Can the use of Marlin fish by-product meal affect the performances of broiler chickens and the economic value of production?

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O uso de farinha de subprodutos de peixe marlim-preto pode afetar o desempenho de frangos de corte e o valor econômico da produção?

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Abstract

Exploring fish cutting discards, for instance, Marlin fish (*Makaira indica*) originated from traditional fish markets, may provide a product of fish meal at a cheaper price. The objective of this study was to evaluate the growth and economic value of broiler chickens fed the commercial diet, of which 20% were substituted with a mixture feed containing Marlin fish by-product meal (MFM) or commercial local fish meal (CFM) in 4 and 8% of inclusion. This study used 100 broiler chickens of strain MB202 in mixed batches. The study was performed in a completely randomized design consisting of five treatments, four replications, and five birds per experimental unit with the treatments: control (C) = 100% commercial diet (CD); CFM4 = 80% CD + 20% mixture feed with 4% CFM; CFM8 = 80% CD + 20% mixture feed with 8% CFM; MFM4 = 80% CD + 20% mixture feed with 4% MFM; and MFM8 = 80% CD + 20% mixture feed with 8% MFM. The results of this study showed that raising broilers fed the diet containing 4% MFM vs. 4% CFM for up to 35 days-old did not show the significant differences ($p > 0.05$) of all performance parameters. However, at the level of 8%, final body weight and daily body weight gain were significantly higher ($p < 0.05$) and feed conversion ratio was significantly better ($p < 0.05$) in MFM than in CFM-based diets. Protein efficiency ratio was very significantly higher ($p < 0.01$) in MFM than in CFM-based diets. Using MFM in broiler diet declined feed cost and increased income over feed costs, with the best economic receiving at 8% usage of MFM. In conclusion, using MFM in the diet resulted in better performances of broiler chickens and generated better economic value of production compared to using CFM.

Keywords: Cost. Fish waste. Poultry. Profit. Weight gain.

Resumo

*Explorar descartes de cortes de peixes, como o marlim-preto (*Makaira indica*), originário de mercados de peixes tradicionais, pode fornecer um produto de farinha de peixe a um preço mais barato. O objetivo deste* *estudo foi avaliar o crescimento e o valor econômico de frangos de corte alimentados com dieta comercial, sendo 20% substituídos por uma mistura de ração contendo farinha de subproduto de peixe Marlin (SPM) ou farinha de peixe local comercial (FPC) em 4 e 8% de inclusão. Este estudo utilizou 100 frangos de corte da linhagem MB202 em lotes mistos. O estudo foi realizado em um delineamento inteiramente casualizado consistindo de cinco tratamentos, quatro repetições e cinco aves por unidade experimental com os tratamentos: controle (C) = 100% dieta comercial (CD); FPC4 = 80% CD + 20% de ração mistura com 4% FPC; FPC8 = 80% CD + 20% de ração mistura com 8% FPC; SPM4 = 80% CD + 20% ração misturada com 4% SPM; e SPM8 = 80% CD + 20% ração misturada com 8% SPM. Os resultados deste estudo mostraram que a criação de frangos de corte alimentados com a dieta contendo 4% de SPM vs. 4% de FPC por até 35 dias de idade não apresentou diferenças significativas (p > 0,05) em todos os parâmetros de desempenho. No entanto, no nível de 8%, o peso corporal final e o ganho de peso corporal diário foram significativamente maiores (p < 0,05) e a taxa de conversão alimentar foi significativamente melhor (p < 0,05) em dietas baseadas em SPM do que em FPC. A taxa de eficiência proteica foi significativamente maior (p < 0,01) em dietas baseadas em SPM do que em FPC. O uso de SPM na dieta de frangos de corte diminuiu o custo da ração e aumentou a renda sobre os custos da ração, com o melhor recebimento econômico com 8% de uso de SPM. Concluindo, o uso de SPM na dieta resultou em melhores desempenhos de frangos de corte e gerou melhor valor econômico de produção em comparação ao uso de FPC.*

Palavras-chave: *Custo. Resíduos de peixe. Aves. Lucro. Ganho de peso.*

Introduction

Fish meal is one of the most common animal protein sources composed in poultry diets. This meal carries large amounts of energy per unit weight, high-quality protein, digestible essential amino, and fatty acids (Zinn et al., 2009). Fish meal and fish oils are rich in n-3 long-chain polyunsaturated fatty acids docosahexaenoic acid, and eicosapentaenoic acid (Cho and Kim, 2011). Because it is nutritious, fish meal is one of the pivotal feedstuffs composted into commercial diets. Unfortunately, in some countries, such as Indonesia, the price of fish meals is still more expensive than the prices of other feed ingredients formulated in the diet. Approximately 70% of total fish meal required by feed mills in this country is imported, especially from Chile and Peru (Anam and Indarto, 2018).

