



The effects of partial replacement of fishmeal with hermetia meal on the growth and fatty acid profile of African catfish fry

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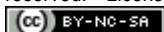
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Abstract: Fishmeal is becoming an increasingly expensive resource. Therefore, it is important to find other sources of protein to reduce feed costs. The larvae of the black soldier fly, *Hermetia illucens*, was evaluated as an alternative protein source for the African catfish, *Clarias gariepinus*, in six-week feeding trials. Three experimental diets were iso-nitrogenous (35% crude protein) and iso-lipidic (18 % crude fat). The following ratios of fish meal were used in the study: 1 fish meal (FM, control); 1:2 hermetia meal to fish meal (1HM:2FM); and 1:1 hermetia meal to fish meal (1HM:1 FM). Two hundred and seventy catfish fingerlings (mean initial weight: 2.45 g) were distributed to nine tanks corresponding to three treatments with three replicates. The experiment examined weight gain, specific growth rate (SGR), feed conversion ratio (FCR) and muscular body composition as growth parameters. The study found that substitution of one-third of fish meal protein with hermetia meal had no negative effect on the growth performance of African catfish fry fed 1HM:2FM, which showed greater weight gain ($17.74 \pm 0.722g$). The muscle composition of fish fed 1H:1FM showed a significant proportion of protein between diets. The fatty acid profile of fish muscle reflected the content of the diet. Based on the results, it was concluded that the protein meal of the black soldier fly can serve as a substitute for the diet of the African catfish.

INTRODUCTION

Aquaculture is one of the fastest growing food production industries in the world. Production increased from 61.8 million tonnes in 2010 to about 80 million tonnes in 2016 and is projected to increase by another 36.7 per cent to about 109 million tonnes in 2030 (FAO, 2018). That the aquaculture industry can grow so rapidly is due to the availability of external supplies of nutrients in the form of feed, and if growth is to be sustained, the supply of feed must also grow more or less rapidly (Tacon et al., 2011, Turchini et al., 2019). Due to its high content of easily digestible proteins, amino acid composition, highly digestible lipids and long-chain polyunsaturated fatty acids, fishmeal is one of the most important ingredients for feed (Turchini et al., 2019, Trushenski and Rombenso, 2020). Increasing demand with a limited supply of fishmeal has caused the price of fishmeal to skyrocket over the years (Imtiaz, 2022). This has led to many studies being conducted to find ways to reduce the reliance on fishmeal in animal

feed (Shekarabi et al., 2022; Kari et al., 2021; Kari et al., 2022; Kari et al., 2020; Zulhisyam et al., 2020; Kumar et al., 2020; Liu et al., 2020).

Insect protein has been identified as a possible ingredient to partially or completely replace fishmeal as a protein source in aquafeed for omnivorous species (Riddick, 2014). Insects grow and reproduce easily, have a high feed conversion ratio as they are cold-blooded and can be raised on organic waste (Palma et al., 2019, Spranghers et al., 2017). This enables the commercial production of insect meal. A favourable insect species as an alternative protein source to fishmeal is the pre-pupae of the black soldier fly (*Hermetia illucens*), as the pre-pupae have a high protein content of about 40 to 44 per cent crude protein and several experiments conducted show that black soldier fly larvae can partially or completely replace fishmeal in fish feed (Abdel-Tawwab et al., 2020, Belghit et al., 2019, Bolton et al., 2021).

Catfish is one of the most commonly farmed finfish in the world and one of the farmed catfish species is the African catfish (*Clarias gariepinus*) (FAO, 2014). Although the production of African catfish is not very large globally, it is the most farmed fish species in Africa, Indonesia and Malaysia. In Malaysia, the African catfish having been introduced through aquaculture from Thailand between 1986 and 1989, and since 2008, it has overtaken the production of red tilapia and plays an important role in the aquaculture industry (Dauda et al., 2018). The African catfish is an opportunistic omnivore that feeds on a variety of foods, with insects being one of the most important foods, especially when it is still small (Tesfahun, 2018). There is therefore a possibility that insect meal can be included in the diet of African catfish in aquaculture, as insects are part of their natural diet. The aim of this study is to determine the effects of replacing fish meal with different ratio of hermetia meal larvae on growth performance and fatty acid profile of the fish.

