Improving feed quality by utilizing fermented fig (*Ficus racemosa*) flour for gourami (*Osphronemus goramy* Lac.) aquaculture development

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Abstract. Fig flour (*Ficus racemosa*) can be used as an alternative feed ingredient for gourami (*Osphronemus goramy* Lac.) seeds. Fermentation is able to break down complex compounds into simpler ones using microorganisms. A fermentation process can be carried out to increase the protein content and reduce crude fiber. This study aimed to analyze the physical, organoleptic, and chemical properties for quality feed of gourami seed with fermented fig flour. This study used an experimental method with a completely randomized design (CRD) by five treatments and with five replications. The treatments for fermented fig flour with different percentages in artificial feed were: F0 0%, F1 10%, F2 20%, F3 30% and F4 40% fermented fig flour using Effective Microorganism-4. The results showed that fermented fig flour had a significant effect on organoleptic tests (texture, aroma, and color) and physical tests (deliciousness, solid dispersion, breaking speed, sinking speed, and level of feed hardness). The chemical analysis showed that all feeds' nutritional content was in the optimal range for gourami seed requirements. 30 % fermented fig flour in artificial feed can substitute the vegetable protein of soy flour in feed to produce good quality feed for gourami.

Key Words: alternative feed, artificial feed, feed ingredient, fermentation.

Introduction. Fig (*Ficus racemosa* L.) is an alternative raw material for fish feed as vegetable protein to replace soybean flour. Fig flour has the potential as a feed ingredient because it contains 9.87% protein and 18.08% crude fibre (Hasan 2019). The requirements for selecting feed raw materials are to be easy to digest, cheap, with high nutritional content, do not compete with basic human needs and do not contain harmful metals (Arisa et al 2019; Adeyemi et al 2020; Yustiati et al 2020). The high crude fibre content in fig flour makes it difficult for fish to digest the feed (Zakaria et al 2022).

Fermentation is an effective method that can improve the quality of feed raw materials. Fermentation of feed is able to break down complex compounds into simpler ones so that they are ready for use by fish, and a number of microorganisms are able to synthesize vitamins and amino acids needed by aquatic animals (Budiman et al 2021). The working principle of fermentation itself is to break down indigestible materials such as cellulose into simple sugars that are easily digested with the help of microorganisms (Pratiwy et al 2020; Adelina et al 2021). Fermentation of fig flour is carried out to reduce crude fibre and increase protein content (Han et al 2001), deactivate anti-nutrients (Frias et al 2008) and increase nutrient bioavailability (Hotz & Gibson 2007).

The enzymes produced in the fermentation process can improve nutritional value and growth, and increase the digestibility of crude fibre, protein and other feed nutrients. The types of microbes found in commercial probiotics produce enzymes such as protease, amylase and lipase. The protease enzyme functions to convert protein into amino acids, amylase converts starch into maltose and lipase converts fat into fatty acids and glycerol (Kim et al 2011). Enzymes are a group of proteins that regulate and carry out chemical changes in biological systems. However, too many bacterial colonies will cause the bacteria to quickly sporulate (form spores) so that their function and activity in the fermentation process is not optimal (Zhang et al 2020; Yigit et al 2020).

Too many inoculums will compete for nutrients and the growth becomes slow and microbes tend to experience sporulation due to competition in utilizing nutrients. High microbial density leading to competition in the uptake of nutrients resulting in microbial activity become obstructed. It was further explained that the increase in the number of inoculums will cause sporulation that is too fast so that some of the energy is not used for multiplying cells (Aslamyah et al 2018). Based on this, it is necessary to determine the amount of fermented ingredients in a fish feed formulation. This is because not all fermented ingredients are good for fish digestion, so the right amount is needed for feed formulation to suit the quality of the feed and the nutritional needs of the fish. This study aimed to analyze the use of fermented fig flour in feed to improve the quality of gourami (*Osphronemus goramy* Lac.) feed.

Material and Method

Location and time of research. This research was carried out from August to November 2022. Physical and organoleptic tests of feed were carried out at the Animal Ecology Research Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Andalas University, Padang. Feed chemical tests were carried out at the Chemistry Laboratory, Bung Hatta University, Padang.

