



Improving quality of cassava peel meal as raw material for tilapia feed

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ABSTRACT

Cassava peel meal (CPM) has potential as a raw material for fish feed due to its abundant availability and good nutritional content. The high crude fiber content inhibits the use of CPM as a raw material for fish feed. Therefore, this study aims to evaluate the effect of *Aspergillus niger* fermentation of CPM on dietary nutrient digestibility and growth performance of tilapia (*Oreochromis niloticus*). It was conducted in 2 stages. The first stage was a fermentation process of CPM, which used a factorial randomized design consisting of a dose difference of *A. niger*, namely 10, 15, 20, 30 g.kg⁻¹ and a fermentation time of 0, 12, 24 hours with 3 replications each. At a dose of 1.5% of *A. niger* during 24 hours of fermentation, the crude fiber content of fermented CPM was reduced up to 7.19%. The second stage was a 45 days feeding trial on tilapia used a completely randomized design consisting of 3 different treatments with 3 replications, namely: reference feed, unfermented cassava peel meal based diet (CPMD), and *A. niger* fermented CPMD. *A. niger* fermented CPMD showed an increase in growth, dry matter, protein, energy, and raw material digestibility, as well as daily growth rate compared to unfermented CPMD. The daily growth rate of fermented CPMD of 1.32%/day was significantly higher with $P < 0.05$ than the unfermented CPMD of 0.72%/day. Furthermore, the digestibility value of material test in the fermented CPMD (48.73%) was significantly higher ($P < 0.05$) than unfermented CPMD (11.74%). These results indicate that *A. niger* fermented CPM has the potential to be used as raw material for tilapia fish feed.

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Introduction

Artificial feed is one of the main components in aquaculture as 50-60% of production costs are usually used as a feed cost (Nates, 2016). According to Sunarno *et al.* (2017), in intensive tilapia cultivation, approximately 70% of the total production cost is used for feed. Consequently, the need for artificial feed continues to increase along with the rising demand for aquaculture commodities (Suprayudi *et al.*, 2015; Hermawan *et al.*, 2021). The availability of feed raw materials such as fish, soybean, and meat bone meal are still dependent on imports and the price is increasing in the market (Mukti *et al.*, 2019). This dependence needs to be avoided to reduce the price of artificial feed and increase profits in fish farming (Hakim *et al.*, 2019). Local raw materials have been considered as alternative ingredients in the manufacture of fish

feed because of their low price and high availability (Putri *et al.*, 2017; Achmad *et al.*, 2020).

CPM is one of the potential local raw materials that can be used as an alternative ingredient in the manufacture of fish feed. The Central Statistics Agency, BPS (2017) reported that cassava production in Indonesia in 2017 reached 19,341,233 tons. Meanwhile, Hermanto and Fitriani (2019) stated that the waste from cassava peels was approximately 16%. The nutritional content in 100 g of CPM includes 4.08% protein, 4.02% fat, 56.06% carbohydrates, and 27.23% crude fiber (Mirzah and Muis, 2016). Furthermore, it contains anti-nutritional substances, namely cyanide (Stephanie and Purwadaria, 2013). The high crude fiber content and the presence of cyanide inhibit the use of this meal as a raw material for fish feed.

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Fermentation using microorganisms is an effective approach to reduce the content of crude fiber and anti-nutrients in fish feed raw materials (Sun et al., 2015). Most anti-nutritional substances do not directly cause death in fish but potentially affect physiological processes, by inhibiting growth and decreasing the immune system (Dawood and Khosio, 2020). Fermentation can also increase nutrient digestibility and protein content in feed (Hassaan et al., 2018; Yanto et al., 2018; Ardiansyah et al., 2018; Anwar et al., 2020). Mukherjee et al. (2016) stated that microorganisms such as bacteria, yeast, and molds are effective in fermenting feed raw materials. Moreover, fermentation using *Aspergillus niger* reduces the value of crude fiber and the content of anti-nutrients in fish feed raw materials (Kanetro et al., 2017; Phulia et al., 2017; Putra et al., 2018 and 2019; Mahmood et al., 2022).

Tilapia (*Oreochromis niloticus*) has a high economic value and has widely cultivated in Indonesia (Andriani et al., 2018; Putra et al., 2020a). KKP (2018) reported that annual production of tilapia was 1.2 million tons and ranked the 2nd largest position after seaweed. The use of cassava peel meal fermented by *A. niger* in the formulation of tilapia fish feed has been reported by Azwar and Melati (2012). However, data regarding the effect of different doses and fermentation time in the process is unknown. Therefore, this study aims to evaluate the effect of *A. niger* fermentation of CPM on diet digestibility and growth of tilapia.

Materials and Methods

Making CPM

Cassava peels were obtained from the cassava chip SMEs production waste in Cipete Village, Kragilan Sub-district, Serang, Banten. The inner part was washed and dried in direct sunlight for 2 to 3 days, it was then ground into a CPM.