MATERIALS AND METHODS

Experimental fish and husbandry conditions

The African catfish fry used in this experiment were purchased from a commercial supplier Chia Bee Aquaculture, Sungai Petani, Kedah. The fish were quarantined in a fibreglass tank for one week before being used in the experiment. They were properly treated, such as with methylene blue and salt to rule out possible diseases and transported to the Kompleks Penyelidikan Akuatik (L24) at Universiti Sains Malaysia. Two weeks prior to the experiment, the fish were acclimatised to the environmental conditions in the laboratory upon arrival. During the acclimatisation period, the fish were fed twice daily with a commercial tilapia pellet containing 35% protein and 8% lipid.

Healthy fish with an average weight of 2.45g were randomly placed in the round polyester polytank (37-inch x 24-inch) with the water level in all tanks 1/3 the height of the tank. Each feeding treatment had three replicate tanks and each tank contained 30 fish. All tanks were continuously aerated and fish were reared in carbon filtered water. The water in the rearing tank was changed daily. The light cycle of the indoor system used for this experiment was set to 12 hours. The feeding experiment lasted for 12 weeks, during which the fish were fed the formulated diets twice daily at 09:00 and 17:00 until they were full. Each diet was replicated in three tanks. Every fortnight, growth progress was monitored by weighing the fish in large quantities, depending on the tank. The fish were not fed for 24 hours before being touched to avoid stress. Food intake was measured daily. The fish were weighed individually at the last sampling to determine the final weight. During the study, temperature, pH and DO of the culture conditions were maintained at 25.84 ± 0.07 °C, 6.70 ± 0.06 and 7.2 ± 0.09 mg/L, respectively.

Experimental Design and Feed Preparation

A feeding trial was performed to assess the potential inclusion of hermetia meal in aquafeed for African catfish. Three practical diets comprising the same protein level (35%), lipid (8%), and energy were prepared. Table 1 shows the formulation and chemical analysis of the experimental diets.

Table 1: Ingredients and proximate composition of experimental diet (g/100g dry matter).

Ingredients (g/100g)	FM (Control)	1HM:2FM	1HM:1FM
Fish meal ¹	40.00	30.00	20.00
Hermetia meal ²	0.00	20.20	33.00
Soybean meal ³	18.00	18.00	18.00
Palm oil ⁴	13.50	10.34	6.95
Corn starch ⁵	20.2	18.60	12.50
Cellulose ⁶	1.50	1.36	0.95
Vitamin premix ⁷	0.50	0.50	0.50
Mineral premix ⁸	0.50	0.50	0.50
Chromium oxide ⁹	0.50	0.50	0.50
Proximate composition (g/100g)			
Moisture	7.05	6.33	6.63
Protein	34.68	34.92	34.75
Lipid	17.92	17.35	17.88
Ash	11.27	11.21	11.06
Fibre	5.87	6.37	6.63
NFE ¹⁰	20.26	17.17	19.68

¹Danish fishmeal²Hermetia meal³Soybean meal⁴Palm oil⁵Corn starch⁶Cellulose

⁷Vitamin premix (Rovimix 6288; F.Hoffman La-Roche Ltd, Basel, Switzerland), containing (per kg, dry weight): Vitamin A, 50 million IU; Vitamin D3, 10 million IU; Vitamin E, 130 g; Vitamin B1, 10 g; Vitamin B2, 25 g; Vitamin B6, 16 g; Vitamin B12, 100 mg; biotin, 500 mg; panthothenic acid, 56 g; folic acid, 8 g; niacin, 200 g; anti-cake 20 g; antioxidant, 200 mg; Vitamin K3, 10 g; and Vitamin c, 35 g