Fish meals can be produced from the whole, by-catch, and fish by-products. It is expected fish meals produced from cuts or by-products by industry could reduce their price. This may be uncertain, once the price of fish meal is still unsatisfactory for feed formulators. All in all, there are extraordinary sources of waste materials originating from traditional fish markets which are highly ignored, and cause pollutants. These waste of fish are derived from various fish species, and contain high nutrition value, so have the potency to be used as fish meal. According to Afreen and Ucak (2020), fish by-products, such as viscera, head, fins, and skin, contain high protein, minerals, and vitamins and can be used as supplementation in animal feed. The by-products can be utilized as fish meal, fish oil, protein hydrolysates, and fish silage. It is better to sort them into a single fish species to achieve a product of fish by-product meal with stable properties. The chemical composition of fish varies widely among species and from one individual fish to another (Petricorena, 2014).

In most studies, the uses of fish waste meals processed from well-known species in broiler diets have been reported to give more advantages for bird growth and feed cost. Zulfan et al. (2020, 2021), in their studies of leubim fish (*Canthidermis maculata*) waste meal (LFWM) reported this fish waste meal contained protein 49.24% in the entire waste, 55.84% in the waste components without skin, and 46.72% in its skin. All parts of these by-products can be integrated into fish meals to support the broiler performances and increase income over feed and chick costs. Miranti et al. (2019) reported fish waste (head and bone) of *Sardinella lemuru* can generate a fish meal with 40.68 ± 0.42% protein content.

Another fish broadly found in traditional fish markets is marlin fish. The black marlin (*Makaira indica*) is a migration species and one of the highest predators in the ocean (Hill et al., 2016). This fish, recently classified as *Istiompax indica* and belonging to the family of Istiophordae, is usually found in shallow waters close to the coast or on coral reefs in the warm waters of the Indian and the Pacific Ocean (Whitehouse, 2020). It is a large fish group sold habitually in retail rather than in the whole, causing lot of waste squandered. Nevertheless, there was a limited study on the utilization of marlin by-product meals in poultry diets. Black marlin by-products can be used to make a nutritious fish meal, low price, and prospectively introduced in the feed formulation as an alternative practice of commercial fish meal. The objective of this study was to evaluate the performances of broiler chickens fed a commercial diet (CD) and the effects on production costs by substituting the CD to marlin fish by-product meal (MFM) or commercial fish meal (CFM) in 4 and 8% of inclusion during the period from 1 to 35 days of age of the broilers.

Material and methods

The research was conducted under the ethics protocol of the legislative requirements from the Council Directive 2007/43/EC laying down minimum rules for the protection of chickens that broilers.

Processing marlin fish by-product meal

Processing marlin waste meal was performed with a scale, stove, pan, dryer, and disk mill. The marlin fish co-products were collected from Lambaro Traditional Fish Market, Aceh Besar District, Aceh Province, Indonesia. All waste parts, such as bones, meat-attached bones, skins/scales, and fins were used in the processing. The larger size of the discards, such as bones, tails, and fins, were cut into small pieces (± 10 cm/piece). All fragments of marlin by-products were mixed, rinsed, and then boiled for 30 minutes. Subsequently, the materials were drained and dried under sunrise and then transferred into a dryer to attain a moisture content of less than 14%. Finally, the dry by-products were ground by using a disk mill to produce MFM. Approximately 500 g of the samples were sent to the Laboratory of Balai Standarisasi dan Pelayanan Jasa Industri (BSPJI) Banda Aceh for chemical composition determination. The results of laboratory analyses of the nutrient contents of the MFM were protein 46.13%, crude fat 10.78%, crude fiber 1.61%, calcium 7.26%, and phosphorus 3.14%.

Broilers, experimental design, treatments and, diets

One hundred broiler chicks (day old chicks), MB 202 strain, mixed batches in equal numbers of male and female, produced by PT JAPFA, Medan, Indonesia, were used in this research. Twenty pens with 100 x 100 cm each composed the experimental units, each facilitated by a 60-watt heating light bulb, feeder, and drinker. The study was performed in a completely randomized design with five treatments and four replicates. Replicates were experimental units consisting of five chickens each. The birds were placed randomly into the experimental units. The experiment lasted 35 days.

Feed ingredients consisted of commercial diet (CD) CP511 (from 0-21 days), and CP512 (from 22-35 days). This study used a commercial CD to broilers. As much as 20% of CDs were replaced with feed mixture containing the local CFM at 4 and 8% (CFM4 and CFM8) or MFM at 4 and 8% (MFM4 and MFM8). To either the CFM4 or the MFM4 was added 5.5% broken rice + 5% rice bran + 5% yellow corn + 0.5% top mix, while to either the CFM8 or MFM8 was added 6.5% broken rice + 2.5% rice bran + 2.5% yellow corn + 0.5% top mix. Therefore, the experimental diets were: control = 100% CD (CP511 or CP512); CFM4 = 80% CD + 4.0% CFM; CFM8 = 80% CD + 8.0% CFM; MFM4 = 80% CD + 4.0% MFM; and MFM8 = 80% CD + 8.0% MFM.

The nutritional requirements of broilers followed a recommendation of the National Research Council (NRC, 1994). The nutrient contents of commercial diets were based on the information on the market product label of PT Charoen Pokphand. The nutrient content of commercial local fish meal was referred to Utomo (2013) and Sihite (2013). Other feed ingredients composted into the diets, such as broken rice, rice bran, and yellow corn, were adopted from Tables of Feed Composition for Indonesia (Hartadi et al., 2005). The nutrient content of MFM were determined in the Laboratory of BSPJI. The chemical composition and calculated dietary nutrients of the experimental diets are presented in Table 1.

