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Effects of blood meal as a substitute for fish meal in the culture of juvenile Silver Pompano *Trachinotus blochii* (Lacepède, 1801) in a circulating aquaculture system

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Abstract

A feeding trial was conducted for 12 weeks to evaluate the nutritive value of fermented and un-fermented blood meal as a possible protein source for diets of juvenile silver pompano, *Trachinotus blochii*. The experiments were carried out concurrently in a completely randomized design. A total of 330 fish (10.98 ±0. 5g and 12. 52±0. 01 cm) were stocked in 33 tanks (1000 L) for 8 weeks and fed one of the experimental diets at 10% body weight per day in 3 equal feedings. Eleven isonitrogenous experimental diets (45% crude protein and 12% crude lipid) were prepared by replacing fish meal levels from 5, 15, 25, 35 and 45% with) fermented and unfermented blood meal, and a 100% fish meal based diet was used as a control diet. Fish fed a 35% experimental diet of fermented blood meal and unfermented blood meal exhibited significantly higher growth performance compared to fish fed the control diet of 100% fish meal and 5, 15, 25 and 45% experimental diets replaced with both fermented and unfermented blood meal (weight gain 88.06 – 67.33 g; FCR 1.14 - 1.65; SGR 3.2 - 3.11; and PER 1.94 -1.34) respectively. The overall performance was significant higher in fermented diets (88.06 g at 35%) than unfermented diets (67.33 g). The levels of lipid and ash in the whole body carcass increased as both fermented and un-fermented blood meal substitution in diets increased, whereas protein and moisture decreased in all treatment groups compared with the control. These results showed that approximately 35% of fish meal protein could be replaced by both fermented and unfermented blood meal for juvenile silver pompano without compromising growth performance and feed efficiency, potentially leading to significant cost saving.

Keywords: *Trachinotus blochii*, alternative diets, fermented blood meal, marine fish culture

Introduction

Aquaculture has been the fastest growing food sector over the past two decades worldwide (Mimako *et al.*, 2015). This rapid growth has led to increased demand for key raw materials used in aquaculture feeds such as fish meal and fish oil (Thilsted *et al.*, 2016). Fish meal diets reflect natural diets of fish as they contain a balance of all essential amino acids, minerals, phospholipids and fatty acids (Hardy, 2010; Lund *et al.*, 2012). In 2007 aquaculture industries consumed 87% of global fish oil production. Continued expansion of aquaculture production reflects the global population increase which has resulted in an increased demand for fish protein (FAO, 2010). Global fisheries production has not matched demand for both human consumptions and the aquaculture industry (Hardy, 2010). This situation has led to unaffordable prices of fish meal and fish oil and forced the aquaculture sector to look for alternative ingredients from a wide range of sources, including plant and animal by- products

(Hardy, 2010; Tacon *et al.,* 2011; Lech & Reigh, 2012; Sugumaran & Radhakrishnan, 2015).

Fish meal-based diets are characterized by high digestibility and palatability with adequate amounts of micronutrients, thus identification of ideal replacements is not straightforward (Kaushik & Seiliez, 2010; Lund *et al.,* 2012). For example, the essential omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are basic nutrients required in the diets of farmed larvae and broodstock, are produced by marine plankton and cannot be synthesized by fish. These fatty acids can only be obtained by utilizing fish oil (Baron *et al.,* 2013).

Slaughterhouse wastes, including blood, are potential protein sources that can be utilized to replace fish meal in aquaculture diets (Tacon *et al.,* 2011). Sub-Saharan Africa, including the WIO region, possesses large amounts of livestock such as cattle, sheep and goats, and thousands are slaughtered annually (FAO, 2000). Blood produced in the slaughterhouses is usually deposited in stabilization lagoons or directly discarded into the environment. From an environmental viewpoint it is desirable that the blood from the slaughterhouse is re-used. Drying it to produce blood meal for use as an aquaculture feed ingredient is one option for re-use (FAO, 2000). In aquafeed industries blood meal has received much attention due to a high quality protein content, as a good source of lysine and histidine, a high digestibility of 80-99 %, and the presence of haem-iron together with other forms of iron which may promote oxidation of feed components (Bureau *et al.,* 1999; El-Haroun & Bureau, 2007; Millamena, 2002). Processing affects the blood meal in terms of nutritive quality and digestibility. The spray dried process has been reported to result in a product with excellent protein digestibility (~99%) whereas other drying processes may reduce digestibility to ~80% in rainbow trout (Bureau *et al.,* 1999). On the other hand, fermentation processes have been reported to improve the nutritive quality, digestibility and potability of various feed ingredients in aquaculture diets (Wee, 1999).