Research design. This study used an experimental method with a completely randomized design (CRD) by five treatments and with five replications. The treatments contain fermented fig (*Ficus racemosa*) flour with different percentages in artificial feed as follows: F0 0%, F1 10%, F2 20%, F3 30% and F4 40% fermented fig flour using Effective Microorganism-4. Five isonitrogenous experimental feeds with a protein content of around 32% were formulated to meet the nutritional needs of gourami (*Osphronemus goramy* Lac.) fry feed. The ingredients used to make feed formulations are soybean flour, fish meal, corn flour and fine bran used as a source of carbohydrates, tapioca flour as an adhesive, fish oil as a source of fat, vitamins and mineral mixtures. All raw materials are ground into a fine powder, then mixed evenly and enough water is added to form a feed mixture. The dough is then printed into pellets using a pellet machine. Experimental feeds were dried at room temperature at around 28°C and stored in sealed plastic bags until use. The stages of making feed refer to Abasubong et al (2019).

Fig flour fermentation using Effective Microorganism-4. 2000 g of fig flour was weighed and then poured in 1200 ml of distilled water gradually until an even mixture was obtained, then put into a heat-resistant plastic to steam for 30 minutes. The fig flour is then refrigerated for 30 minutes. Next, 2000 g of fig flour was weighed and mixed until homogeneous with 5% Effective Microorganism-4 (EM-4) solution. A mixture of fig flour and EM-4 was put in a 14 cm x 30 cm plastic. The process of fermenting fig flour was carried out aerobically by making holes in the plastic and incubating it for 72 hours. The fermented fig flour was dried in an oven for 24 hours to a moisture content of ±80% and then sieved to obtain fine fig flour with a uniform size. The stages of the fermentation process refer to research (Listiowati & Pramono 2014; Aisyah et al 2021).

Parameters assessed. Testing the organoleptic quality of feed was carried out by giving experimental feed samples and questionnaires to 15 correspondents. The organoleptic assessment of feed includes texture, aroma and color which refers to Sulistiyanto et al (2016). Testing the physical quality of feed refers to Aslamyah and Karim (2012) and Zakaria et al (2022). The physical parameters of the feed tested were allurement, deliciousness, solid dispersion, breaking speed, sinking speed and hardness level of the feed. The chemical feed test was carried out by measuring the nutritional content of the feed consisting of crude protein, carbohydrates, crude fat, crude fiber, moisture content and ash content using proximate analysis according to the Association of Official Analytical Chemist (AOAC 2012).

Data analysis. The data obtained from the research results were analyzed by parametric and non-parametric statistical tests using the IBM SPSS 26 application. The physical test data of the feed was tested for normality using the Shapiro-Wilk test. The normally distributed data were then analyzed using a parametric statistical test, namely analysis of variance (ANOVA). If a significant difference is found ($p<0.05$) at the 95% confidence level between treatments, then we proceeded with the Duncan's New Multiple Range Test (DNMRT). The results are expressed by mean ± SE in the table. Feed organoleptic test data were analyzed using a non-parametric statistical test, namely the Kruskal Wallis test, if a significant difference was found ($p<0.05$) then it was continued with the Mann Whitney test to see differences between treatments. All data on the results of physical, organoleptic and chemical feed tests are displayed in tabular form and presented descriptively and compared with related literature.

Results. This research is an effort made to evaluate the physical, organoleptic and chemical quality of feed, designed for gourami (*Osphronemus goramy* Lac.) seeds optimal use. The average value of the physical quality of artificial feed for gourami seeds for each treatment is shown in Table 1.

Table 1

Results of physical quality test of artificial feed

Parameters	*Treatment±SE*				
	F0	*F1*	*F2*	*F3*	*F4*
Allure (cm/s)	4.45±1.29	4.63±0.41	6.46±1.24	6.73±0.96	5.43±0.52
Deliciousness (g/weight/day)	0.66±0.08^{a}	0.54±0.07^{a}	0.71±0.07^{a}	0.91±0.02^{b}	0.75±0.02^{ab}
Density dispersion (%)	6.71±0.39^{a}	7.68±0.35^{ab}	9.84±0.61^{c}	8.92±0.70^{bc}	8.79±0.69^{bc}
Breaking speed (min)	126.87±7.53^{d}	102.86±6.07^{c}	96.73±3.07^{c}	72.12±3.78^{b}	52.34±3.90^{a}
Sinking speed (cm/s)	1.59±0.13^{bc}	2.13±0.57^{c}	6.13±0.61^{a}	4.38±0.70^{ab}	2.63±0.42^{abc}
Hardness level (%)	88.78±2.44^{a}	95.59±0.57^{b}	96.55±0.63^{b}	97.94±0.59^{b}	96.14±1.28^{b}

Note: Superscript letters showed significant differences ($p<0.05$) between treatments.