CPM fermentation test

This stage used a randomized factorial design consisting of a dose difference of *A. niger*, namely 10, 15, 20, 30 g.kg⁻¹, and a time factor, namely 0, 12, 24 hours with 3 replications each. The fermentation process began with steaming 3 kg CPM in boiling water (100 °C) for 30 minutes. Furthermore, accordingly appropriate dose of *A. niger* was dissolved in 100 mL of distilled water, added to the meal, and incubated at room temperature (29 °C). Each replicate was subjected to treatment for 0, 12, and 24 hours of fermentation. After the

fermentation process was completed, the CPM was dried in an oven at 60 °C for 10 minutes. The value of crude fiber for each treatment was measured to determine the effect of *A. niger* fermentation on the cassava peel meal. Measurement of crude fiber content was carried out at the Fish Nutrition Laboratory, IPB University, based on the method described by AOAC (1999). The combination of *A. niger* dose and period of fermentation which performed best in reducing crude fiber content of CPM would be used in the next stage.

Feeding and digestibility test on tilapia

A reference diet and two test diet were formulated (Takeuchi, 1988) which consists of 70% commercial feed and 30% test material. The commercial feed used contained 32% protein, 5% fat, 5% fiber, 10% ash, and 11% water content. It was ground into a meal, then pelleted and homogenized with chromium oxide (Cr₂O₃) as a digestibility indicator, while tapioca was used as a binder. The mixing of the test material was carried out in stages starting from the smallest to the largest composition, blending all ingredients into a moist dough by adding some warm water, then the mixture was peletized on a pellet molding machine and dried in the sun. A completely randomized design consisting of 3 different treatments with 3 replications was used, these include reference feed (A), unfermented CPMD (B), and *A. niger* fermented CPMD (C). The test feed formulations are presented in Table 1.

Tilapia used were monosex males obtained from Fish Seed Center (BBI) Baros, Serang, with a weight of 4-5 g/head. They were randomly distributed into 9 aquariums with a density of 15 fish/aquarium, a dimension of 60 cm x 30 cm x 30 cm and filled with 40 L of water. It was equipped with aeration using a recirculation system for 45 days, while the fish were adapted for 7 days by giving the test feed 3 times a day, namely at 08.00 am, 12.00 pm, and 06.00 pm, ad libitum. The sample collection was carried out by siphoning after 1 hour of feeding, feces were collected in plastic bottles and stored in the refrigerator (-4 °C) before being analyzed. Water quality measurements were carried out daily to assess the temperature parameters at the beginning and end of fish rearing for pH, DO (Dissolved Oxygen), and ammonia parameters. The temperature range in this study was 28.3-30.3 °C, pH 8.16-8.22, DO 5.2-5.8 and ammonia 0.0048-0.006 ppm. Based on Begum et al. (2014), the value of water quality parameters in this study

is still within the range of water quality values for tilapia rearing.

Test parameters

At the end of rearing, the collected feed and feces were analyzed proximately to determine the nutritional content and calculate the digestibility value. The dry matter and the nutrient digestibility values including the protein, fat, and energy were calculated based on the equation proposed by Takeuchi (1988). Meanwhile, the digestibility value of the test material was calculated based on the equation proposed by Watanabe (1988), namely:

Dry matter digestibility (%) = $100 \times (1 - (\text{Cr}_2\text{O}_3 \text{ content of feed} / \text{Cr}_2\text{O}_3 \text{ content of feces}))$

Nutrient digestibility (%) = $100 \times (1 - (\text{Cr}_2\text{O}_3 \text{ content of feed} / \text{Cr}_2\text{O}_3 \text{ content of feces}) \times (\text{nutrient content of feces} / \text{nutrient content of feed}))$

Raw material digestibility (%) = $\text{digestibility value of test feed} - ((0.7 \times \text{digestibility value of test material}) / 0.3)$

The weight and number of tilapia at the beginning and end of rearing were calculated to determine the value of daily growth rate, total feed consumption, feed conversion, and survival rate based on the equation proposed by Huisman (1987), namely:

Total feed consumption (g) = $\text{Final feed weight} - \text{initial feed weight}$

Daily growth rate (%/day) = $100 \times (\text{Ln final fish biomass} - \text{Ln initial fish biomass}) / 45$

Survival rate (%) = $100 \times (\text{final number of fish} / \text{initial number of fish})$

Observation of blood parameters were carried out at the end of fish rearing to determine the effect of using fermented and unfermented CPMD on the blood parameters of tilapia. The number of erythrocytes and leukocytes in the blood was calculated using the method proposed by Blaxhall and Daisley (1973). Additionally, the hemoglobin level was calculated based on the Sahli method (Archana and Arun, 2015) and the procedure for calculating blood hematocrit levels referred to the method described by Anderson and Siwicki (1999).

Chemical analysis

At the end of the rearing, a proximate analysis of the tilapia feed and feces was carried out at the Fish Nutrition Laboratory, IPB University. The proximate analysis performed included the value of protein, fat, crude fiber, ash, and moisture content according to the method described by AOAC (1999).

Statistical analysis

All data obtained except for the blood parameter were analyzed using analysis of variance with a 95% confidence level. The follow-up test used Duncan's Multiple Range test with the SPSS 17 program, while the raw material digestibility test used the t-test with a 95% confidence level. The blood parameter value was analyzed descriptively.

Table 1. Formulation of test feed on tilapia rearing (% dry weight).