Previous research has shown that blood meal can be incorporated up to a level of 6% to 10 % in diets of the grouper, *Epinephelus coioides* (Martins & Guzman, 1994), tambaqui, *Colossoma macropomum* (Martínez-Llorens *et al.,* 2008), and gilthead sea bream, *Sparus aurata* (Ribeiro *et al.,* 2011), and 20% in diets of juvenile trout, *Oncorhynchus mykiss* (Luzier *et al.,* 1995). Moreover, Agbebi *et al.* (2009) reported that fish meal can be replaced completely (100%) by blood meal with no adverse effect on growth, survival and feed conversion in cat fish, *Clarias gariepinus*, juveniles. However, the level of fishmeal replacement was species-specific and varied according to fish size and feeding habits (Barnes *et al.,* 2012; Dedeke *et al.,* 2013). Little is known about the effect of fermented and unfermented blood meal on replacement of fish meal in silver pompano diets. The current study aims to evaluate the effects of different levels of fish meal replacement with fermented and unfermented blood meals on growth performance of juvenile silver pompano. Furthermore, the study examines the influence of different inclusion levels of processed and un-processed blood in the silver pompano carcass composition. Lastly the study evaluates the economic benefit of utilization of blood meal as an alternative source of protein for fish meal replacement in the aquaculture diet of silver pompano.

Methodology

Fish sampling and experimental setup

Juvenile silver pompano were obtained from Nungwi Beach located at the northern tip of Unguja Island, Zanzibar (5.72°S and 39.30°E). Fingerlings were collected using beach seine nets and placed in small net cages within Nungwi Aquarium before being loaded into 100 l tanks equipped with a supplemental oxygen supply system. The collected fingerlings were transported in the early morning and the open tops of the plastic tanks were covered with plastic material to avoid exposure to direct sun light. The tanks were filled with water to 50% of their volume and water exchange was carried out every 30 minutes while the fingerlings were transported by boat to the Institute of Marine Sciences Mariculture Center (IMS-MC) at Pangani, Tanga. Subsequently, ten fingerlings were stocked randomly into each of 1m^3 concrete tanks directly connected to a flow through seawater system and supplemental aeration was provided by a regenerative air blower and air diffusers. The juvenile silver pompano were acclimated to the facilities for two weeks at the experimental site and fed with a commercial fish meal diet to apparent satiation. Fish were cultured under conditions presumed optimal for silver pompano growth (see water quality information below) and fed artificial feed (crude protein = 50% minimum; crude fat = 10% minimum; crude fiber = 3% maximum; crude ash = 6% maximum; average pellet size = 1.mm).

Diet formulation

Fishmeal – control diet (FM)

The fish meal described here was derived from the Indian anchovy (*Stolephorus commersonnii*), a small schooling fish which is found in most tropical areas of the Indian Ocean. In Tanzania anchovy fisheries are artisanal and subsistence and are conducted by women and men in coastal waters. The anchovy were sun dried for 1-2 days, milled and incorporated into feed formulations.

Blood Meal – Fermented (FBML) and Unfermented (BML)

Fresh cow blood was collected from slaughter houses in 10 L buckets. Unwanted materials were removed before sun-drying for 5 days. For blood fermentation, 10% of fermented milk was added before sun drying and thoroughly mixed to facilitate the fermentation process. The mixture was then incubated for 14 days at room temperature, and stirred twice daily. After 14 days the fermented blood meal was sun-dried for 5 days. Both fermented and unfermented blood were ground to powder form using a hammer mill and subjected to proximate analysis. Eleven isonitrogenous (50g $100g^{-1}$), isolipidic (10g $100g^{-1}$), and isoenergetic (19kj) experimental diets were formulated. A diet with fish meal (FM) as the main protein source was used as the control diet (FM). The experimental diets were formulated to produce diets in which 5 (FBML/BML 5), 15 (FBML/BML 15), 25 (FBML/BML 25), 35 (FBML/BML 35) and 45 (FBML/BML 45) % of FM protein was replaced by that of FBML or BML protein. Fish oil, sunflower oil, and vitamins were used at a 1:1 ratio (Table 1). The dietary ingredients were mixed in a food blender with warm water until a soft slightly moist consistency was achieved. This was then cold-press-meat mixer extruded to produce a 1mm pellet. The moist pellets were then sun-dried and stored frozen at -20°C until use.

