

Previous research indicates that the antioxidant compounds in figs play a role in strengthening fish immunity and enhancing feed utilization efficiency (Prasad *et al*., 2014). Replacing part of the artificial feed with fig flour results in significant improvements in feed quality and growth performance of giant gourami (Zakaria *et al*., 2022). Accordingly, the partial replacement of dietary ingredients with fig flour may improve protein and lipid retention efficiency in giant gourami.

Research on the effects of feed substitution with fermented fig flour (*F. racemosa*) on protein and lipid retention. The objective of this study was to assess the impact of fig flour substitution in diets on protein and lipid retention in giant gourami. The results are anticipated to provide scientific insights into the use of local feed resources and to support the development of efficient and sustainable fish farming.

MATERIALS AND METHODS

Time and Location

The research was conducted during the period of August–December 2021 at the Fish Seed Center in Bungus Timur Village, Bungus Teluk Kabung District, Padang, Indonesia, and data analysis was carried out at the Animal Ecology Research Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Andalas University, Padang, West Sumatra.

Experimental Design and Formulated Feed

This study employed an experimental approach using a completely randomized design comprising 5 treatments with 5 replicates each. The experimental treatments were as follows:

(F1) Feed with 0% fermented fig flour

(F2) Feed with 10% fermented fig flour

(F3) Feed with 20% fermented fig flour

(F4) Feed with 30% fermented fig flour

(F5) Feed with 40% fermented fig flour

The feed to be used in this study was first analyzed proximately to determine its nutritional content. The feed formulation used was based on the study (Fitra, 2021) with fig fermentation. The feed formulation was prepared using the isonitrogenous method with a protein content of 32%. The raw materials used in the feed mixture were soybean meal, fish meal, tapioca flour, corn flour, fine bran, fish oil, vitamins and minerals (Premix Aquavita), and water, as well as fermentation materials, namely Effective Microorganism-4 (EM-4) and distilled water. Fermentation of fig flour was conducted under aerobic conditions using Effective Microorganisms 4 (EM-4) with an incubation period of 72 h. Initially, 2.000 g of fig flour was weighed and gradually mixed with 1.200 mL of distilled water until a homogeneous slurry was obtained. The mixture was transferred into a heat-resistant plastic container and steamed for 30 min to reduce microbial contamination. After steaming, the fig flour was allowed to cool at room temperature for approximately 30 min. Subsequently, 2.000 g of the cooled fig flour was mixed thoroughly with a 5% EM-4 solution until uniform. The fermented mixture was then placed into a plastic bag measuring 14 × 30 cm for further incubation (Listiowati & Pramono, 2014).

The test fish used were 250 giant gourami weighing 15 - 20 g, obtained directly from the Padang City Fish Seed Center. The experiment was carried out in a 12 × 8 m earthen pond fitted with hapa nets to separate experimental units and maintain uniform rearing conditions. Water depth was consistently maintained between 60 and 75 cm throughout the experimental period. Feeding was carried out at 07:00 and 17:00 WIB with a dose of 3% of the fish biomass. The experimental fish were reared for 70 days, and growth parameters (length and weight) were measured at 14 day intervals (Arifiina *et al*., 2020). Fish weight and length were observed every 14 days by weighing all fish from each treatment container (Fitra, 2021).

The total length of fish was measured from the anterior snout tip to the posterior end of the caudal fin using either a measuring board or a digital caliper with a precision of 0.1 cm. All measurements were conducted under consistent handling procedures to reduce stress and measurement bias. After measurement, the fish were immediately returned to their respective rearing containers. The collected data were used to calculate growth performance parameters during the experimental period. Prior to measurement, all fish from each treatment container were carefully collected to ensure accurate biomass estimation. Excess water on the fish body surface was gently removed using a soft cloth to minimize weighing error. Individual fish were weighed using a digital balance with a precision of 0.01 g to obtain accurate body weight data.

Three fish samples for each treatment were taken at the beginning and end of the study and analyzed for moisture, protein, lipid, crude fiber, and ash content to determine protein and lipid retention in giant gourami. Chemical analyses to determine protein and lipid contents of fish bodies at the start and end of the experiment were carried out at the Chemistry Laboratory, Bung Hatta University, Padang City. Protein and lipid levels in fish and feed samples were analyzed using standard Kjeldahl and Soxhlet methods based on AOAC (2019).