Table 1 - Composition and calculated dietary (%) nutrients of experimental diets

Ingredients	Period from 0-21 day					Period from 22-35 day				
	CD	CFM4	CFM8	MFM4	MFM8	CD	CFM4	CFM8	MFM4	MFM8
Composition										
CD-CP511	100	80.00	80.00	80.00	80.00	-	-	-	-	-
CD-CP512	-	-	-	-	-	100	80.00	80.00	80.00	80.00
CFM	-	4.00	8.00	-	-	-	4.00	8.00	-	-
MFM	-	-	-	4.00	8.00	-	-	-	4.00	8.00
Broken rice	-	5.50	6.50	5.50	6.50	-	5.50	6.50	5.50	6.50
Rice bran	-	5.00	2.50	5.00	2.50	-	5.00	2.50	5.00	2.50
Yellow corn	-	5.00	2.50	5.00	2.50	-	5.00	2.50	5.00	2.50
Top mix[1]	-	0.50	0.50	0.50	0.50	-	0.50	0.50	0.50	0.50
Total	100	100	100	100	100	100	100	100	100	100
Calculated dietary nutrients										
Protein (%)	22.00	21.59	23.29	21.23	22.58	20.00	19.99	21.69	19.63	20.98
Crude fiber (%)	5.00	4.97	4.77	4.91	4.96	5.00	4.97	4.77	4.91	4.96
Ether extract (%)	5.00	5.43	5.28	5.59	5.62	5.00	5.43	5.28	5.59	5.62
Calcium (%)	0.90	0.83	0.92	1.02	1.31	0.90	0.83	0.92	1.02	1.31
Phosporous (%)	0.60	0.77	0.91	0.72	0.82	0.60	0.77	0.91	0.72	0.82

Note: CD = control diet; CFM = commercial fish meal in 4 and 8 %(CFM4 and CFM8); MFM = marlin fish meal by-product in 4 and 8% (MFM4 and MFM8). [1]Feed supplement; top mix per 100 kg contained vitamins A (12,000,000 IU), D3 (2,000,000 IU), E (8,000 mg), K3 (2,000 mg), B1 (2,000 mg), B2 (5,000 mg), B6 (500 mg), B12 (12,000,000 mg), and C (25,000,000 mg), calcium-D-pantothenate (6000 mg), niacin (40,000 mg), choline chloride (10,000 mg), methionine (30,000,000 mg), lysine (30,000,000 mg), mn (120,000,000 mg), Fe (20,000 mg), I (200 mg), Zn (100,000 mg), Co (200 mg), Cu (4,000 mg), santoquin (antioxidant) (10,000 mg), growth promotor (1,300,000 mg).

Research procedures

A broiler house and equipment (feeders and drinkers) were washed and then disinfected by a disinfectant agent. Twenty pens, composed by a heating system, feeder, and drinker, were set up within the house. Litters with an initial height of up to 5 cm were scattered on the floors of the pens. Then, the house was rested for two weeks. The experimental diets were composed based on the formulations and mixed weekly. Feeding the broilers with the control and experimental diets started from the first day until for up to 35 days, *ad libitum* with adding feeds in the feeders twice a day. Drinking water was delivered *ad libitum* and displaced with fresh water daily. During 1-28 days, drinking water was supplemented by vita stress, a commercial feed supplement to reduce birds' stress. On the last day of the week, bird and residual feed were weighed. The vaccines were applied to increase the body immune systems of the birds from the possibility of infected virus of new castle disease and infectious bursal disease. New castle disease vaccine was given by eye drop on the 3rd day and recurred via intramuscular on the 21st day, while the infectious bursal disease vaccine was offered by mouth drop on the 12th day.

Parameters

Performance parameters of broilers determined in this study were body weight (BW), average daily body weight gain (ADWG), feed intake (FI) and average daily feed intake (ADFI), average daily protein intake (DPI), feed conversion ratio (FCR), and protein efficiency ratio (PER). On the last day of the 5th week, all birds were weighed individually to record their final BW. The performance parameters were calculated based on the period from 0 to 21 days, 22 to 35 days, and total period from 0 to 35 days.

The daily protein intake (DPI), and protein efficiency ratio (PER) were computed as follows: DPI (g/b/d) = ADFI x dietary protein level; PER = ADWG (g)/DPI (g).

Economic-value variables involved revenue, feed cost, and income over feed cost (IOFC). All were expressed per bird of the average variables of total birds in every treatment. These variables were computed as follows:

Revenue = average BW x broiler price per bird;
Feed cost = FI x feed price per kg;
Total cost = total variable cost + total fixed cost;
IOFC = revenue-feed cost;
Total gross income = revenue-total cost.