Feed composition	Test Feed (%)		
	Reference feed	Unfermented CPMD	Fermented CPMD
Commercial feed	96.50	66.50	66.50
CPM	-	30.00	-
Fermented CPMD	-	-	30.00
Tapioca meal	3.00	3.00	3.00
Cr ₂ O ₃	0.50	0.50	0.50
Total	100.00	100.00	100.00
Proximate composition			
Protein	32.63±0.01	26.12±0.10	30.34±0.33
Lipid	6.23±0.15	4.65±0.01	5.20±0.16
Crude fiber	5.35±0.05	9.05±0.71	5.43±0.05
NFE*	35.64±0.01	49.56±0.58	43.96±0.58
Energy**	387.35±1.46	393.20±1.84	399.02±1.48
C/P***	11.87±0.04	15.05±0.12	13.15±0.05

*CPM: Cassava peal meal, CPMD: cassava peal meal-based diet, NFE: Nitrogen-free extract

**Energy: Gross energy (kcal/100 g), 1 g protein = 5.6 kcal; lipid = 9.4 kcal, carbohydrate = 4.1 kcal

***C/P: ratio of energy per protein

Table 2. Crude fiber value of CPM fermented by *A. niger* with different doses and incubation time*

<i>A. niger</i> Dose (%)	Fermentation time (hours)		
	0	12	24
0	15.06±0.13 ^d A	15.06±0.13 ^b A	15.06±0.13 ^c A
1	9.13±0.35 ^b B	7.76±0.21 ^a A	7.75±0.27 ^b A
1.5	12.41±0.22 ^c B	7.56±0.21 ^a A	7.19±0.07 ^a A
2	8.64±0.08 ^b C	7.55±0.50 ^a B	6.51±0.15 ^a A
3	7.34±0.36 ^a B	7.19±0.15 ^a B	6.45±0.26 ^a A
<i>A. niger</i> Dose	p<0.05	p<0.05	p<0.05
Fermentation time	p<0.05	p<0.05	p<0.05
Dose^time	p<0.05	p<0.05	p<0.05

*Description:

- A completely randomized factorial design consisted of 2 factors, such as *A. niger* dose (0, 1, 1.5, 2, 3%) and fermentation time (0, 12, 24 hours).
- Crude fiber values followed by different superscript letters showed a significant value (P<0.05). Superscript letters "A, B, C" are read horizontally (rows) and letters "a, b, c, d" are read vertically (columns).

Table 3. Digestibility and growth performance of tilapia*.

Parameter	Treatment		
	Reference feed	Unfermented CPMD	Fermented CPMD
Average initial weight (g)	4.57±0.02	4.70±0.01	4.58±0.02
Total feed consumption (g)	127.43±12.63	139.24±5.46	120.27±4.01
Dry matter digestibility (%)	54.64±1.15 ^b	34.44±7.42 ^a	54.03±8.29 ^b
Protein Digestibility (%)	74.03±0.63 ^b	63.27±4.99 ^a	73.66±6.06 ^b
Fat Digestibility (%)	81.50±2.63 ^b	76.16±6.62 ^b	51.52±4.01 ^a
Energy digestibility (%)	50.12±1.43 ^b	26.24±8.86 ^a	44.15±9.55 ^b
Daily growth rate (%/day)	1.33±0.04 ^b	0.72±0.04 ^a	1.32±0.03 ^b
Life sustainability (%)	91.11±3.85	93.33±6.67	97.78±3.85
Feed efficiency (%)	85.77±4.45	63.50±3.92	84.46±3.37

*The value shown is the average±standard deviation. Different superscript letters in the same line show significantly different results (P<0.05).

Results

A. niger Fermentation Test on CPM

The results of *A. niger* fermentation test with different doses and times are shown in Table 2. There was no difference in the crude fiber value of CPM with *A. niger* 0% dose at 0-24 hours of 15.06%. The crude fiber value of the meal began to decrease at 1% fermentation dose with a time of 12 hours namely 7.76%. Furthermore, the 1% and 2% *A. niger* fermentation doses had crude fiber values ranging between 7.19-12.41% and 6.51-8.64%, respectively. The value began to stabilize in 3% dose at 0 to 24 hours.

Digestibility test on tilapia

The digestibility test results of CPMD are shown in Table 3. The results showed no significant difference (P>0.05) in the value of total feed consumption, feed efficiency, and survival rates in all treatments. The highest and

significantly different dry matter digestibility value (P<0.05) was found in the reference feed of 54.64% and fermented CPMD with 54.03% compared to the unfermented CPMD of 34.44%. Furthermore, the highest protein digestibility value with P<0.05 was found in the reference feed of 74.03% and fermented CPMD of 73.66% compared to the unfermented CPMD of 63.27%. The fat and energy digestibility values ranged from 51.52-81.50% and 26.24-50.12%, respectively. Meanwhile, the largest and significantly different daily growth rate value with P<0.05 was found in the reference feed (1.33%/day) and fermented CPMD (1.32%/day). The digestibility values of test material for the fermented and unfermented CPMD were 48.73% and 11.74%, respectively as shown in Table 4.