Crude protein levels in fish and feed samples were quantified using the Kjeldahl procedure following AOAC Official Methods 978.04 and 984.13. This method involved determination of total nitrogen through acid digestion, distillation, and titration, after which nitrogen values were converted to crude protein using a conversion factor of 6.25. Crude lipid content was determined by Soxhlet extraction in accordance with AOAC Official Method 920.39, where oven-dried samples were subjected to continuous extraction with a non-polar solvent and lipid content was subsequently measured gravimetrically.

Parameters Assessed

This study assessed protein retention, lipid retention, length and body weight of giant gourami.

Fish absolute weight gain was computed using the formula of Effendie (1997), as presented in Equation (1):

$$Wm = Wt - Wo \qquad (1)$$

Notes:

Wm : Average absolute weight gain of fish (g)

Wt : Average individual weight of fish at the end of the study (g)

Wo : Average individual weight of fish at the start of the study (g)

Fish absolute length increment was computed using the formula of Effendie (1997), as presented in Equation (2):

$$Lm = Lt - Lo \qquad (2)$$

Notes:

Lm : Average absolute length gain of fish (mm)

Lt : Average individual length of fish at the end of the study (mm)

Lo : Average individual length of fish at the start of the study (mm)

Protein retention is defined as the proportion of dietary protein that is deposited in the fish body relative to the total protein intake during the rearing period. The increase in fish body protein is calculated by multiplying the fish's dry weight at the end of the study by its final body protein content, minus the dry weight at the start of the study multiplied by its initial body protein content. The protein retention value was obtained using the formula provided in Equation (3) (Willer *et al.*, 2024).

$$RP\ (\%) = \left(\frac{Pt - Po}{Pp}\right) \times 100 \qquad (3)$$

Notes:

RP = Protein retention (%)

Pt = Total protein in fish at the end of the study (%)

Po = Total protein in fish at the beginning of the study (%)

Pp = Total protein in feed consumed by fish (%)

Lipid retention in fish is the percentage of lipid from feed that is stored as body tissue during the maintenance period. The increase in fish body lipid was calculated by multiplying the fish's dry weight at the end of the study by its final body lipid content, minus the dry weight at the start of the study multiplied by its initial body lipid content. The calculation is generally performed using the formula presented in Equation (4) (Van Nguyen *et al*., 2024).

$$RL\ (\%) = \left(\frac{Lt - Lo}{Lp}\right) \times 100 \quad \ldots\ldots (4)$$

Notes:

RL = Lipid retention (%)

Lt = Total body lipid of fish at the end of the study (%)

Lo = Total body lipid of fish at the beginning of the study (%)

Lp = Total feed lipid consumed by fish (%)

Data Statistic

Protein and lipid retention data were subjected to one-way analysis of variance (ANOVA) at a 5% significance level ($\alpha = 0.05$). When significant differences among treatments were detected, Duncan's New Multiple Range Test (DNMRT) was applied using SPSS software version 26. Prior to analysis, data normality and homogeneity of variances were assessed using the Shapiro–Wilk and Levene's tests, respectively (Zakaria *et al*., 2022).

RESULTS AND DISCUSSION

Protein Retention

Based on one-way ANOVA, variation in the proportion of fermented fig flour included in the artificial diet had a significant effect on protein retention in giant gourami ($p < 0.05$). Further analysis using Duncan's New Multiple Range Test revealed significant differences between treatment F4 and the control (F1), as well as between treatments F2 and F3 (Figure 1). However, treatment F3 did not differ significantly from treatment F1. Treatment F2 had the same effect on protein retention as treatment F1 or the control in giant gourami.