⁸Mineral premix (g/kg)-cobalt carbonate, 100mg; copper sulphate, 780 mg; magnesium sulphate, 137 g; manganese oxide, 800 mg; potassium chloride, 50 g; potassium iodide, 150 mg; sodium chloride, 60 g; sodium selenite, 200 mg and zinc oxide, 1.5 g; calcium lactate, 327 g; ferrous sulphate, 25 g; calcium phosphate (monobasic), 397.5 g.

⁹chromium oxide¹⁰Nitrogen free extract: 100 - (moisture + protein+ lipid +ash+ fibre)

Growth performance and body indices

The collected samples were analyzed to estimate the growth performances using the following formulae:

Weight gain (WG)= final weight – initial weight

Feed conversion ratio= total feed intake. weight gain⁻¹

Specific Growth Rate = (ln Wt_{final} – lnWt_{initial}). duration⁻¹

Protein efficiency ratio (PER) = weight gain.total protein intake⁻¹

Survival = final number fish/ initial number fish x 100

Hepatosomatic index (HSI %) = (liver weight.body weight⁻¹) x 100

Viscerosomatic Index (VSI %) = (viscera weight.body weight⁻¹) x 100

Proximate Analysis

AOAC methods were used to determine the moisture, protein, lipid, fibre, and ash content of raw ingredients, experimental diets, and fish (AOAC, 1997).

Tissue Collection

Fish were euthanised at the last sampling by exposing them to an overdose of clove oil in an ice-cold water bath (20 ml L⁻¹). Three fish from each tank were randomly selected to measure HSI and VSI levels on the whole body, viscera and liver.

Fatty Acid Methyl Ester Extraction and Analysis by Gas Chromatography

Fish muscle tissues were subjected to total lipid extraction and fatty acid methyl esters (FAME) were prepared by methylation and transesterification with boron trifluoride in methanol (Cuniff 1997). Tissues (0.5 g-1.0 g) were mechanically homogenised in chloroform/methanol (2:1, v/v) to obtain total lipid (Folch et al. 1957). A gas chromatograph (GC-2010, Shimadzu) equipped with a flame ionisation detector and a highly polar fused silica cyanosiloxane column (SP-2380 (30 m length, 0.25 mm inner diameter, 0.20 µm film thickness; Supelco, USA) was used to separate the FAME. The temperature was programmed to rise from 100°C to 230°C at a split ratio of 1:50 at a rate of 1.5°C/min, using nitrogen as the carrier gas. The injector and detector temperatures were set at 250°C and 260°C respectively. The individual FAME were identified by comparing the retention times with commercially available standards: 37 Component FAME Mix (Supelco) and PUFA No. 3 from Menhaden Oil (Supelco).

Statistical analysis

Statistical analysis of data on proximate composition, body indices, growth performance, digestive enzyme activities, and haematology was performed using SPSS 26 software. One-way analysis ANOVA was used as statistical analysis and a post hoc test was performed when necessary.

RESULTS

Growth Performance

An average of 2.45 ± 0.02 g of hybrid red tilapia was used for this study ($p > 0.05$), as shown in Table 2. At week 6, fish fed the 1HM: 2FM treatment (20.09 ± 0.731 g) showed no significant difference from fish fed the control diet (FM) (18.85 ± 0.70 g; $p > 0.05$). However, the fish fed 1HM:1FM had a significantly lower final weight than the other two treatments.