The results were described qualitatively by analyzing the ratio of revenue/cost ratio (R/C) and benefit/cost ratio (B/C) generated from the obtained data in the period of 0-35 days of rearing broilers with a decision that rearing the broilers by feeding the trial diet was profitable only if the R/C > 0 and B/C > 1. Then, the flat profit was classified by comparing these values among the trial diets. The R/C and B/C ratio were computed as follows:
R/C ratio = revenue/total cost;
B/C ratio = total gross income/total cost.

Data analyses

A mathematical model for CRD was based on Ott (1991): $Yij = \mu + \alpha i + \varepsilon ij$, where Yij = the jth sample measurement selected from population i, μ = an overall mean, αi = an effect due to population i, and εij = a random error associated with the response on the diet i, replicate j. The data of broiler performances were analyzed by a procedure of an analysis of variance (AOV) based on Ott (1991). Duncan's multiple range test was applied when the means of the calculated parameters detected significant differences ($p < 0.05$).

Results and discussion

Performances of broilers fed the experimental diets are given in Table 2.

Feed intake and protein intake

There was not a significant difference ($p > 0.05$) in ADFI among the groups for all periods of rearing broilers resulting in no significant difference ($p > 0.05$) in feed intake for the overall periods. The substitution diets with the provision of either the CFM or MFM had feed intake/ADFI equal to the control from the period 1 to 35 days.

The MFM used in this study was well accepted by the chickens, even though at a high level of inclusion. Feed intake is predominantly influenced by feed palatability, although this is not a main priority for broilers to eat rather than to acquire the satisfying energy. The acceptance level of a feed ingredient depends on the limit of its usage within the diet formulation that begins to be refused by the bird due to low palatability or antinutritional factors. Different sources of fish meal can affect feed consumption (Raza et al., 2015).

The MFM-based diets were still consumed well by the birds at the level of 8% inclusion, which indicated that this fish by-product meal was so palatable. In a similar study reported by Zulfan et al. (2021), fish meal produced from the leftovers of cutting leubim (*Canthidermis maculata*) fish is greatly impressive by the broilers when offered this meal at 8% in their diet. Adugna et al. (2020) reported broilers fed 3 and 5% fish by-product meal in the diets significantly increased ($p < 0.05$) average DFI compared to those fed the control diet during the period 11 to 20 days. However, during 21 to 32 days of age, it significantly increased ($p < 0.05$) not only on the birds fed the control diet but also on those fed 2% fish by-product meal.

DPI is affected by the dietary protein content and ADFI. There was a significant difference ($p < 0.05$) in DPI during the period of 0-21 days, of which DPI of CFM8 was greater than that of CFM4, and DPI of MFM8 was greater than that of MFM4. At the same level of inclusion, CFM vs MFM were equal in DPI, and only at higher levels (8%) were comparable to the control, but at lower levels of CFM4, those were lower than the control. Increasing the level of provision of either the CFM or the MFM from 4 to 8% caused an increase in the DPI, how ADFI were not strongly affected, the DPI caused an increase as well.

Table 2 - Performances of broilers as a function of commercial diet, levels of commercial and marlin by-product fish meal, and period evaluated

Parameters	CD	Commercial local fish meals		Marline fish by-product meals		p-value
		4%	8%	4%	8%	
0-21 days						
BW 21d	1,115.31 ± 38.29^{Bb}	1,046.98 ± 24.10^{ABb}	0,979.50 ± 21.58^{Aa}	1,046.06 ± 29.04^{ABb}	1,118.63 ± 62.06^{Bb}	0.0006
ADWG	51.12 ± 1.86^{Bb}	47.84 ± 1.13^{ABb}	44.74 ± 1.00^{Aa}	47.86 ± 1.36^{ABb}	51.29 ± 2.91^{Bb}	0.0006
ADFI	64.20 ± 0.82	62.43 ± 1.36	62.06 ± 1.11	62.81± 3.97	64.31 ± 1.70	0.4594
DPI	14.12 ± 0.18^{bc}	13.48 ± 0.29^{ab}	14.45 ± 0.26^{c}	13.33 ± 0.84^{a}	14.52 ± 0.38^{c}	0.0050
FCR	1.26 ± 0.03^{a}	1.31 ± 0.05^{a}	1.39 ± 0.02^{b}	1.31 ± 0.05^{a}	1.26 ± 0.07^{a}	0.0081
PER	3.62 ± 0.09^{Aa}	3.55 ± 0.13^{Aa}	3.10 ± 0.05^{Bb}	3.60 ± 0.13^{Aa}	3.53 ± 0.22^{Aa}	0.0003
22-35 days						
BW 35d	2,248.75 ± 60.41^{a}	2,210.50 ± 94.35^{a}	2,065.50 ± 53.27^{b}	2,215.75 ± 99.09^{a}	2,304.50 ± 71.26^{a}	0.0080
ADWG	80.96 ± 5.29^{a}	83.11 ± 5.67^{a}	77.57 ± 2.93^{b}	83.55 ± 5.95^{a}	84.71 ± 2.21^{a}	0.0080
ADFI	158.29 ± 2.83	160.61 ± 7.06	149.14 ± 9.31	154.36 ± 5.48	149.14 ± 11.22	0.1792
DPI	31.66 ± 0.57	32.11 ± 1.41	32.35 ± 2.02	30.30 ± 1.08	31.29 ± 2.35	0.4437
FCR	1.96 ± 0.10	1.94 ± 0.18	1.92 ± 0.08	1.85 ± 0.08	1.76 ± 0.10	0.1246
PER	2.56 ± 0.13	2.59 ± 0.23	2.40 ± 0.10	2.76 ± 0.11	2.72 ± 0.15	0.0361
0-35 days						
BW	2,248.75 ± 60.41^{a}	2,210.50 ± 94.35^{a}	2,065.50 ± 53.27^{b}	2,215.75 ± 99.09 ^{a}	2,304.50 ± 71.26^{a}	0.0080
ADWG	63.06 ± 1.69^{a}	61.95 ± 2.69^{a}	57.87 ± 1.51^{b}	62.14 ± 2.79^{a}	64.66 ± 2.02^{a}	0.0079
FI	3,564.25 ± 43.96	3,559.50 ± 104.63	3,391.25 ± 149.86	3,480.00 ± 124.90	3,438.50 ± 145.68	0.2309
ADFI	101.84 ± 1.26	101.70 ± 2.99	96.89 ± 4.28	99.43 ± 3.57	98.24 ± 4.16	0.2309
DPI	22.89 ± 0.30	22.79 ± 0.73	23.40 ± 1.12	21.82 ± 0.75	22.91 ± 1.11	0.1765
FCR	1.62 ± 0.03^{a}	1.64 ± 0.10^{a}	1.67 ± 0.05^{a}	1.60 ± 0.02^{ab}	1.52 ± 0.03^{b}	0.0109
PER	2.75 ± 0.05^{Aa}	2.72 ± 0.17^{Aa}	2.48 ± 0.07^{Bb}	2.85 ± 0.04^{Aa}	2.82 ± 0.07^{Aa}	0.0004