Feeding Regime

Fish were hand fed 10% of body weight three times per day with ten experimental diets of fermented blood meal, unfermented blood meal, and a control diet. The diets were offered in equal portions at 09:00, 13:00 and 17.00 hours during the twelve weeks of the experiment. Each feeding treatment was randomly assigned to three replicate tanks (n = 3). The ration was adjusted every two weeks according to fish weight with care being taken to avoid feed wastage.

Environmental parameters

Water quality parameters such as dissolved oxygen, salinity, temperature and pH were measured twice daily through the whole period of the experiment at 09:00 and 16:00 with a WTW multi-parameter probe. Water samples for analysis of ammonium ions were collected twice a week in 250 ml plastic bottles and stored frozen at -20°C at IMS-MC for the whole period of rearing of fingerlings. The samples were then transported in an ice box to the IMS in Zanzibar for analysis. The concentration of ammonia in the water samples was determined as in the UNESCO (1993) protocol. Throughout the experiment, photoperiod was kept at a 12 h light: 12 h dark cycle, and tank inflow rates were maintained at 0.5 L/min.

Growth and feed utilization

The initial body weight (IBW), final body weight (FBW), total weight gain (TWG), specific growth rate (SGR - %/day), feed conversion ratio (FCR), protein efficiency ratio (PER), and survival rate (SR%) were

Table 1. Ingredient requirement to formulate blood meal diets for *T. blochii* (100 g).

Parameters	T1-%0	T2-5%	T3-15%	T4-25%	T5-35%	T6-45%
Fish Meal	51	66	55	41	30	20
Blood Meal	0	5	15	25	35	45
Maize	38	19	20	22	25	25
Herrings Oil	5	3	3	5	3	3
Binder	3	3	3	3	3	3
Premix	3	3	3	3	3	3
Total	100	100	100	100	100	100

Premix contains: Vitamin A, D3, E, K, Thiamine B1, Riboflavin B2 Pyridoxine B6, Vitamin B12 Niacin, Pantothenic acid, Folic acid, Biotin, Choline chloride, Antioxidant, Zinc, Iodide, Iron, Cobalt, Selenium determined according to the methods of De Silva & Anderson (1995). The percentage survival rates were calculated based on Jobling (1996).

Economic Evaluation

The economic evaluation of fermented and unfermented blood meals as alternative protein sources in silver pompano feed was calculated based on the following formulae:

Economic efficiency ratio (ECR) = feed offered (kg) × price index/weight gain (kg)

Percentage Relative Economic efficiency ratio (ECR) = feed offered (kg) × price index/weight gain (kg) x 100

Economic profit index (EPI) = final weight (kg fish-^{1}) × fish sale price (USD kg^{-1}) -
ECR x weight gain (kg)

Pompano sale price was considered as 4.0 USD kg^{-1}.

Price index /weight is the average price per kg

Condition factor (K)

The coefficient of condition was calculated as

Whereby W = Weight of individual fish (g), L = Total length of individual fish, K = condition factor.

Length weight relationship was calculated as $W = a L^b$

Length weight data was transformed into common logarithm as log W = log a + b. log L

Where by W = Weight of fish in gram (g)

L = Total length of fish in centimeters (cm)
a = proportionality constant
b = the value obtained from the length - weight equation/coefficient of regression.

In this analysis only three treatments of (FBML 35, BML 35 and FM control) were selected based on growth performance observed during the 12 weeks feeding trial.

Proximate analysis of fish and experiment diets

The proximate compositions of pompano fish before and after the experiment together with feed ingredients were analyzed at the Department of Animal Science and Production of Sokoine University of Agriculture (SUA) in Morogoro, Tanzania. Crude protein, crude lipid, moisture, and ash contents were analyzed for composition. Analyses were performed according to standard methods (AOAC, 1995). Moisture content was determined by drying samples in an oven at 105°C to constant weight. Crude lipid was determined using a Soxhlet extractor with petroleum ether (40-60°C boiling range). Crude protein was determined by the Kjeldahl method using digestion block and steam distillation, and ash was determined by incineration of the feed sample in a muffle furnace at 550°C to constant weight.

Statistical analysis

A completely randomised design (CRD) was used in assigning dietary treatments to culture units. The main statistical hypothesis tested was that there is no significant difference between treatment means (percentage levels of fermented and unfermented blood meals inclusion, and control diets). Two-way analysis of variance (ANOVA) was used to determine differences between treatment means which were deemed significant at $P<0.05$. Post-hoc analysis was carried out where significant differences existed between treatment means using Tukey's Honest Significant Difference Test. Analyses were performed using SPSS software version 21 (SPSS Inc). Before analysis, data were tested for normality using the Kolmogorov–Smirnov test, and for homogeneity of variance using Levene's test, and transformed in case of non–conformity.