The weight gain of fish fed 1HM:2FM (17.74 ± 0.722 g) was not different from that of fish fed FM (16.42 ± 0.159 g; $p > 0.05$). Fish fed 1HM:1FM recorded the lowest weight gain, which was 14.25 ± 0.572 g ($p < 0.05$). A similar trend was also observed in the SGR value, where fish fed 1HM:2FM (5.02 ± 0.085) showed no significant difference compared to fish fed FM (4.86 ± 0.018 ; $p > 0.05$). The lowest FCR value was found in fish fed FM (1.29 ± 0.006) and this was not a significant difference from fish fed the diet 1HM:2FM. The 1HM:1FM diet had the highest FCR of 1.55 ± 0.021 ($p < 0.05$). The HSI, VSI and survival rate of the fish were not affected by the treatments.

Table 2 : Growth parameters and body indices of African catfish fed with formulated diets for 6 weeks. Data are presented in mean $\pm$ SEM. Different superscripts in each row indicate a significant difference ($p < 0.05$).

Parameters	FM (Control)	1HM:2FM	1HM:1FM
Initial weight (g)	2.45 ± 0.024	2.45 ± 0.025	2.44 ± 0.025
Final weight (g)	18.85 ± 0.701^B	20.09 ± 0.731^B	16.73 ± 0.623^A
Weight gain (g)	16.42 ± 0.159^B	17.74 ± 0.722^B	14.25 ± 0.572^A
Average Daily Weight Gain (g)	0.39 ± 0.006^B	0.42 ± 0.017^B	0.34 ± 0.015^A

Specific Growth Rate (SGR)		4.86 ± 0.018 ^B	5.02 ± 0.085 ^B	4.57 ± 0.081 ^A
Food Conversion Ratio (FCR)		1.29 ± 0.006 ^A	1.39 ± 0.047 ^A	1.55 ± 0.021 ^B
Feed intake (g)		21.18 ± 0.296 ^A	24.68 ± 1.213 ^B	22.10 ± 0.584 ^A
Viscerasomatic Index (VSI)		0.04 ± 0.006	0.04 ± 0.004	0.05 ± 0.007
Hepatosomatic Index (HIS)		0.01 ± 0.001	0.01 ± 0.002	0.01 ± 0.002
Survival Rates (%)		85.56 ± 5.557	74.44 ± 14.184	93.33 ± 3.848

Proximate composition

Proximate composition of fish muscle was affected by diet treatment, as shown in Table 3. Fish fed 1HM:1FM (8.64 ± 0.05%) contained the highest moisture content than fish fed FM and 1HM:2FM, 8.21 ± 0.10% and 8.00 ± 0.04%, respectively ($p < 0.05$). Muscle protein composition increased with the increase in Hermetia meal. Fish fed the diet FM contained the lowest amount of muscle protein (77.87 ± 0.05%, $p < 0.05$) and fish fed the diet 1HM:1FM contained the highest protein in muscle (86.87 ± 0.03, $p < 0.05$).

Table 3: Proximate composition of muscle of African catfish fingerlings fed with experimental diets.

Composition (%)	FM (Control)	1HM:2FM	1HM:1FM
Moisture (%)	8.21 ± 0.10 ^A	8.00 ± 0.04 ^A	8.64 ± 0.05 ^B
Protein (%)	77.87 ± 0.05 ^A	84.50 ± 0.09 ^B	86.87 ± 0.03 ^C
Lipid (%)	20.84 ± 0.43 ^A	25.07 ± 0.52 ^B	19.55 ± 0.19 ^A

Value presented are means ± SEM of three replicates group. Means value having different superscript are significantly difference ($p < 0.05$)

Fatty acid profile

Table 4 shows the fatty acid composition of the experimental feeds. The total saturated fatty acid (SFA) content increased with the increasing level of hermetia meal. FM feed contained the lowest SFA (18.62 ± 0.08), followed by 1HM:2FM (27.15 ± 0.23) ($p < 0.05$). Diet 1HM1: FM had the highest SFA content, 35.78 ± 0.12 ($p < 0.05$). In general, the profile of unsaturated fatty acids decreased with increasing intake of hermetia meal. FM diet contained the highest levels of monounsaturated fatty acids (MUFA), n-3 polyunsaturated fatty acids (n-3 PUFA) and n-6 polyunsaturated fatty acids (n-6 PUFA), namely 28.76 ± 0.23, 7.30 ± 0.07 and 45.32 ± 0.05, respectively ($p < 0.05$). The lowest MUFA, n-3 PUFA and n-6 PUFA values were in the 1HM:1FM diet with 23.42 ± 0.16, 4.92 ± 0.04 and 35.78 ± 0.07, respectively ($p < 0.05$).