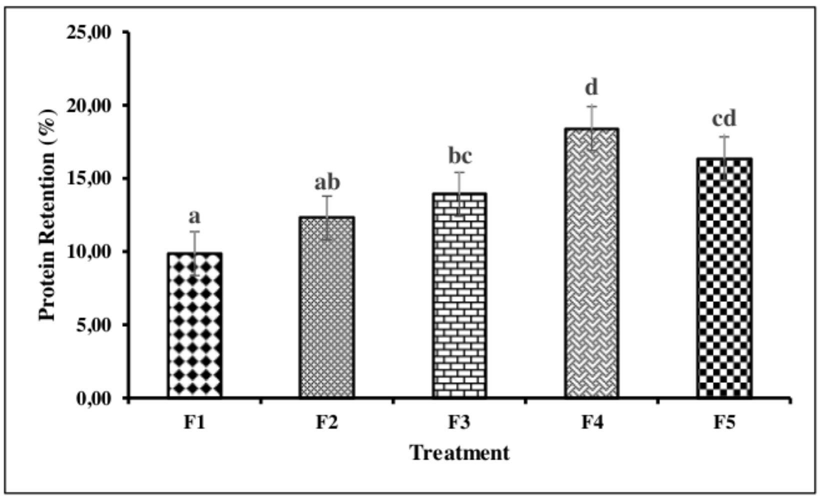

Figure 1. Giant gourami fish protein retention in each treatment: (F1) Diet containing 0% fermented fig flour; (F2) diet containing 10% fermented fig flour; (F3) diet containing 20% fermented fig flour; (F4) diet containing 30% fermented fig flour; and (F5) diet containing 40% fermented fig flour. Different superscript letters above the bars indicate statistically significant differences among treatments at the 95% confidence level ($p < 0.05$).

Protein retention represents the proportion of dietary protein that is deposited in the fish body relative to the total protein intake. Based on the experimental results, the highest mean protein retention in giant gourami was recorded in treatment F4, corresponding to a diet containing 30% fermented fig flour, with a value of 18.41 ± 0.86% at a dietary protein level of 35.46%. Meanwhile, treatment F1 or the control, had the lowest average protein retention value with artificial feed without fermented fig flour, at 9.86 ± 0.10% (feed protein content 31.65%).

Treatment F4 is the best feed for achieving effective, efficient retention in giant gourami. The protein content of the F4 diet (32%) indicates that the inclusion of 30% fermented fig flour was appropriate for meeting the nutritional requirements of giant gourami and promoting efficient protein utilization. This indicates that feed containing fermented fig flour is better for giant gourami than feed without it, which served as the control.

According to Langi *et al.* (2024), the protein requirement range for carnivorous fish is 35–45%, whereas herbivorous fish generally require only 25–35%, depending on growth phase and environmental conditions. This is in line with the results of research that giant gourami fish as a herbivorous fish is able to produce optimal protein retention. Serra *et al*. (2024), stated that protein utilization efficiency is also greatly influenced by alternative protein ingredients, including single cell protein, insect meal, and fermented plant-based materials, have been reported to enhance digestibility and achieve higher protein retention than conventional protein sources when properly formulated.

Appropriate essential amino acid balance and protein to energy ratios significantly influence protein retention and growth performance in fish and crustaceans (Xing *et al*., 2024). Dietary protein quality is not solely defined by its concentration but is strongly affected by amino acid bioavailability and digestibility, which ultimately determine protein retention in fish (Buttle *et al*., 2024). Thus, protein retention can be used as a key indicator of feed protein quality, as high retention values reflect the ability of fish to utilize protein for tissue synthesis and growth (Serra *et al*., 2024).

Lipid Retention

One-way ANOVA indicated that variations in the proportion of fermented fig flour incorporated into the formulated diet significantly affected lipid retention in giant gourami ($p < 0.05$). Subsequent analysis using Duncan's New Multiple Range Test revealed that treatment

F4 differed significantly from the control (F1) as well as from treatments F2, F3, and F5 (Figure 2). However, treatments F3 and F5 had the same effect on lipid retention in giant gourami.

The highest lipid retention value for giant gourami during the study was observed in treatment F4, at 36.30%. The findings demonstrated that treatment F4, incorporating 30% fermented fig flour into the diet, resulted in higher lipid retention in giant gourami compared with the control group, which received a diet without fermented fig flour.