Tilapia blood parameter

The blood parameter values of tilapia at the end of rearing are shown in Table 5, the results showed that the erythrocyte values obtained ranged from 0.80 to 2.81 x 10⁵ cells/mm³, while the leukocytes/white blood cells that function as body defense amounted to 1.03-1.90 x 10⁴ cells/mm³. Additionally, the hemoglobin and hematocrit values ranged from 5.12 to 6.03 g% and 7.16 to 20.72%, respectively.

Table 4. Digestibility value of cassava peel meal test material*.

Treatment	Raw material digestibility value (%)
Unfermented CPMD	11.74±26.02 ^a
Fermented CPMD	48.73±27.43 ^b

*The value shown is the average±standard deviation. Different superscript letters in the same column show significantly different results (P<0.05).

Discussion

The results showed that *A. niger* fermentation reduced the crude fiber content of CPM as shown in Table 2. This is demonstrated by the decrease in fiber content in the treatment of *A. niger* doses of 1-3% with time fermentation of 0-24 hours. In the present study, the decrease in the crude fiber value of CPM began at 0 hour. This result might be due to the different doses of *A. niger* in each treatment. According to Pallinggi et al. (2014), the decrease in the crude fiber value of fermented materials is due to the digestion by microbes. Putra et al. (2021) also stated that *A. niger* fermentation led to the breakdown of indigestible materials such as cellulose and hemicellulose into simple sugars. This result is in line with Shi et al. (2015) who reported that *A. niger* is a beneficial microorganism that can reduce the fiber content of material through the production of fiber-degrading enzymes during the fermentation process. Furthermore, Silva et al. (2022) stated that *A. niger* mold produced cellulose enzymes that can degrade the cellulose content in a material, while Reddy et al. (2015) found that it can also produce cellulose, xylanase, and pectinase. This result is in line with Suharman et al. (2021) which reported that *A. niger* fermentation reduced the crude fiber content of water hyacinth as a raw material for the fish feed from 26.47% to 11.93%. Lani et al. (2021) also reported the same results, *A. niger* fermentation was able to reduce crude fiber and increase protein content in sago waste as ingredient of tilapia feed.

The result show that higher doses of *A. niger* (2-3%) were not followed by a decrease in the crude fiber

value of the meal, indicating that this treatment is the optimum value for the CPM fermentation process. Similar results were obtained by Pangestika and Putra (2020) who reported that the addition of *A. niger* of 8 g/kg dried feed in the fermentation process of wheat bran was not followed by a decrease in crude fiber value. Andriani et al. (2021) also stated that incubation time is one of the factors that affect the effectiveness of the fermentation process by microorganisms.

According to Gatlin (2010), the crude fiber content in fish feed should be less than 10% to minimize feed waste that can reduce the water quality of the rearing media, while Kamarudin et al. (2018) recommends that a tropical carp, as herbivorous fish could tolerate up to 10% of dietary fiber. In this study, the highest decrease in crude fiber value of CPM was found in dose of 3% *A. niger* at 24 hours of 57.17% (from 15.06% to 6.45%), followed by dose of 2% *A. niger* at 24 hours of 56.77% (from 15.06% to 6.51%), and dose of 1.5% *A. niger* at 24 hours of 52.26% (from 15.06% to 7.19%). There was no significant decrease (P>0.05) in the crude fiber value of CPM at dose above of 1.5% and fermentation time of 24 hours. Therefore, *A. niger* dose of 1.5% with a fermentation time of 24 hours was used as the best treatment for further investigations.

Total feed consumption is a parameter that describes the amount of feed that can be consumed by fish. Based on the results in Table 3, there was no significant difference (P>0.05) in total feed consumption between treatments. This indicates that both fermented and unfermented CPM does not interfere with the appetite of tilapia. Similar results were found by Putra et al. (2018) on rearing tilapia using Moringa leaf-based feed. Putra et al. (2021) also stated that there was no difference in the feed consumption between the *A. niger* unfermented and fermented rice bran-based feed by *A. niger*.

The dry matter, protein, and energy digestibility values in the fermented CPMD were significantly higher than the unfermented CPMD. This is presumably due to the role of *A. niger* fermentation which breaks down crude fiber and nutrients contained in the feed, thereby making it easier for fish to digest. *A. niger* could produce phytase enzymes (Mahmood et al., 2022), amylase enzymes (Pangestika and Putra, 2020), protease enzymes (Oui et al., 2021) and cellulase enzymes (Koedrang and Charoendat, 2020) with a role in the process of feed digestion. Anwar et al. (2020) also reported that *A. niger* generates many enzymes, such as amylase, cellulase, xylanase and protease. However, we have not investigated the enzymes activity produced by *A. niger* in this study.

Table 5. The number of erythrocytes, leukocytes, hemoglobin, and hematocrit levels in tilapia.

Blood parameter	Treatment		
	Reference feed	Unfermented CPMD	Fermented CPMD
Erythrocytes (10^5 sel/mm ³)	1.30±0.04	2.81±0.45	0.80±0.11
Leukocytes (10^4 sel/mm ³)	1.03±0.25	1.90±0.04	1.61±0.06
Hemoglobin (g%)	5.33±0.49	5.12±0.13	6.03±0.06
Hematocrit (%)	20.72±3.99	17.79±1.35	7.16±5.47

Similar results were obtained by Pallinggi et al. (2014) who reported that the digestibility of protein and fat in *A. niger* fermented copra meal-based feed were significantly higher than the unfermented one in milkfish rearing. Putra et al. (2021) also obtained the same results, where the *A. niger* fermented rice bran-based feed had higher dry matter digestibility and energy value ($P < 0.05$) in tilapia compared to the unfermented feed.