Results

The overall mean water quality parameters (temperature = 29.65 ± 0.06°C; salinity = 34.1 ± 0.03 g/L; DO = 6.85 ± 0.12 mg/L; total ammonia nitrogen = 0.35 ± 0.017 mg/L; nitrite-nitrogen = 0.43 ± 0.12 mg/L; and pH = 8.27 ± 0.24), were observed for all treatments. The values of DO were significantly decreased with increased levels of blood meal inclusion. The lowest value of 4.83 ± 0.20 and5.07± 0.10were observed at BML 45% and FBML45% respectively, while levels of pH and ammonia increased with an increase of both FBML and BML replacement levels in all treatments. These were however within acceptable ranges for pompano production.

The effects of dietary treatments can be seen in Table 2 and 3 which displays the weight gain over the twelve week study. Fish grew from an average mean initial weight of 10.98 ±0.63g to a final weight of 52.63±0.74 g for fish fed the fishmeal control diet (FM), 78.71±2.10 g for fish fed FBML diets, and 57.27±1.12 g for fish fed

Table 2. Weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio and survival of juvenile *T. blochii* fed the experimental diets (FBML) for 12 weeks.

Fermented feed levels						
Parameters	**0**	**5%**	**15%**	**25%**	**35%**	**45%**
IBW (g)	10.20±0.3[a]	10.6±0.43[a]	9.90±0.56[a]	11.21±2.01[ab]	10.26±0.15[a]	11.09±0.17[ab]
FBW (g)	52.63±0.74[a]	76.3±7.15[b]	83.96±4.1[c]	82.56±5.6[c]	88.06±4.92[d]	62.70±4.32[e]
TWG (g)	42.43±0.44[a]	65.70±6.72[b]	74.06±3.54[c]	71.35±3.59[c]	77.80±4.77[d]	51.61±4.15[e]
SGR (% day^{-1})	3.03±0.02[a]	3.29±0.07[a]	3.25±0.03[a]	3.22±0.21[a]	3.27±0.12[a]	2.99±0.1[a]
FCR	1.67±0.004a	1.62±0.01[a]	1.46±0.004[b]	1.47±0.03[bc]	1.14±0.01[d]	1.17±0.01[e]
PER	1.32±0.003[a]	1.36±0.009[a]	1.51±0.004[b]	1.50±0.03[b]	1.94±0.02[bc]	1.89±0.02[bc]
SR (%)	96[a]	97[a]	99[a]	99[a]	97[a]	96[a]

[a, b, c] Treatment means within the same row with different superscript letters are significantly different (P < 0.05)

BML diets. The average Specific Growth Rate (SGR%) was directly proportional to increased blood meal inclusion levels for both fermented and unfermented diets to 35% levels, and dramatically decreased at 45% inclusion. The lowest value was observed at 45% diets (2.99±0.1 for fermented, and 2.80±0.14 for unfermented diets), and the highest value was recorded at 35% blood meal inclusion levels (3.27±0.12 and 3.11±0.04), for fermented and unfermented diets respectively. The feed conversion ratio (FCR) from fermented diets increased with a decrease in fish meal levels and the highest value recorded was at 35% blood meal inclusion (1.14±0.01) and poor performance was observed at 45%, with a value below control diets (1.17±0.01). The unfermented diets indicate the poor FCR value at all levels compared to the control diets (Tables 2 and 3).

The actual feed consumption was similar in all groups; none of the feeds was specifically preferred or ignored, with consequent similar protein efficiency ratios between experimental treatments (BML), while for FBML the protein efficiency increased with increased levels. The average cumulative mortality during the experiment was less than 5% for both fermented and unfermented blood meals diets (Table 2 and 3). The growth performance of *T. blochii* showed negative allometric growth in all three of the selected treatments (FBML 35, BML 35 and FM control), with the coefficient of regression "b" values ranging from 2.1 to 2.23 (Figs 1, 2 and 3).The determination coefficients (R^2) ranged from 0.88-0.85. The regression analyses showed strong correlation between fish weights and lengths at all stocking densities. Also, the correlation analyses were significant ($r = 0.96$, $p< 0.01$) and the two

Table 3. Weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio and survival of juvenile *T. blochii* fed the experimental diets (BML) for 12 weeks.