Note: BW = body weight (kg/b); ADWG = average daily body weight gain (g/b/d); ADFI = average daily feed intake (g/b/d); DPI = daily protein intake (g/b/d); FCR = feed conversion ratio (g/g); PER = protein efficiency ratio (g/g); FI = feed intake (kg/b). ^{ab}Means in the same row with different superscripts indicate a significant difference ($p < 0.05$). ^{ABC}Means in the same row with different superscripts indicate a very significant difference ($p < 0.01$).

AOV determined this expansion was not statistically different ($p > 0.05$) among the groups during the period of 22-35 days. This could be explained that although the diets at 8% usage (either CFM8 or MFM8) contained higher dietary protein than the diets at 4% usage (either CFM4 or MFM4), regardless p-value, the amount of ADFI of the former was less than the latter, resulting no significance in DPI among the treatments. Since the DPI during this period was not higher than that during 0-21 days, AOV could not detect a significant difference in the DPI for the overall periods. The dietary protein content in the experimental diets was close to the values under the recommendation of NRC (1994).

Daily weight gain and final body weight

There was a significant difference ($p < 0.05$) in ADWG in all periods (0-21 and 22-35 days) and overall periods (0-35 days). Final BW among the treatments demonstrated a significant difference ($p < 0.05$). Utilizing either the CFM or MFM at the level of 4% in the mixture feed in substitution of 20% commercial diet did not significantly decrease ADWG and BW compared to the control. In contrast, increasing the provision of the CFM from 4 to 8% significantly declined the ADWG and BW of broilers. On the other hand, increasing the provision of the MFM from 4 to 8% had no significant effect on ADWG and BW, and even tended to be better at 8% of the MFM inclusion. There was no significant difference between CFM and MFM at the level of 4%, but at 8% usage, ADWG was significantly lower in the CFM than in the MFM. A very significant difference ($p < 0.01$) in ADWG and BW has been indicated in the period of 0-21 days. During the period of 22-35 days, only ADWG was detected, while BW at the end of three weeks was not significantly different.

Fundamentally, there was a connection between ADWG/FBW and FI/ADFI, but in this case, they were dependent. Adugna et al. (2020) stated the increased ADWG of broilers fed the diet with the provision of fish by-product meal is due to the increased ADFI. In the recent study, there was no strong reason the broilers fed the diets containing the MFM maintained their ADWG and BW close to the control because of their TFI/ADFI ($p > 0.05$), but the enriched dietary nutrients coming from the MFM might be more reasonable. It was signaled on the DPI that statistically there was no significant difference ($p > 0.05$) among the treatment diets for overall periods. However, the increased DPI of the CFM8 at the period 0-21 days did not support the improvement of ADWG/BW, but adversely maintained it. It did not ensue in the MFM8 diet, and then it was assumed that this fish by-product meal was better than the CFM. Kamran et al. (2008) observed a significantly different positive correlation ($p < 0.01$) between FI and TPI ($r = 0.62$), but no significant correlation between TPI and body weight gain (BWG) ($r = 0.08$) of chicks. In contrast, Naik et al. (2017) found BWG was significantly ($p < 0.05$) affected by TPI, a product of dietary protein level and FI. Zulfan et al. (2021) believed the increased BWG of broilers fed the LFWM in their study is more responded by the micro-nutrient availability within this meal rather than as the impact of the increased ADFI.