Table 4: Fatty acids composition in the experimental diets. Value presented are means $\pm$ SEM of three replicates group. Means value having different superscript are significantly difference ($p < 0.05$)

Component	Diet FM (Control)	1HM:2FM	1HM:1FM
<i>Saturated fatty acids</i>			
C10:0			0.28 $\pm$ 0.00
C12:0	0.00 $\pm$ 0.00 ^a	5.75 $\pm$ 0.04 ^b	11.66 $\pm$ 0.02 ^c
C14:0	0.63 $\pm$ 0.00 ^a	2.38 $\pm$ 0.01 ^b	4.03 $\pm$ 0.03 ^c
C15:0	0.00 $\pm$ 0.00 ^a	0.14 $\pm$ 0.00 ^b	0.18 $\pm$ 0.01 ^c
C16:0	13.05 $\pm$ 0.02 ^a	14.09 $\pm$ 0.10 ^b	15.07 $\pm$ 0.03 ^c
C17:0	0.22 $\pm$ 0.01 ^{ab}	0.21 $\pm$ 0.01 ^a	0.25 $\pm$ 0.01 ^b
C18:0	4.28 $\pm$ 0.04 ^b	4.18 $\pm$ 0.05 ^b	3.99 $\pm$ 0.01 ^a
C20:0	0.32 $\pm$ 0.00	0.29 $\pm$ 0.02	0.24 $\pm$ 0.00
C22:0			
C24:0	0.12 $\pm$ 0.00	0.13 $\pm$ 0.01	0.09 $\pm$ 0.01
Total SFA	18.62 $\pm$ 0.08 ^a	27.15 $\pm$ 0.23 ^b	35.78 $\pm$ 0.12 ^c
<i>Monounsaturated fatty acids</i>			
C14:1	0.00 $\pm$ 0.00 ^a	0.17 $\pm$ 0.01 ^b	0.31 $\pm$ 0.00 ^c
C16:1	0.86 $\pm$ 0.01 ^a	1.16 $\pm$ 0.02 ^b	1.46 $\pm$ 0.05 ^c
C17:1	0.13 $\pm$ 0.01	0.10 $\pm$ 0.01	0.11 $\pm$ 0.01
C18:1n9	23.80 $\pm$ 0.10 ^c	20.77 $\pm$ 0.24 ^b	19.50 $\pm$ 0.02 ^a
C18:1n7	0.92 $\pm$ 0.04 ^b	0.58 $\pm$ 0.13 ^a	0.69 $\pm$ 0.03 ^{ab}
C20:1n9	1.33 $\pm$ 0.05 ^c	0.95 $\pm$ 0.02 ^b	0.68 $\pm$ 0.03 ^a
C22:1n9	1.48 $\pm$ 0.03 ^a	1.09 $\pm$ 0.02 ^c	0.68 $\pm$ 0.02 ^b
C24:1n9	0.24 $\pm$ 0.01 ^c	0.15 $\pm$ 0.01 ^b	0.09 $\pm$ 0.01 ^a
Total MUFA	28.76 $\pm$ 0.23 ^c	24.97 $\pm$ 0.46 ^b	23.42 $\pm$ 0.16 ^a
<i>n-3 Polyunsaturated fatty acids</i>			
C18:3n3	4.83 $\pm$ 0.01 ^a	3.89 $\pm$ 0.01 ^c	3.38 $\pm$ 0.01 ^b
C20:3n3	0.00 $\pm$ 0.00 ^a	0.28 $\pm$ 0.02 ^b	0.00 $\pm$ 0.00 ^a
C20:4n3			
C20:5n3	0.87 $\pm$ 0.02 ^c	0.73 $\pm$ 0.01 ^b	0.54 $\pm$ 0.02 ^a
C22:5n3	0.09 $\pm$ 0.01	0.08 $\pm$ 0.01	0.06 $\pm$ 0.01
C22:6n3	1.51 $\pm$ 0.04 ^c	1.28 $\pm$ 0.03 ^b	0.93 $\pm$ 0.01 ^a
Total n-3 PUFA	7.30 $\pm$ 0.07 ^c	5.98 $\pm$ 0.06 ^b	4.92 $\pm$ 0.04 ^a
<i>n-6 Polyunsaturated fatty acids</i>			
C18:2n6	45.32 $\pm$ 0.05 ^c	41.51 $\pm$ 0.14 ^b	35.73 $\pm$ 0.07 ^a
C20:3n6			
C20:4n6	0.00 $\pm$ 0.00	0.07 $\pm$ 0.01	0.05 $\pm$ 0.00
Total n-6 PUFA	45.32 $\pm$ 0.05 ^c	41.58 $\pm$ 0.15 ^b	35.78 $\pm$ 0.07 ^a
Total PUFA	52.62 $\pm$ 0.12 ^c	47.56 $\pm$ 0.20 ^b	40.69 $\pm$ 0.12 ^a