The high dry matter, protein, and energy digestibility in the fermented CPMD were directly proportional to the daily growth rate. According to NRC (2011), high feed digestibility increases the availability of nutrients that can be used by fish for energy and growth. The results showed that the daily growth rate of fermented CPMD was significantly higher than the unfermented CPMD. This is in line with Putra et al. (2018) which stated that *A. niger* fermented moringa leaves as a raw material for tilapia fish feed showed a higher daily growth rate than the unfermented. Moreover, there was no difference in the survival rate between treatments. Based on the results, the use of CPM as a raw material for feed does not affect the physiological processes in the body of tilapia. Similar results have been obtained in previous studies which reported that *A. niger* fermentation in feed material did not affect the survival rate of test fish, including *Labeo rohita* (Shamna et al., 2015), *Penaeus vannamei* Boone, 1931 (Jannathulla et al., 2018a; Jannathulla et al., 2018b; Dayal et al., 2020), catfish (Raudah et al., 2018), Asian seabass (Koedrang and Charoendat, 2020), common carp (Anwar et al., 2020), and tilapia (Lani et al., 2021).

The digestibility value of the test material indicates the percentage of the material that can be digested by fish (Putra et al., 2020b). Based on Table 4, the digestibility value of test material in fermented CPMD was significantly higher than the unfermented CPMD. This shows that fermented CPM with *A. niger* at a dose of 1.5% and a fermentation time of 24 hours has the potential to be used as raw material for tilapia fish feed. A previous study also found that the digestibility of *A.*

niger fermented rice bran feed was higher than the unfermented (Putra et al., 2021).

Blood parameters are part of the haematological parameters which describe the effect of environment, nutrition, water quality, stress and pathogen on fish (Fazio, 2019; Witeska et al., 2022). Erythrocytes are the blood cells with the highest number in the body of fish that function to circulate nutrients and oxygen to all body cells. According to Bittencourt et al. (2003), the normal erythrocyte count in fish is $0.7-28 \times 10^6$ cells/mm³. The results showed that the erythrocyte values in tilapia ranged from 0.80 to 2.81×10^5 cells/mm³ indicating that the value in this study was within the normal range of fish erythrocyte. Furthermore, the leukocyte values were within the normal range. Leukocytes are a form of a specific immune system for fish and the normal value ranges from 10,000-50,000 cells/mm³ (Osman et al., 2018). The result showed that the use of CPM as raw material did not affect erythrocyte and leukocytes of tilapia. Similar results were reported by Hosseini & Khajepour (2013), the use of soybean meal in the feed has no effect on erythrocyte and leukocyte of juvenile of beluga, *Huso huso*.

According to Esmaili (2021), the normal range value of fish hemoglobin and hematocrit are 2.6-19.9 g% and 9.89-58.00 %. This implies that the hemoglobin and hematocrit value of tilapia in this study was within the normal range. The hematocrit value was 7.16-20.72% and is within the normal range. *A. niger* fermentation in CPM as ingredient feed has no negative effect on blood parameters of tilapia which were within the normal range. This result was in line with the results of Putra et al. (2019), the utilization of fermented lamtoro leave meal in the diet has no impact on the blood parameters of catfish.

Conclusion

The fermentation by *A. niger* degraded the fiber content in cassava peel meal, with the 1.5% dose and a fermentation time of 24 hours reducing the value of crude fiber up to 7.19%. The dry matter,

protein, and energy digestibility, as well as daily growth rate, were also increased by the fermentation process with no negative impact on the survival rate and blood parameters. Therefore, CPM fermented by *A. niger* has potential as a raw material for tilapia feed. However, future research on evaluating mechanism and typer of enzyme that can be produced by *A. niger* fermentation should be carried out to confirm the role *A. niger* fermentation in fish feed raw materials.