Based on the results of the one-way statistical test ANOVA showed that the addition of fermented fig flour in artificial feed had a significant effect ($p<0.05$) on the delicious power, solid dispersion, breaking speed, sinking speed and level of hardness of artificial feed for gourami seeds. However, it had no significant effect ($p>0.05$) on the attractiveness of the feed.

The results of organoleptic observations (texture, aroma and color of feed) for each treatment are shown in Table 2. Based on the results of the Kruskal Wallis statistical test it showed that the addition of fermented fig flour in artificial feed had a significant effect ($p<0.05$) on texture, aroma and the color of artificial feed for gourami seeds. The Mann Whitney test showed that the F0 feed was significantly different from the F2, F3 and F4 feeds, but had the same effect as the F1 feed on the texture, aroma and color of the gourami seed feed. Based on the results of the organoleptic tests (Table 2), the five experimental feeds met the criteria of good feed to be used as gourami seed feed. This study proved that the more the percentage of fermented fig flour in the feed, the better the quality of the texture, aroma and color of the feed produced.

Table 2

Results of organoleptic quality test of artificial feed

Parameters	*Treatment*				
	F0	*F1*	*F2*	*F3*	*F4*
Texture	the surface is smooth and there are fine cracks	the surface is smooth and there are fine cracks	the surface is smooth and there are fine cracks	smooth surface and no cracks	smooth surface and no cracks
Aroma	less stinging	less stinging	less stinging	stinging, typical pellet smell	stinging, typical pellet smell
Color	less bright, brown and there are dark patches	bright, patchy brown with a few dark patches	bright, patchy brown with a few dark patches	bright, even brown with a few dark patches	bright, even brown with a few dark patches

The chemical test results for gourami seed feed for each treatment are shown in Table 3. Chemical testing is used to evaluate the quality of the feed produced and to determine the nutritional content of each treatment feed. The nutritional content of the feed was obtained from the results of the proximate test conducted in the laboratory. The chemical quality of the feed measured was the macronutrient profile consisting of protein, carbohydrates, crude fat, crude fiber, moisture content and ash content.

Table 3

Chemical test results of artificial feed

Parameters	*Treatment*				
	F0	*F1*	*F2*	*F3*	*F4*
Protein (%)	31.65	32.64	34.55	35.46	32.93
Carbohydrates (%)	40.72	38.74	37.92	36.45	37.71
Crude fat (%)	6.35	6.31	5.41	5.71	5.86
Crude fiber (%)	6.06	5.83	5.44	5.11	5.65
Water content (%)	8.95	9.60	9.13	9.18	9.58
Ash content (%)	12.29	12.70	12.93	13.14	13.88

Discussion. The addition of fermented fig flour in the feed showed a fairly high average value of attractiveness and deliciousness. All experimental feeds given were immediately responded to and consumed by gourami (*Osphronemus goramy* Lac.) fry. In this study, F3 feed with the addition of 30% fermented fig flour showed higher attractiveness and palatability values than other feeds, especially feeds with the addition of non-fermented fig flour. This is because the fermented fig flour produces a strong and sharp aroma that gives gourami seeds a strong allurement and deliciousness. The allure and deliciousness of feed in this study showed higher results than Aslamyah and Karim (2012) and Zakaria et al (2022). Fig flour contains aromatic amino acids in the form of tyrosine and phenylalanine which can be used as lures, thereby stimulating the attractiveness of fish to respond and consume the feed provided (Aryani et al 2009; Aslamyah & Karim 2012). In addition, the texture of the feed can also affect the deliciousness of the feed for fish. Feed that has a hard texture will make it difficult for fish to consume and digest the feed, thereby reducing the level of palatability of the feed for fish (Saade et al 2013).

Water stability is a parameter of the physical quality of feed which is very important to note in feed production. The water stability observed in this study is solid dispersion and breaking speed. Based on the test results on all the test feeds, it was shown that the addition of fermented fig flour in the feed had a value of the ability of the feed to resist in water above 50 minutes. The dispersion of feed solids in this study showed a higher value than Jacobsen et al (2018) and Zakaria et al (2022), but lower than Aslamyah et al (2021). The dispersion value of feed solids for aquatic organisms should not exceed 10% because it greatly affects the nutritional quality of the feed (Aslamyah et al 2021). The level of refinement of all raw materials used in the manufacture of feed is a factor that can affect the water stability of the feed (Sebayang et al 2020). The very low water stability value is due to the high-water content in the feed, so the feed is easily crushed and dispersed in water (Aslamyah & Karim 2012; Zakaria et al 2022). Then it will cause the accumulation of oil contained in the feed in the stomach of the fish, so that the feed cannot be digested properly (Aas et al 2011).