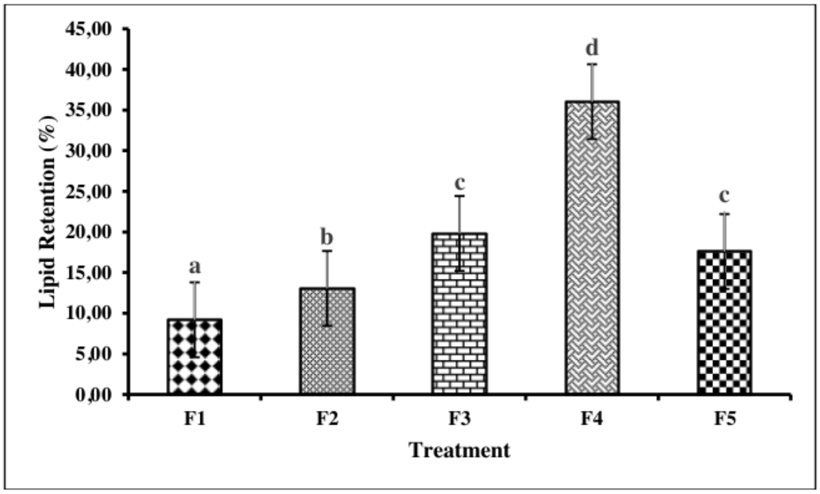

Figure 2. Giant gourami fish lipid retention in each treatment: (F1) Diet containing 0% fermented fig flour; (F2) diet containing 10% fermented fig flour; (F3) diet containing 20% fermented fig flour; (F4) diet containing 30% fermented fig flour; and (F5) diet containing 40% fermented fig flour. Different superscript letters above the bars indicate statistically significant differences among treatments at the 95% confidence level ($p < 0.05$).

Lipid retention is an indicator of the efficiency of energy utilization from feed by fish, defined as the ratio of lipid stored in the fish's body to the lipid provided during maintenance. This parameter is closely related to feed nutrient composition, protein-to-lipid ratio, and lipid metabolism processes (Li *et al*., 2023; Všetičková *et al*., 2020). The inclusion of fermented fig in artificial feed can increase lipid retention in giant gourami. Based on the research data treatment F4 had the highest average lipid retention of 36.03 ± 1.60% (feed lipid content:

5.71%). Meanwhile, the lowest average lipid retention value was observed in treatment F1 (control), at 9.19 ± 0.09% (feed lipid content 6.35%).

The higher the lipid retention value, the more efficiently fish utilize energy from feed for tissue growth, rather than just as a metabolic energy reserve (Phan *et al.*, 2021; Tacon & Metian, 2015). According to Li *et al*. (2023), increasing the lipid content of feed to an optimal level can improve the protein-to-energy (P:E) ratio and shift the main energy source from protein oxidation, thereby simultaneously increasing protein and lipid retention efficiency. However, excessively high lipid levels (>15%) can lead to visceral fat accumulation and reduced retention efficiency due to an imbalance in energy metabolism.

In addition to fatty acid composition, feed quality and fermentation processes also significantly affect lipid retention. According to Sartipiyarahmadi *et al*. (2023), fermentation of plant materials can reduce crude fiber content, increase lipid digestibility, and improve lipid retention efficiency without causing excessive Lipid accumulation in fish tissue. A similar finding was reported by Mao *et al.* (2024), who discovered that supplementing feed with naturally fermented ingredients can improve Lipid digestibility and increase the lipid retention ratio in freshwater fish.

CONCLUSIONS

Variations in the inclusion level of fermented fig flour (*Ficus racemosa*) in the formulated diets significantly affected protein and lipid retention in giant gourami ($p < 0.05$). Among the treatments, F4, containing 30% fermented fig flour, proved to be the most effective formulation for achieving optimal protein and lipid retention in giant gourami.

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AUTHOR CONTRIBUTION

All authors have contributed to the completion of this research. The contributions of each author were as follows: RF; conceptualization, data curation, formal analysis, investigation, methodology, resources, software, visualization, writing original draft, review, and editing. IJZ; conceptualization, data curation, funding acquisition, project administration, supervision, and validation. FAF; conceptualization, data curation, funding acquisition, project administration, supervision, and validation. WW; investigation and methodology. MF; investigation and methodology. All authors participated in the discussion of the results and contributed to the preparation of the final manuscript.

DECLARATION OF COMPETING INTEREST AND USE GENERATIVE AI

The authors declare no competing interests. Artificial intelligence–based tools were used to assist in literature retrieval and language refinement. All content was reviewed and approved by the authors, who assume full responsibility for the final manuscript.

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