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References

- Ahmad, N., P.J.A. Siddiqui, K.M. Khan, A. Ali, M. Tahir, N.U. Akbar, M. Amin, M. Attaullah, I.D. Boneri. 2020. Effects of partial substitution of fishmeal by soybean meal in Nile tilapia (*Oreochromis niloticus*) diet. *Journal of Animal & Plant Sciences*, 30(2): 364-370.
- Anderson, D.P., A.K. Siwicki. 1993. Basic haematology and serology for fish health program. *Proceeding of the second symposium on diseases in Asian Aquaculture "Aquatic Animal Health and the Environment"* in Phuket, Thailand, 1993, pp. 185-202.
- Andriani, Y., A.A. Hutapea, I. Zidni, W. Lili, M.F. Wiyatna. 2021. Literature review on fermentation factors of restaurant organic waste affecting feed quality. *Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan*, 10(3): 277-283.
- Anwar, A., A.H.L. Wan, S. Omar, E. El-Haroun, S.J. Daves. 2020. The potential of a solid-state fermentation supplement to augment white lupin (*Lupinus albus*) meal corporation in diets for farmed common carp (*Cyprinus carpio*). *Aquaculture Report*, 17: 100348.
- [AOAC] Association of Official Analytical Chemists. 1999. Official method of analysis of the association of official analytical of chemist. Arlington, Virginia, USA: Published by the association of official analytical chemist, Inc.
- Archana, G., K. Arun. 2015. Haematological studies of some edible freshwater fishes of NRC region. *World Journal Pharmacy and Pharmaceutical Sciences*, 6(4): 1476-1479.
- Ardiansyah, Dahlia, Hartinah, Ibrahim, Wahidah. 2018. Improvement of the nutritive quality of Sargassum powder through *Aspergillus niger*, *Saccharomyces cerevisiae*, and *Lactobacillus* spp. fermentations. *AACL Bioflux*, 11(3): 753-764.
- Azwar, Z.I., I. Melati. 2012. Utilization of fermented cassava peel in artificial feed formulation for nile tilapia. *Jurnal Riset Akuakultur*, 7(3): 429-436.
- Begum, A., S. Mondal, Z. Ferdous, M.A. Zafar, M. Ali. 2014. Impact of water quality parameters on monosex tipalia (*Oreochromis niloticus*) production under pond condition. *International Journal of Animal and Fisheries Science*, 2(1): 14-21.
- Bittencourt, N.L.R., L.M. Molinari, D.O. Scoaris, R.B. Pedrosa, C.V. Nakamura, T. Ueda-Nakamura, B.A.A. Filho, B.P.D. Filho. 2003. Haematological and biochemical values for Nile tilapia *Oreochromis niloticus* cultured in semi-intensive system. *Maringa*, 25(2): 385-389.
- Blaxhal, P.C., K.W. Daisley. 1973. Routine haematological methods for use with fish blood. *Journal Fish Biology*, 5: 577-581.
- [BPS] Badan Pusat Statistik. 2017. Peningkatan produksi singkong di Indonesia. Badan Pusat Statistik, Jakarta.
- Dawood, M.A.O., S. Khosio. 2020. Application of fermentation strategy in aquafeed for sustainable aquaculture. *Reviews in Aquaculture*, 12(6): 987-1002.
- Dayal, J.S., R. Jannathulla, K. Ambasankar, M. Muralidhar. 2020. *Aspergillus niger* fermented plant protein mix as a potential substitute for fishmeal in the diet of *Penaens vannamei* (Boone, 1931). *Aquaculture Nutrition*, 26(3): 853-865.
- Esmaceli, M. 2021. Blood performance: a new formula for fish growth and health. *Biology*, 10: 1236.
- Fazio, F. 2019. Fish hematology analysis as an importan tool of aquaculture: a review. *Aquaculture*, 500: 237-247.
- Hermawan, D., M.A. Suprayudi, D. Jusadi, Alimuddin, J. Ekasari. 2021. Evaluation of corn steep powder as a protein source of Nile tilapia *Oreochromis niloticus* diet. *Jurnal Akuakultur Indonesia*, 20(2): 115-129.
- Gatlin III, D.M. 2010. Principles of fish nutrition. Southern Regional Aquaculture Center Publication No. 5003.
- Hakim, A.R., K. Kurniawan, Z.A. Siregar. 2019. Pengaruh penggantian tepung ikan dengan tepung larva *Hermetia illucens* dan *Azolla* sp. terhadap kualitas pakan ikan terapung. *Jurnal Riset Akuakultur* 14(2): 77-85.
- Hassaan, M.S., M.A. Soltan, E.Y. Mohammady, M.A. Elashry, E.R. El-Haroun, S.J. Davies. Growth and physiological responses of Nile tilapia, *Oreochromis niloticus* fed dietary fermented sunflower meal inoculated with *Saccharomyces cerevisiae* and *Bacillus subtilis*. *Aquaculture*, 495: 592-601.
- Hermanto, Fitriani. 2019. Pemanfaatan kulit dan daun singkong sebagai campuran bahan pakan ternak unggas. *Jurnal Riset Teknologi Industri*, 13(2): 284-295.
- Hosseini, S.A., F. Khajepour. 2013. Effect of partial replacement of dietary fish meal with soybean meal on some hematological and serum biochemical parameters of juvenile beluga, *Huso huso*. *Iranian Journal of Fisheries Sciences*, 12(2): 348-356.
- Huisman, E.A. 1987. Principles of Fish Production. Department of Fish Culture and Fisheries, Wageningen Agriculture University, Wageningen, Netherland. 170p.
- Indariyanti, N., Rakhmawati. 2013. Peningkatan kualitas nutrisi limbah buah kako dan daun lamtoro melalui fermentasi sebagai basis protein ikan nila. *Jurnal Penelitian Pertanian Terapan*, 13(2): 108-115.
- Jannathulla, R., J.S. Dayal, D. Vasanthakumar, K. Ambasankar, M. Muralidhar. 2018a. Effect of fungal fermentation on apparent digestibility coefficient for dry matter, crude protein and amino acids of various plant protein sources in *Penaens vannamei*. *Aquaculture Nutrition*, 24(4): 1318-1329.
- Jannathulla, R., J.S. Dayal, K. Ambasankar, A.C. Eugene, M. Muralidhar. 2018b. Fungus, *Aspergillus niger*, fermented groundnut oil cake as a fishmeal alternative in the diet of *Penaens vannamei*. *Aquaculture Research*, 49(8): 2891-2902.
- Kamarudin, M.S., M.A. Sulaiman, M.F.S. Ismail. 2018. Effect of dietary crude fiber level on growth performance, body composition, liver glycogen and intestinal short chain fatty acids of a tropical carp (*Barbonymus gonionotus* ♀ × *Hypsibarbus wetmorei* male ♂). *Journal of Environmental Biology*, 39: 813-820.
- Kanetro, S.B., F. Fidiyanti, Triyatun. 2017. Nutrient content of cassava dregs and rice bran fermented with *Aspergillus niger*. *International Journal of Scientific & Engineering Research*, 8(8): 1235-1238.
- [KKP] Kementerian Kelautan dan Perikanan. 2018. Kelautan dan perikanan dalam angka. [cited 2020 December 12], Available at <https://kkp.go.id/setjen/satudata/page/1453-kelautan-dan-perikanan-dalam-angka>.
- Koedrang, W., U. Charoendat. 2020. Effect of *Aspergillus niger* fermented soybean meal supplementation in formulated diets on growth performance in juvenile Asian Seabass (*Lates culcarifer* Bloch). *Walailak Journal*, 17(9): 916-923.
- Lani, N., A. Husaini, A., N.S. Ngieng, A.S. Lee, K.A.A. Rahim, H.A. Roslan, Y. Esa. 2021. Solid substrate fermentation of sago waste and its evaluation as feed ingredient for red hybrid tilapia. *Malaysian Applied Biology*, 50(1): 85-94.
- Mahmood, S., M.G. Shahid, R. Nadeem, R. Nelofer, M. Irfan. 2022. Application of statictial design for the economical production of