The sinking speed of the feed in this study was quite high and good for gourami fry. Feed F2 had the highest sinking speed value. The more percentage of fermented fig flour in the feed, the higher the sinking speed value. However, the feed F3 and F4 decreased. The difference in the average value of the feed sinking speed is thought to be due to differences in the water content contained in the feed. The average value of feed sinking speed in this study was lower than Aslamyah et al (2021) and Zakaria et al (2022). Feed sinking speed is influenced by the water content contained in the feed. Feed that has a high-water content will cause the density to be lower, so it has a faster sinking speed (Saade et al 2013). In addition, the sinking speed of feed is also influenced by the adhesive used (Astuti et al 2016).

The hardness level of the feed will increase as the crude fiber content in the feed increases (Wu et al 2021; Yang et al 2015). The level of feed hardness in this study showed a value above 80% and continued to increase with the addition of fermented fig flour up to 30%. Around 2.06 - 11.22% of the feed is destroyed and the rest is still intact. This happens because the level of fineness of the texture of the feed raw materials used is quite good. The hardness level of the feed is also affected by fermented fig flour. F3 feed with 30% fermented fig flour in the feed is the highest value of feed hardness. According to Cai et al (2022) and Zakaria et al (2022), the finer the feed ingredients used, the better the feed produced to be given to fish, so that it can affect the hardness level of the feed. Furthermore, Weththasinghe et al (2021) stated that an increase in fat content can also affect the hardness level of the feed.

The texture of the feed that meets the criteria to be given to fish is a smooth texture (Aslamyah & Karim 2012). F3 and F4 feeds showed the best feed texture compared to other feeds. The texture quality of the feed is influenced by the content of crude fiber, the fineness of the raw materials and the type of adhesive used in the manufacture of the feed. The type of adhesive used in this study was tapioca flour. According to Romano and Kumar (2018), tapioca flour is a source of starch which can increase the hardness of feed. Sumardiono and Siqhny (2019), stated that starch gelatinization can increase the bonds between raw material particles thereby affecting the texture of the feed. Texture quality is affected by moisture content, coarse fiber and drying process (Akerina et al 2022). All treated feed in this study was air-dried in indirect sunlight. Zakaria et al (2022) reported that the substitution of soy flour with fig flour in feed for gourami seeds which were air-dried in the sun indirectly resulted in a feed texture that was smooth and without cracks.

Feed F3 and F4 produced a pungent aroma and a distinctive smell of pellets and was the feed with the best aroma compared to the other treatment feeds. The quality of the aroma of the feed produced in each treatment was thought to have come from the fermented fig flour used. Fermented fig flour produces a stronger aroma than non-fermented fig flour, so it can increase the response and appetite of fish to consume the feed given. The smell of feed is an indicator of feed quality because it can affect the attractiveness of fish to consume feed. The aroma of the feed in this study was better than in the study of Zakaria et al (2022). The fermentation process can affect the aroma of the feed (Zhang et al 2021). In addition, the smell of feed can also be affected by the Maillard reaction (Starowicz & Zieliński 2019).

Color is an indicator of appearance that can be seen directly by the correspondent on the color of the experimental feed. The test results showed that the F3 and F4 feeds showed the best feed from the others, which were evenly brown in color, bright and had a few dark spots. This research shows that the difference in the color of the feed in each treatment is influenced by the composition of the raw materials used. The color of the feed in this study was better than Aslamyah and Karim (2012) and Zakaria et al (2022). Feed that meets good criteria for fish is brown in color (Aslamyah et al 2021). Brown color and dark spots on the feed are formed due to the Maillard reaction, mainly due to the formation of melanoidin and acrylamide (Starowicz & Zieliński 2019).

Provision of fermented fig flour in gourami seed feed showed the chemical content of the feed, namely, protein ranged between 31.65–35.46%, carbohydrates between 36.45–40.72%, crude fat between 5.41–6.35%, crude fiber between 5.11–6.06%, moisture content between 8.95–9.60% and ash content between 12.29–13.88%. The increase in protein content in feed occurred due to the fermentation process carried out on fig flour. This study showed that feed with the addition of fermented fig flour had a higher protein content than feed without the addition of fermented fig flour (Zakaria et al 2022). Fermented feed has a higher protein content than unfermented feed (Adejuwon et al 2020; Zhang et al 2021). The use of alternative plants as a source of vegetable protein in fish farming is quite promising and can increase sustainable aquaculture industry activities (Fitra & Zakaria 2022). The protein content in this study was high and good for the growth of gourami fry.