The declined ADWG of broilers fed the CFM at the level of 8% inclusion disagreed with a previous study reported by Zulfan et al. (2021), who used the same CFM to compete with the leubim fish waste meal. Although the BW of the latter was relatively better than that of the former, the statistical difference was undetected. The CFM was not as good as the former, as examined by the odor, texture, and color. The CFM is generally processed from "ikan rucah", the priceless miscellaneous wild-catch fishes trapped unexpectedly in the fishermen's nets. Those are highly off-market and then send to fishmeal processors. Hence, the property of this fishmeal varies from time to time.

There were limited reports concerning the exploration of marlin fish by-products processed into fish meals and composed in a poultry diet. However, the use of various species of fish-cutting by-products besides marlin has been reported by some researchers, with most findings being satisfaction, such as leubim fish waste meal (Zulfan et al., 2020, 2021). In a similar report by Silitonga et al. (2019), feeding the broilers with fish by-product meal at 5, 10, and 15% has a better effect on MFMand BWG.

Feed conversion ratio and protein efficiency ratio

There was a significant difference ($p < 0.05$) in FCR among the treatments in the period from 0-21 days and for the overall periods. In the period from 0-21 days, the inclusion of 8% of CFM worsened the FCR, proving to be inferior to MFM. In the period from 22-35 days, there was not significant difference in FCR among the treatments. For the overall period (0-35 days), FCR was significantly better in the diet containing 8% MFM than in the diet containing 4 or 8% CFM, even in the control diet. However, the diets containing either 4 or 8% CFM did not show a significant difference in the FCR compared to the control and the MFM at the level of 4%. This means that including 4% CFM did not affect FCR since the broilers were capable of converting the ingested dietary nutrients within the CFM to reach ADWG as responded by the broilers fed the control diet. Hence, in lower inclusions of fish meal, the FCR was not significantly affected.

This result agreed with Adugna et al. (2020), who reported that the average FCR of the broilers fed on the experimental feeds was not affected significantly by 5% FBM. FCR is a ratio between feed intake and BWG; the smaller the FCR, the better the feed quality. The diets with the inclusion of MFM8 had FCR lower than those with the inclusion of CFM8. In the period from 0-21 days, the inclusion of 8% of CFM worsened the FCR. Incorporating the MFM within the diet resulted in FCR better than the CFM. It agreed with Asrat et al. (2023), that the FCR of broilers fed up to 20% of fish waste meal in the diets was considerably smaller ($p < 0.05$) than the control group during the finisher and entire phases.

PER was one of the methods in assessment of protein quality. There was a very significant difference ($p < 0.01$) in PER among the treatments in the period of 0-21 days and overall periods. For overall periods, at the level of 4%, PER was not different between the MFM and CFM diets. Despite this, at the level of 8%, PER was significantly higher ($p < 0.01$) in the MFM than in the CFM diets, indicating the protein quality in the MFM was more excellent than in the CFM. This result agreed with Zulfan et al. (2021), who used LFWM and found that PER in the LFWM-based diet was higher than in the CFM-based diet. Hence, the increased FBW of broilers fed the 8% MFM was thought not to be caused by the DPI, but the tremendous valuable protein derived from MFM was supposed to play a pivotal role in this case. Fish viscera, one of the most crucial wastes, is rich in protein and amino acids (Ahmadi et al., 2021). However, PER is criticized in protein quality assessment because many factors are engaged (Lamb and Harden, 1973). The other micro-nutrients besides protein and essential amino acids, such as minerals, vitamins, and essential fatty acids in the MFM, may have responsibility in chicken development. As reported by Ahmadi et al. (2021), fish by-products also contain other nutrients such as oils, minerals (zinc, selenium), enzymes, pigments, condiments, and unsaturated fatty acids, and are highly perishable and can be used in animal nutrition and play a pivotal role in the growth. Meanwhile, fish by-products furnish vital omega-3 fatty acids and vitamins necessary for growth, cognitive development, and a healthy immune system. Unfortunately, those were not available in the recent study, suggesting to perform further studies to expose the complete micro-nutrients in the MFM.

Economic values

The bird performance is not the only factor to conclude a new feed source is eligible to be composed into the diet formulation. It should also mean the economic value of gaining income, interpreted from the potential changes in revenue, feed cost, and IOFC.

The economic values were presented in revenue, feed cost, and IOFC. The results of the economics analysis of rearing broiler chickens fed the experimental diets are presented in Table 3. The highest revenue was obtained in the MFM8-based diet, while the lowest was in the CFM8-based diet. Using CFM did not generate higher income than using 100% commercial diet or 8% MFM. Using 4% of MFM also did not result in higher income, but could be higher when introduced at 8% compared to the others. Using CFM at a higher level (8%) gained the lowest revenue.

Revenue is gained from the number of products produced in a farming activity multiplied by the selling price prevailing in the market. Using MFM or CFM-based diets provided different revenues because the average FBW of the chickens from both treatments was unequal. With the same price, the amount of money earned was also not identical. At a lower level (4%), whatever fish meal incorporated into the diet impacted none of the returns. Conversely, at a higher level (8%), using MFM obtained the highest revenue because the average FBW of broilers from this treatment was very significant ($p < 0.01$) higher than that of those from the CFM treatments. The only revenue could not be used to decide whether the use of these fish meals would give more advantages or not since the production costs were not included.