- phytase by *Aspergillus niger* using solid state fermentation. Journal of Animal & Plant Sciences, 32(1): 238-246.
- Mukti, R.C., D. Yonarta, A.D. Pangawikan. 2019. The use of *Indigofera zollingeriana* leaves as feed ingredient of Patin *Pangasius* sp. Jurnal Ilmu-ilmu Perairan, Pesisir dan Perikanan, 8(1): 18-25.
- Mirza, Muis H. 2016. Biokonversi limbah kulit ubi kayu menjadi pakan unggas. Jurnal Ilmu Ternak, 16(2): 59-70.
- Mukherjee, R., R. Chakraborty, A. Dutta. 2016. Role of fermentation in improving nutritional quality of soybean meal-a review. Asian-Australian Journal of Animal Sciences, 29(11): 1523.
- Nates, F.S. 2016. Introduction. In: Nates, F.S (Ed), Aquafeed formulation. Academic Press, Oxford (UK), pp.xiii-xxii.
- [NRC] National Research Council. 2011. Nutrient requirement of fish and shrimp. National Academic Press, Washington DC, USA. 376 pp.
- Ooi, C.K., N. Rasit, W.R.W. Abdullah. 2021. Optimization of protease from *Aspergillus niger* under solid-state fermentation utilizing shrimp shell substrate. Biointerface Research in Applied Chemistry, 11(6): 14809-1484.
- Osman, A.G.M., K.Y. AboulFadls, A.E.M. El Reheem, U.M. Mahmoud, W. Kloas, M.A. Moustofa. 2018. Blood biomarkers in Nile tilapia *Oreochromis niloticus* and African catfish *Clarias gariepinus* to evaluate water quality of the river Nile. Journal of Fisheries Sciences, 12(1): 01-15.
- Palinggi, N.N., Usman, Kamaruddin, A. Laining. 2014. Perbaikan mutu bungkil kopra melalui *Bioprocessing* untuk bahan pakan ikan bandeng. Jurnal Riset Akuakultur, 9(4): 417-426.
- Pangestika, W., S. Putra. 2020. Fish feed formulation with the addition of sludge of dairy waste water and fermented wheat bran. Jurnal Ilmiah Perikanan dan Kelautan, 12(1): 21-30.
- Putra, A.N., C.W. Ningsih, F.S. Nurani, Mustahal, F.R. Indaryanto. 2018. Evaluasi fermentasi daun kelor (*Moringa oleifera*) sebagai bahan baku pakan ikan nila (*Oreochromis niloticus*). Jurnal Perikanan dan Kelautan, 8(2): 104-113.
- Putra, A.N., A.C. Pradana, D. Novriansyah, Mustahal. 2019. Effect of dietary fermented lamtoro (*Leucaena leucocephala*) leaves flour in feed on digestibility and hematological parameter of catfish (*Clarias* sp.). Jurnal Rekayasa dan Teknologi Budidaya Perairan, 8(1): 951-964.
- Putra, A.N., S. Ristiani, Musfiroh, M.B. Syamsunarno. 2020a. Pemanfaatan eceng gondok (*Eichornia crassipes*) sebagai pakan ikan nila: efek terhadap pertumbuhan dan pencernaan pakan. Leuit (Journal of Local Food Security), 1(2): 77-82.
- Putra, A.N., I.M. Maula, Aryati, M.B. Syamsunarno, Mustahal. 2020. Evaluasi tepung daun kelor (*Moringa oleifera*) yang dihidrolisis cairan rumen domba sebagai bahan baku pakan ikan lele (*Clarias* sp.). Jurnal Perikanan UGM, 22(2): 133-140.
- Putra, A.N., D. Rohayati, M.B. Syamsunarno, Mustahal. 2021. Effect of fermented rice bran used as feed ingredient on apparent digestibility coefficient of tilapia (*Oreochromis niloticus*) feed. Paper presented at the 10th International and National Seminar on Fisheries and Marine Science, 15-16 September 2021, Riau, Indonesia, available at <https://iopscience.iop.org/article/10.1088/1755-1315/934/1/012009>. pdf. (accessed 17 January 2022).
- Putri, N.T., D. Jusadi, M. Setiawati, M.T.J. Sunarno. 2017. Potensi penggunaan rumput laut *Caulerpa lentilifera* sebagai bahan baku pakan ikan nila *Oreochromis niloticus*. Jurnal Akuakultur Indonesia, 16(2): 184-192.