Un-Fermented feed levels						
Parameters	**0**	**5**	**15**	**25**	**35**	**45**
IBW (g)	10.20±0.3[a]	10.56±0.94[ab]	11.90±0.37[bc]	12.30±2.47[c]	12.33±0.84[c]	10.33±0.33[a]
FBW (g)	52.63±0.74[ab]	55.60±4.90[b]	58.30±1.18[b]	59.50±2.99[b]	67.33±2.74[c]	45.66±4.66[a]
TWG (g)	42.43±0.44[ab]	45.04±3.96[b]	46.40±0.81[b]	47.20±0.52[b]	55.00±1.90[c]	35.33±4.33[a]
SGR (%)	3.03±0.02[a]	3.06±0.10[a]	2.95±0.06[a]	2.99±0.23[a]	3.11±0.14[a]	2.80±0.14[a]
FCR	1.67±0.004[a]	1.66±0.01[a]	1.68±0.013[a]	1.68±0.05[a]	1.65±0.02[a]	1.72±0.03[a]
PER	1.32±0.003[a]	1.33±0.01[a]	1.31±0.01[a]	1.31±0.03[a]	1.34±0.02[a]	1.29±0.02[a]
SR (%)	96[a]	98.6[a]	96[a]	98[a]	96[a]	97[a]

[a, b, c] Treatment means within the same row with different superscript letters are significantly different (P < 0.05)

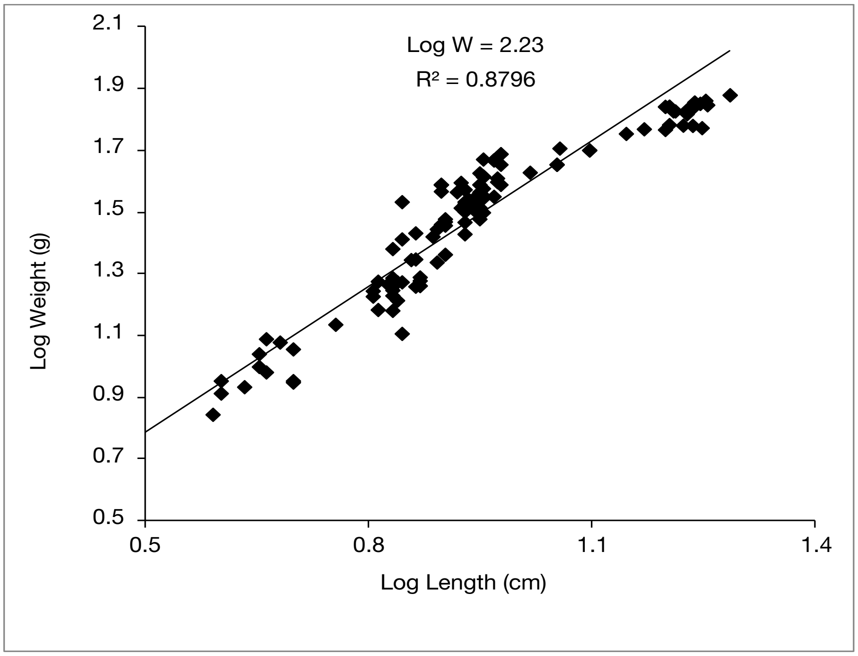

Figure1. Length–weight relationship of *T.blochii* fed FBML 35% for the 12 week feeding trail.

way analysis of variances indicated that there were no significant differences in length-weight performances between the three selected diets of FBML 35, BML 35 and FM control (p< 0.057). The growth condition factor (K) value showed marginally similar conditions (1.25, 1.32 and 1.44) from FBML 35, BML 35, and FM control, respectively. The "K" values did not differ significantly among salinity treatments.

The proximate chemical composition of whole-body analyses showed significant differences (Table 4). Moisture, crude protein, crude lipid and ash content of fish fed FM as a control diet were significantly differently compared with the experimental diets (FBML/BML), respectively. The amount of moisture and crude protein show a negative correlation with increased replacement levels of both FBML and BML, while ash and crude lipid contents significantly increased with increased blood meal substitute levels. The highest ash content was recorded in the FBML diet (3.17 ± 0.01) while the highest crude lipid was observed in fish feed BML diets (13.01 ± 0.01). Proximate composition of all experimental diets was very similar, with protein ranging from 45% to 49%, and total lipid values between 11.62% and 12.30%.

The results of the economic evaluation indicated that the incorporation of fermented and unfermented blood meal at appropriate levels as a substitute to fish meal decreased feed costs, leading to a better economic conversion ratio. Costs of 1 kg gain in weight were reduced by 18.2% and 11.6% compared to 3.3% for the control diet. Economical profit index (EPI) revealed that FBML and BML diets presented best economic viability, considering both fish sale price and cost of diets, although no significant differences were found between the treatments.