The CFM-based diets could reduce 4.67 and 6.23% of the total cost at 4 and 8% usages of the CFM, respectively. When the MFM was used instead of the CFM at those levels, the total cost declined 7.79 and 9.03%, respectively. The CFM or the MFM-based diets was not exclusively included the fish meal in the mixture feeds, but both were composted of other feed ingredients, such as corn, broken rice, rice bran, and top mix, in the compositions given in Table 1 to constitute 20% of CD replacement. Therefore, using MFM produced lower production costs than using CFM.

The lowest pro-duction costs were found in the MFM8-based diet. The decreased production costs were due to the decreased total feed costs because other variable costs were the same for all treatments. Total feed cost was affected by the feed (diet) price and FI. The feed prices were calculated based on diet for-mulation (Table 1) and the feed ingredient prices per kilogram presented in the notes of Table 3.

Table 3 - Revenue, cost, increased income over feed costs (IOFC), and total gross income of raising broilers as a function of commercial diet, and levels of commercial and marlin by-product fish meal

Parameters	Commercial diet	Commercial local fish meal		Marlin fish by-product meal	
		4%	8%	4%	8%
Revenue					
Broiler weight (kg/b)	2,249.00	2,211.00	2,066.00	2,216.00	2,300.00
Broiler price (US$/kg)	1.53	1.53	1.53	1.53	1.53
Revenue (US$/b)[1]	3.44	3.38	3.16	3.39	3.51
Costs					
Feed intake 0-21 days (Kg/b)	1,348.25	1,311.01	1,303.26	1,319.01	1,350.51
Feed price starter diet (US$/kg)	0.66	0.62	0.64	0.61	0.60
Feed cost 0-21 days (US$/b)[2]	0.90	0.82	0.83	0.80	0.82
Feed intake 22-35 days (Kg/b)	2,216.06	2,248.54	2,087.96	2,161.04	2,088.94
Feed price grower/finisher diet (US$/kg)[3]	0.66	0.62	0.63	0.60	0.60
Feed cost 22-35 days (US$/b)[2]	1.46	1.39	1.32	1.30	1.25
Total feed cost 0-35 days (US$/b)[3]	2.35	2.21	2.15	2.10	2.07
Feed cost percentage 0-35 days[4]	73.28	72.02	71.47	71.00	70.67
Chick cost (US$/b)	0.45	0.45	0.45	0.45	0.45
Other variable costs 0-35 days (US$/b)	0.35	0.35	0.35	0.35	0.35
Total variable cost 0-35 days (US$/b)[5]	3.16	3.01	2.95	2.90	2.87
Total fix cost 0-35 days (US$/b)	0.50	0.50	0.50	0.50	0.50
Total cost 0-35 days (US$/b)[6]	3.21	3.06	3.01	2.96	2.92
IOFC (US$/b)[7]	1.08	1.17	1.01	1.29	1.44
Total gross income (US$/b)[8]	0.23	0.32	0.15	0.43	0.59
R/C ratio	1.07	1.10	1.00	1.14	1.20
B/C ratio	0.07	0.10	0.05	0.14	0.20

Note: [1]Final body weight x broiler price/kg; broiler price followed the market price when this study run = US$1.53/kg live weight; 1US$ = IDR15,050. [2]Feed intake x diet price; feed ingredient price per kg: CP511 Bravo = US$0.664, CP 512 Bravo = US$0.658, broken rice = US$0.365, yellow corn = US$0.399, rice bran = US$0.226, commercial local fish meal = US$0.664, marlin fish waste meal (based on processing) = US$0.250, top mix = US$2.392. [3]Feed cost 0-21 days + feed cost 22-35 days. [4]Total feed cost/total cost x 100%. [5]Total feed cost + chick cost + other variable cost. [6]Total variable cost + total fixed cost. [7]Revenue – total feed cost. [8]Revenue - total cost.

The grower/finisher feed cost was lower than the starter feed cost because the price of the CP512-grower/finisher diet was cheaper than the price of the CP511-starter diet. Replacing 20% of commer-cial diet with the mixture feed containing 4% CFM minimized diet price per kilogram down to 6.17%

in the starter diet and 6.08% in the finisher diet. At 8% of CFM usage, feed price only declined 4.07% in the starter diet and 3.95% in the finisher diet. Despite this, replacing 20% of the commercial diet with the mixture feed containing 4% MFM depressed diet prices by 8.58% in the starter diet and 8.51% in the finisher diet, and progressively declined at 8% MFM usage. This difference was due to the lower price of the MFM-based diets than the CFM-based diets. It agreed with Asrat et al. (2023), including up to 20% fish waste meal in broiler diets results in a lower feed cost per kilogram of BWG and the highest net return and marginal rate of return. Also agreed with Zulfan et al. (2020), that using leubim fish waste meal reduced the feed cost of rearing broilers. This finding supported Thirumalaisamy et al. (2016), that using unconventional feed ingredients available locally to formulate the least-cost feed formulation leads to a decline in poultry feed cost. In the current study, 73.28% of the total costs was feed cost in rearing broilers fed a full commercial diet, which was somewhat higher than reported by Thirumalaisamy et al. (2016), feed composed of approximately 60 to 70% of the total expenditure of broiler production. When the commercial diet was replaced 20% with mixture feed containing 4 and 8% CFM, feed costs lessened slightly to be 72.02% and 71.47%, respectively. If MFM was used instead of CFM at those levels, respectively, feed costs declined progressively to be 71 and 70.67% of the total costs for saving 2.28-2.61% feed costs. The percentages of changing in price, cost, and profit of fish meal inclusion based diets over the control diet (%/bird) are presented in Table 4.