- Rahardjo, M.F., D.S. Sjafei, R. Affandi, Sulistiono. 2011. Iktiologi.
- Raudah, P., I. Suharman, H. Alawi. 2018. Utilization of leucaena leaves meal gung (*Leucaena leucocephala*) fermented by *Aspergillus niger* as substitution of soybean meal in the diets on the growth of thai cat fish (*Pangasius hypophthalmus*). Jurnal Perikanan dan Kelautan, 23(2): 1-8.
- Reddy, G.P.K., G. Narasimha, K.D. Kumar, G. Ramanjaneyulu, A. Ramya, B.S.S. Kumari, B.J. Reddy. 2015. Cellulase production by *Aspergillus niger* on different natural lignocellulosic substrates. International Journal of Current Microbiology and Applied Sciences, 4(4): 835-845.
- Shamna, N. P. Sardar, N.P. Sahu, A.K. Pal, K.K. Jain, Phulia. 2015. Nutritional evaluation of fermented jatropha protein concentrate in *Labeo rohita*. Aquaculture Nutrition, 21(1): 33-42.
- Shi, C., J. He, J. Yu, B. Yu, Z. Huang, X. Mao, P. Zheng, D. Chen. 2015. Solid state fermentation of rapeseed cake with *Aspergillus niger* for degrading glucosinolates and upgrading nutritional value. Journal of Animal Science and Biotechnology, 6:13.
- Siva, D., G. Srivethi, P.T. Vasan, D. Rajesh, A. Alfarhan, R. Rajagopal. 2022. Enhanced cellulose enzyme production by *Aspergillus niger* using cellulose/iron oxide magnetic nano-composites. Journal of King Saud University, 34: 101695.
- Stephanie, T. Purwadaria. 2013. Fermentasi subtract pada kulit singkong sebagai bahan pakan ternak unggas. Jurnal Wartazoa 23(1): 15-22.
- Suharman, I., I. Lukostyowati, S. Ramayani, C.M.A. Caipang, A. Adelina, N. Aryani. 2021. Quality improvement of water hyacinth (*Eichornia crassipes*) leaf meal fermented with *Aspergillus niger* as fish feed ingredient. Paper presented at the 10th International and National Seminar on Fisheries and Marine Science, 15-16 September 2021, Riau, Indonesia, available at <https://iopscience.iop.org/article/10.1088/1755-1315/934/1/012007>. pdf. (accessed 17 January 2022).
- Sun, H., J-W. Tang, X-H. Yao, Y-F. Wu, X. Wang, Y. Liu, B. Lou. 2015. Partial substitution of fish meal with fermented cottonseed meal in juvenile black sea bream (*Acanthopagrus schlegelii*) diets. Aquaculture, 446: 30-36.
- Sunarno, M.T.D. 2017. Pemanfaatan bahan baku lokal di klungkung, Bali untuk pakan ikan nila BEST (*Oreochromis niloticus*). Media Akuakultur, 12(2): 105-112.
- Suprayudi, M.A., B. Faisal, M. Setiawati. 2013. The growth of red tilapia fed on organic-selenium supplemented diet. Jurnal Akuakultur Indonesia, 12(1): 48-53.
- Suprayudi, M.A., D. Yaniharto, N. Priyoutomo, A. Kurnianto, J. Ekasari, D. Jusadi, Y. Haga. 2015. Evaluation of practical diets containing high level of corn distillers dried grains with soluble on red tilapia floating net cage production performance. Pakistan Journal of Nutrition, 14: 708-711.
- Takeuchi, T. 1988. Laboratory work-chemical evaluation of dietary nutrients in Watanabe, editor. Fish nutrition and mariculture. Kanagawa International Fisheries Training. Japan International Cooperation Agency (JICA), Japan. pp 179-233.
- Watanabe, T. 1988. Fish nutrition and mariculture. Department of Aquatic Bioscience. Tokyo University of Fisheries. Japan International Cooperation Agency (JICA), Japan. pp 79-82.
- Witeska, M., E. Kondera, K. Lugowska, B. Bojarski. 2022. Hematological methods in fish-Not only for beginners. Aquaculture, 547: 737498.

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