Discussion

The results from the present study indicate that replacement of fish meal with fermented and unfermented blood is possible. The findings demonstrate that replacement of up to 35% fish meal protein with processed and unprocessed blood meal allowed growth rates similar to, or better than, those exhibited by the control group. The juvenile pompano readily accepted the diets at all levels of fish meal replacement by fermented and unfermented blood meals, as shown by the high feed conversion ratios, specific growth rate, and protein efficient ratios (Tables 2, 3). Similar results were reported for other species including juvenile red snapper *Lutjanus argentimaculatus*, where fish protein was replaced with blood meal up to 23% without negative effects on growth performance (Lee *et al.*, 2001), and 40-50% fish meal replacement levels were reported in the diet of seabream, S*parus aurata* (Davies *et al.*, 1991). In addition, 75-100% fish meal replacement with blood meal was reported to be successful in juvenile grouper, *Epinephelus coioides*, and rainbow trout, *Oncorhynchus mykiss* (Millamena, 2002; Lu *et al.*, 2015). Despite the successful fishmeal replacement by blood meal in various aquaculture diets, some species such

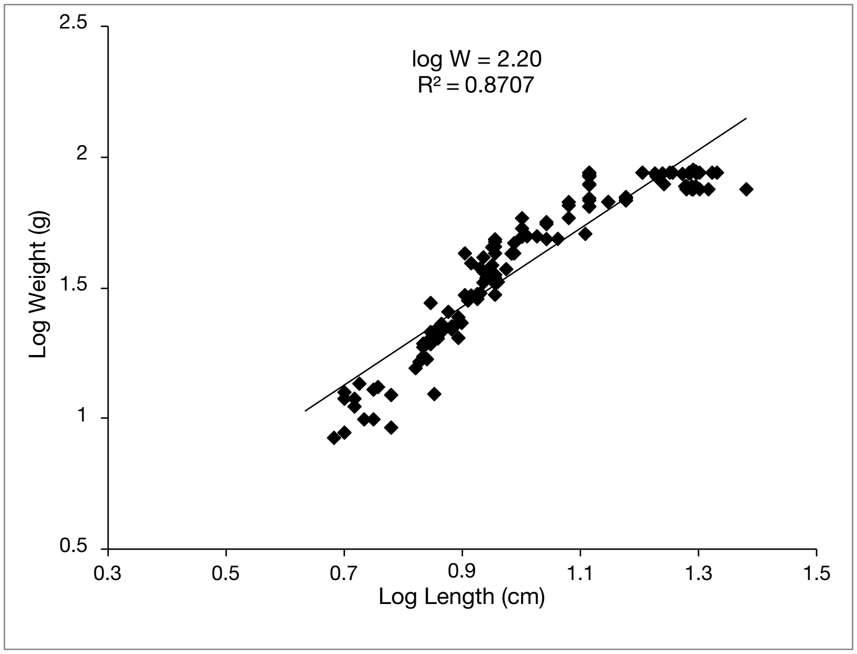

Figure 2. Length–weight relationship of *T.blochii* fee BML 35% for the 12 week feeding trail.

as the Murray cod, *Maccullochella peelii peelii*, and rainbow trout, express negative growth responses with high mortalities when fed diets with increased blood meals inclusion levels (Abery *et al.*, 2002; Bahrevar & Faghani, 2015). In the present study fish survival was not affected by increasing blood meal inclusion levels. These results concur with findings reported by Millamena (2002), Ribeiro *et al.* (2011), and Bahrevar & Faghani (2015). The overall growth performances indicate that fish fed fermented blood meal as a substitute for fish meal attained higher weight gain than un-fermented and control diets. The differences may be related to the processing levels of the blood meal used (Barnes *et al.*, 2012; Dedeke *et al.*, 2013). The reduced weight gain, lower daily growth rates and feed conversion ratio observed in fish fed more than 45% blood meal inclusion levels was possibly related to deficiencies in essential nutrients as well as low palatability and digestibility of blood meal diets (Ribeiro *et al.*, 2011; Burr *et al.*, 2012; Siddika *et al.*, 2012; Bahrevar & Faghani, 2015).