Table 4 - Revenue, cost, increased income over feed costs (IOFC), and total gross income of raising broilers as a function of commercial diet, and levels of commercial and marlin by-product fish meal

Items	Commercial local fish meal		Marline fish by-product meal	
	4%	8%	4%	8%
Feed price (US$/kg)				
Starter diet	-6.17	-4.07	-8.58	-9.04
Finisher diet	-6.08	-3.95	-8.51	-8.97
Feed cost (US$/b)	-5.96	-8.51	-10.64	-11.91
Starter period	-8.82	-7.37	-10.71	-8.93
Finisher period	-4.66	-9.53	-10.84	-14.27
Cost (US$/b)				
Variable cost	-4.75	-6.65	-8.23	-9.18
Total cost	-4.67	-6.23	-7.79	-9.03
Profit (US$/b)				
IOFC	+8.33	-6.48	+19.44	+33.33
Total gross income	+34.78	-34.78	+86.96	+156.52

Feed price affected feed cost depending on the FI. Statistically no significant difference, but the substitution of the 20% CD with mixture feed consisting of either CFM or MFM has a slightly lower FI than using 100% CD (Table 2). With lower FI and feed prices, the feed costs were also lower (Table 3). The result of a study by Zulfan et al. (2020) also showed a decrease in feed costs due to a decreased price of the commercial diet substituted with feed ingredients containing leubim fish waste meal. Using MFM4 or MFM8 as the partial substitution of the CD increased profits versus using 100% CD. The provision of CFM increased profit by 34.78% only when used at 4% but decreased 34.78% when used at 8%. In contrast, including MBM at 4 or 8% usage provided a higher advantage up to 156.52%. It was caused by the increased IOFC up to 33.33% of rearing broilers fed the MFM-based diets due to the reduced feed cost.

In the present study, whatever the diets fed to the broilers, the farmers got a profit, indicated by the R/C > 1 and B/C > 0. According to Sjahrial (2008), a farm business will be profitable if R/C > 1 and B/C > 0, but unprofitable if R/C < 1 and B/C < 0. It meant both the revenues and the benefits achieved over the costs. By only feeding a CD, the broiler producers have reached the advantages, but the margin was still relatively low. Hence, the diet cost needs to be minimized, for example, by replacing part of a commercial diet with a mixture feed composed of feed ingredients at a cheaper. This could change the R/C and B/C ratios. In this study, reduce total cost 7.79 and 9.03% in 4 and 8% MFM-based diets, respectively successfully increased the R/C and B/C ratios. On the other hand, CFM-based diets could increase R/C and B/C ratios unless used at 4%. At 8% of CFM usage, although, total cost has reduced 6.23%, the lower revenue and benefit could not help to improve R/C and B/C ratios. It meant if the CFM was being considered to apply in the feed mixture, its provision should be not more than 4%. In contrast, the MFM could be exposed to up to 8% to generate the highest profit revenue, total feed cost, and IOFC of raising broilers from all treatments are illustrated in Figure 1.

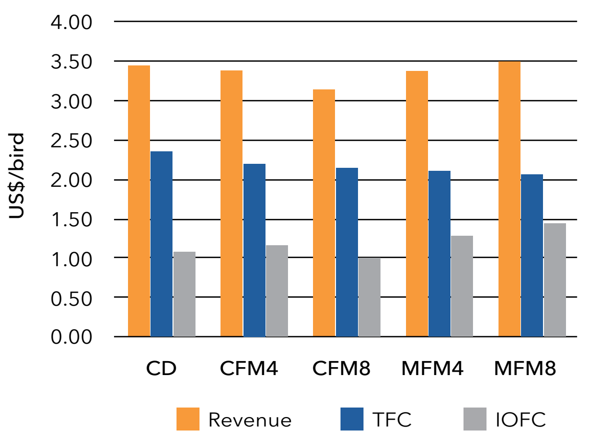

Figure 1 - Revenue, total feed cost (TFC), and income over feed cost (IOFC) of raising broilers fed the diets containing commercial local fish meal (CFM) or Marlin fish by-product meal (MFM) in 4 and 8% of inclusion.

Conclusion

This study concluded that using MFM in the diet resulted in better performances of broiler chickens and reduced feed cost and generated better profit of production compared to using commercial fish meal. Another benefit of employing the unused marlin cut-ups was to reduce pollutants originating from traditional fish markets.

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