The fatty acid composition in the muscle of the experimental fish reflect the profile of diets and presented in Table 5. Overall, the level of SFA in the muscle was increased with the inclusion level of dietary hermetia meal. The lowest level of muscular SFA was in the fish fed with FM diet that was 20.82 ± 0.35 and the highest level was detected in fish fed with 1HM:1FM diet that was 34.11 ± 0.27 ($p < 0.05$). Similar to dietary fatty acid profile, unsaturated fatty acid in the muscle also reduced with an increase of dietary hermetia meal. The highest level of MUFA, n-3 PUFA and n-6 PUFA were in fish fed fish FM diet that are 29.60 ± 1.64 , 8.60 ± 0.16 and 40.60 ± 0.67 , respectively ($p < 0.05$)

Table 5: Fatty acids composition in the muscle of fish fed with the experimental diets. Value presented are means $\pm$ SEM of three replicates group. Means value having different superscript are significantly difference ($p < 0.05$)

Component	Muscle FM (Control)	1HM:2FM	1HM:1FM
<i>Saturated fatty acids</i>			
C10:0	-	-	-
C12:0	0.00 $\pm$ 0.00 ^a	3.90 $\pm$ 0.04 ^b	7.61 $\pm$ 0.04 ^c
C14:0	0.59 $\pm$ 0.01 ^a	2.28 $\pm$ 0.03 ^b	3.93 $\pm$ 0.02 ^c
C15:0	0.00 $\pm$ 0.00 ^a	0.17 $\pm$ 0.01 ^b	0.24 $\pm$ 0.04 ^b
C16:0	14.21 $\pm$ 0.22 ^a	16.19 $\pm$ 0.12 ^b	16.20 $\pm$ 0.02 ^b
C17:0	0.24 $\pm$ 0.02	0.26 $\pm$ 0.01	0.29 $\pm$ 0.01
C18:0	4.86 $\pm$ 0.07 ^b	5.08 $\pm$ 0.04 ^b	4.51 $\pm$ 0.11 ^a
C20:0	0.22 $\pm$ 0.00	0.19 $\pm$ 0.02	0.17 $\pm$ 0.02
C22:0	0.71 $\pm$ 0.03	0.83 $\pm$ 0.03	1.17 $\pm$ 0.02
C24:0	-	-	-
Total SFA	20.82 $\pm$ 0.35 ^a	28.91 $\pm$ 0.30 ^b	34.11 $\pm$ 0.27 ^c
<i>Monounsaturated fatty acids</i>			
C14:1	0.11 $\pm$ 0.01 ^a	0.16 $\pm$ 0.01 ^b	0.27 $\pm$ 0.01 ^c
C16:1	0.94 $\pm$ 0.03 ^a	1.39 $\pm$ 0.01 ^b	1.67 $\pm$ 0.04 ^c
C17:1	0.13 $\pm$ 0.08	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
C18:1n9	24.71 $\pm$ 1.27 ^b	21.19 $\pm$ 0.17 ^a	20.27 $\pm$ 0.12 ^a
C18:1n7	1.39 $\pm$ 0.16	0.96 $\pm$ 0.08	1.11 $\pm$ 0.08
C20:1n9	1.19 $\pm$ 0.05 ^c	0.94 $\pm$ 0.05 ^b	0.73 $\pm$ 0.01 ^a