Carbohydrates in feed that have been digested and absorbed by fish will be used by body cells to meet various energy needs for metabolism and growth (Villasante et al 2019). Excess carbohydrate energy will be stored in the form of glycogen as an energy reserve and for the synthesis of amino acids (proteins) and fats. The carbohydrate content is inversely proportional to the water content (Hermita et al 2017). The carbohydrate content in this study was lower than that of Zakaria et al (2022). Carbohydrates are a non-protein composition in feed that can be used as an energy source for fish metabolic processes (Alam et al 2020; Glencross et al 2014; Mohseni et al 2011). In line with that, optimal carbohydrate content in feed can increase protein and fat retention in several fish species (Kamalam et al 2017). The carbohydrate content above 33.5% in the feed can increase the growth and feed efficiency of fish (Sulaiman et al 2020). Feed carbohydrates in this study are thought to be able to increase the growth performance of gourami fry (Khandan et al 2019).

The crude fiber content comes from cellulose, hemicellulose and lignin which are constituents of cell walls and are needed in feed to increase peristalsis (Subandiyono & Hastuti 2016). Evaluation of the quality of fish feed by carrying out the fermentation process on fig flour can reduce the crude fiber content of the feed. The crude fiber content of the feed is still considered optimal for the growth of gourami fry. Crude fiber feed in this study was lower than in other studies (Abdelwahab et al 2020; Adelina et al 2021; Aryani et al 2017). However, it is higher than the research by Yigit et al (2020) and Zakaria et al (2022). The crude fiber content in the feed is thought to be due to the fermentation process. Based on several research results, the fermentation process can reduce the high crude fiber content of feed ingredients (Ali et al 2020; Augustine et al 2020; Cao et al 2021; Yigit et al 2020). F3 feed with the addition of 30% fermented fig flour had the lowest crude fiber content in this study. This was due to the fermentation process carried out on fig flour using EM-4, so that the research feed could be digested properly by the fish (Putra et al 2021).

Fat is one of the important feed nutrients in providing a source of energy and essential fatty acids (Peng et al 2015). Excess or deficiency of fat in feed can lead to decreased feed consumption, decreased growth and health of fish (Liao et al 2016). This study showed that the highest fat content was found in feed F0, while feed F2 had the lowest fat content. Feed with the addition of fermented fig flour has a lower crude fat content compared to feed without fermented fig flour (Zakaria et al 2022). The fermentation process in a sample can reduce the fat content because it is related to the colonization activity of microorganisms and lipolytic enzymes (Ijarotimi & Keshinro 2013). Low fat content can increase storage time because it reduces the possibility of rancidity in the sample. However, exceeding the optimal limit will reduce growth performance in several fish species (Akinola et al 2017; Li et al 2012), increase protein utilization in feed (Xiao et al 2016) and disrupt fish digestive activity (Chang et al 2017).

High water content in feed can cause microbes to grow quickly and reduce shelf life (Gunawan & Khalil 2015). The moisture content of all feed is still at the optimal limit for fish to use. The water content of the feed in this study was higher than (Aslamyah & Karim 2012). The use of fig flour as a substitute for soybean flour in gourami seed feed can increase the water content in the feed. The higher the percentage of fig flour, the higher the moisture content of the test feed (El-Tawil et al 2020; Zakaria et al 2022).

Ash content is the total mineral content contained in the feed. Feed that has a high ash content is rich in inorganic nutrients compared to crude fiber (Adejuwon et al 2020; Aluge et al 2016; Lucy & Ifedayo 2012). Feed ash content in this study was higher than in Zakaria et al (2022) research. This shows that the feed with the addition of fermented fig flour can increase the ash content in the feed. Ash content below 4% is classified as low and poor in mineral content (Adane et al 2013). High ash content indicates that these fruits are rich in mineral content (Hasan 2019). This study showed that the more the percentage of fermented fig flour in the feed, the higher the ash content of the feed.

Conclusions. Based on the results of physical, organoleptic and chemical tests of the feed, it was shown that the addition of fermented fig flour resulted in a different quality of gourami (*Osphronemus goramy* Lac.) seed feed for each treatment. Fermented fig flour has a significant effect on the texture, aroma, color, deliciousness, solid dispersion, breaking speed, sinking speed and level of hardness of the feed. The results of the proximate analysis showed that the nutritional content of all treated feeds was within the optimal range for gourami seed requirements. 30% fermented fig flour can be used as a source of vegetable protein to replace soy flour in feed to produce good quality feed for gourami.

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