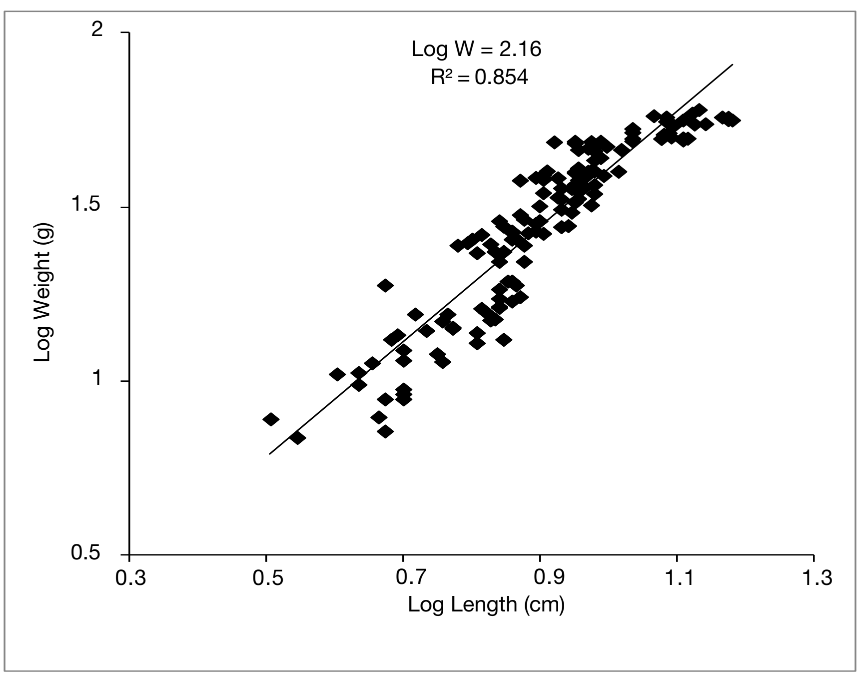

Figure 3. Length–weight relationship of *T.blochii* fed FML for the 12 week feeding trail.

Table 4. Carcass proximate composition of *T. blochii* in the 12-week feeding trial. Fermented feed levels.

Ingredients %	0	5	15	25	35	45
Moisture	69.32± 0.01^{b}	69.01± 0.02^{b}	68.09± 0.01^{b}	67.83± 0.11^{bc}	67.51 ± 0.01^{bc}	65.01± 0.01^{a}
Crude Protein	17.45 ± 0.01^{c}	17.12 ± 0.02^{c}	16.91 ± 0.11^{c}	16.71 ± 0.03^{c}	16.20 ± 0.21^{b}	15.08 ± 0.01^{a}
Crude Lipid	11.9 ± 0.03^{a}	12.02 ± 0.02^{ab}	11.89 ± 0.01^{a}	12.43 ± 0.01^{ab}	12.51 ± 0.03^{bc}	13.01 ± 0.02^{c}
Ash	2.45 ± 0.01^{a}	2.73 ± 0.01^{ab}	2.98 ± 0.02^{ab}	3.06 ± 0.01^{b}	3.17 ± 0.01^{b}	3.69 ± 0.01^{c}

$^{a, b, c}$ Treatment means within the same row with different superscript letters are significantly different ($P < 0.05$)

Table 5. Carcass proximate composition of *T. blochii* in the 12-week feeding trial. Unfermented feed levels.

Ingredients %	0	5	15	25	35	45
Moisture	69.32± 0.01^{c}	69.41± 0.03^{c}	69.12± 0.02^{c}	68.74± 0.01^{bc}	67.51 ± 0.01^{ab}	67.00± 0.01^{a}
Crude Protein	17.45 ± 0.01^{c}	17.50 ± 0.01^{c}	17.39 ± 0.21^{c}	16.52 ± 0.01^{bc}	16.20 ± 0.21^{ab}	15.72 ± 0.02^{a}
Crude Lipid	11.9 ± 0.03^{a}	11.92 ± 0.01^{a}	12.64 ± 0.01^{ab}	12.49 ± 0.02^{ab}	12.51 ± 0.03^{ab}	13.61 ± 0.01^{b}
Ash	2.45 ± 0.01^{a}	2.97 ± 0.01^{b}	3.11 ± 0.02^{bc}	3.16 ± 0.02^{bc}	3.17 ± 0.03^{bc}	3.91 ± 0.01^{c}