C22:1n9	0.96 $\pm$ 0.03 ^b	0.07 $\pm$ 0.02 ^a	0.00 $\pm$ 0.00 ^a
C24:1n9	0.18 $\pm$ 0.01 ^b	0.17 $\pm$ 0.02 ^b	0.11 $\pm$ 0.00 ^a
Total MUFA	29.60 $\pm$ 1.64 ^b	24.88 $\pm$ 0.36 ^a	24.16 $\pm$ 0.27 ^a
<i>n-3 Polyunsaturated fatty acids</i>			
C18:3n3	3.96 $\pm$ 0.03 ^c	3.22 $\pm$ 0.01 ^b	2.64 $\pm$ 0.04 ^a
C20:3n3	-	-	-
C20:4n3	0.18 $\pm$ 0.01 ^a	0.16 $\pm$ 0.01 ^b	0.13 $\pm$ 0.01 ^b
C20:5n3	0.70 $\pm$ 0.03 ^c	0.50 $\pm$ 0.01 ^b	0.38 $\pm$ 0.00 ^a
C22:5n3	0.32 $\pm$ 0.01	0.27 $\pm$ 0.01	0.29 $\pm$ 0.01
C22:6n3	3.43 $\pm$ 0.07 ^a	2.68 $\pm$ 0.04 ^b	2.83 $\pm$ 0.03 ^b
Total n-3 PUFA	8.60 $\pm$ 0.16 ^c	6.84 $\pm$ 0.08 ^b	6.28 $\pm$ 0.09 ^a
<i>n-6 Polyunsaturated fatty acids</i>			
C18:2n6	39.88 $\pm$ 0.57 ^c	37.99 $\pm$ 0.17 ^b	33.67 $\pm$ 0.18 ^a
C18:3n6	0.39 $\pm$ 0.02 ^a	0.51 $\pm$ 0.03 ^b	0.88 $\pm$ 0.01 ^c
C20:3n6	0.33 $\pm$ 0.08 ^a	0.41 $\pm$ 0.05 ^a	0.43 $\pm$ 0.05 ^b
Total n-6 PUFA	40.60 $\pm$ 0.67 ^c	38.90 $\pm$ 0.25 ^b	34.98 $\pm$ 0.24 ^a
Total PUFA	49.20 $\pm$ 0.83 ^c	45.75 $\pm$ 0.34 ^b	41.26 $\pm$ 0.33 ^a

DISCUSSION

The partially replacement of fishmeal using hermetia meal was aimed to assess the potential of direct use of hermetia meal and to reduce the use of fishmeal dependent in aquafeed. Indeed many studies have been done to reduce fishmeal inclusion in aquafeed. In this study, African catfish fingerling can tolerate up to 25% of hermetia meal in the diet (1HM:2FM) to reduce the usage of fishmeal protein without compromising the growth performance of the fish. In this study, hermetia meal used was not undergo lipid removal and the chitin residue may exist naturally in the feed. Shiau & Yu, (1999) reported that hermetia meal contains 20 to 100.0 g kg⁻¹, dry matter amount of chitin in which could interfere with

digestibility and nutrient absorption. Study conducted by Kroeckel et al., (2012) supports this reporting that the presence of chitin may have decreased feed intake and thus decreased growth efficiency.

Li et al., (2017) stated that up to 100% fishmeal can be substituted for defatted hermetia meal in diets for Jian carp with no adverse effect on performance growth. However, in grass carp, 50% dietary inclusion is the most highest level can be tolerate by the fish without adverse effect (Lu et al., 2020). Another study also found that dietary replacement fishmeal with hermetia meal did not result in the growth performance difference in Atlantic salmon. Defatting hermetia larvae would lead to meals with higher protein values, than those commonly found in soybean meals (Veldkamp and Bosch, 2015). According to Tschimer & Simon (2015), these varied findings may be attributed to variation in insect species, insect substrates and insect processing, fish size and fish species.

Based on this experiment, at the end of the feeding trial, weight gain and specific growth rate (SGR) was higher in fish feed with 25% hermetia meal (1HM:2FM) replacement compared to other diets. Supplying more than 25% of hermetia meal in the diet reduced the growth of African catfish and in this study the lowest weight gain displayed by fish fed with 50% replacement. Although the growth of African catfish fed with 50% hermetia meal (1HM:1FM) was the lowest compared to other diets, there were no signs of nutritional shortage or higher mortality. A similar observation was also reported in rainbow trout where 50% hermetia meal was considered as an inclusion but feeding the fish with 75% of hermetia meal did not cause negative impact on the fish weight gain (Stamer et al., 2014). In addition to that, protein content in muscle increased in fish fed hermetia meal compared to controls. Although it is assumed that an increase in muscle protein is associated with an increase in dietary protein content (Ng et al., 2001), there has been no report of muscle protein content being altered by different protein sources. In contrast to protein, lipid content was higher in fish fed 25% BSFL, which could be because the amount of food ingested was higher than in fish fed other diets. The amount of food ingested was associated with the muscle lipid content of the fish (Noeske-Hallin et al., 1985).

The fatty acid content of the fish appears to reflect the fatty acid profile of the diet, with fish fed fishmeal having a higher content of LC-PUFA, which decreased with increasing intake of hermetia meal. A similar observation was also note in Atlantic salmon when dietary hermetia meal has been increased (Bruni et al., 2020). Hermetia meal contains a high proportion of saturated fatty acids (Ewald et al., 2020), possibly due to the larval food source, palm kernel cake (PKC). The hermetia meal used in this study was commercially produced and the pupae were fed PKC. This is a common practise because hermetia larvae are also a bioconverter that converts waste into higher value products. Malaysia is one of the world's palm oil producers and using PKC to make hermetia meal is one of the ways to contribute to sustainability. In the case of African catfish, the change in fatty acid profile due to the hermetia meal is not critical to the market value as the fish is consumed as an affordable source of protein and not for its fatty acid content like marine fish.

CONCLUSION

African catfish can tolerate a higher admixture of fishmeal in the diet. This reduces the use of fishmeal as the main protein source. The change in the fatty acid profile in the fish with increasing admixture of hermetia meal reflects the feed offered and should not cause negative affect the quality of the fish and its value.

Patents

Not applicable.

Author Contribution

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, N.K.A.H, Z.A.K; methodology, N.A.M.A., L.K.C., A.J.R; software, N.A.M.A.; validation, N.K.A.H., A.J.R. and.; formal analysis, N.K.A.H., A.J.R., N.A.M.A., L.K.C; investigation, N.A.M.A., L.K.C.; resources, N.K.A.H., H.A.H; data curation, N.A.M.A., A.J.R., N.K.A.H ; writing—original draft preparation, NKAH.; writing—review and editing,

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