Fish length–weight relationship assessment between three selected replacements levels of FBML 35%, BML 35% and FM control diets revealed that in all treatmenst growth performance was negative allomentric with *b* values of 2.23, 2.20 and 2.16, respectively. The present findings concur with previous observation on pompano species including the oval pompano (*Trachinotus ovatus*) with *b*–values ranging between 2.52 and 2.77 (Guo *et al.,* 2014; Nan–Zhang *et al.,* 2016), *Trichinotus draco* and *T. avatus* with b values of 2.83 and 2.96 respectively (Morato *et al.*, 2001; Morey *et al.*, 2003). In contrast to this, a positive allometric trend was reported for *Trachinotus radiatus* with a b value of 3.2 (Morey *et al.*, 2003). The condition factors for *T. blochii* for both selected feeding treatments were greater than 1 with 'K' values ranging from 1.25 to 1.44. Similar observations of K values were reported for juvenile *T. blochii* and *T. marginatus* cultured under different conditions and feeding regimes, with values ranging between 1.56 to 1.9 (Cunha *et al.,* 2013; Jayakumar *et al.,* 2014). The K values recorded from the present study were comparatively lower than those obtained by Guo *et al*. (2014) and Nan-Zhang *et al*. (2016) for premature *T. ovatus* (3.31 to 3.79 and 11.47 to 14.31, respectively). The observed variation in length-weight relationship and K values in the present study might be attributed to a difference in geographic location, sample size, species, size, and feeding quality (Mommsen, 1998; Anani *et al.,* 2010).

Regarding proximate body composition, the present results reveal that an increase in blood meal contents (fermented and unfermented) in *T. blochii* diets results in significantly increased lipid and ash contents, while moisture contents and crude protein significantly decreased after 35 % blood meal inclusion levels (Tables 4, 5). Similar observations were made on the diet of gibel carp, *Carassius auratus gibelio*, when fish meal was replaced by blood meal at the level of 500 g kg^{-1} (50%). It was reported that the crude protein

Table 6. Economic parameters of *T. blochii* in the 12-week feeding trial.

	Diets		
	FML	FBML	BML
Price Index	1.1	1.14	1
ECR	1.69	1.72	1.16
EPI	0.62	0.63	0.65
Relative ECR %	3.3	11.6	18.2

Calculated from following price of the ingredients (June 2016): Fish meal = 3.0 USD kg^{-1}; Blood meal = 0.50 USD kg^{-1}; Corn meal = 1.0 USD kg^{-1}

content, apparent dry matter digestibility and gross energy were significantly decreased (Yang *et al.,* 2004). Moreover, the findings of Lee *et al*. (2001) demonstrate that an increase of crude protein content in carcasses of juvenile red snapper, *L. argentimaculatus*, related to the increased inclusion level of mixtures of animal by-products in their diet. These findings slightly differ with the observation of a significant difference in the final whole body proximate composition of fingerling rainbow trout, *O. mykiss*, fed a diet with different blood meal inclusion levels, where an increase in moisture content and decrease in ash and lipid contents was reported. Similar findings of a decrease in ash, and increase in lipid, protein and moisture contents, were also reported from carcass composition of Gilthead Seabream (*S. aurata*) fed diets with different levels of blood meal inclusion (Nogueira *et al.,* 2012). Moreover, no significant effects of the fish meal replacement with rendered animal protein were observed on carcasses composition of red sea bream (Takagi *et al*., 2000), grouper species (Shapawai *et al.,* 2007; Gunben *et al.,* 2014), rainbow trout (Bureau *et al.,* 1999), gilthead seabream (Robaina *et al.,* 1997) and European Catfish, *Silurus glanis* (Kumar *et al.,* 2015). In this study, an increase in ash and lipid content with increasing levels of FBML and BML meal was reflected in the proximate analysis of the diets. The economical profit index (EPI) revealed that FBML and BML diets presented best economic viability, considering both fish sale price and cost of diets (Table 6), although no significant differences were found between the treatments. Similar results have been reported when levels of blood have been used in diets of gilthead Seabream, *Sparus aurata* (Nogueira *et al.,* 2012).

Conclusion

Formulated aquaculture feeds are often high in protein and fat, and the bulk of these are generally provided by fish meal and fish oil. Because of their high cost and foreseeable long-term supply problems, a progressive increase in the use of economical protein and lipid sources in aquaculture feeds is inevitable. Feed manufacturers consequently require information on the nutritive value of various alternative protein and lipid sources, such as blood meal.

Fish meal replacement with fermented and unfermented blood meal diets showed promising results for cultured silver pompano, *T. blochii* (Lacépède, 1801). The results from FCR, survival rate, the good growth indicators, and good economic returns, justify the need to commercialize the technology for pompano culture, utilizing locally available sources of protein. Pompano culture could serve as a livelihood for fisher folk and will add to the fish production of the region.

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