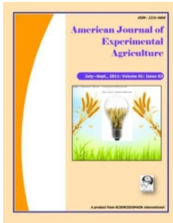

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Dietary Crystalline DL-Methionine Supplementation of Oilseed Meal-Based Diets: Effects on Growth and Feed Utilization of Juvenile Nile Tilapia (*Oreochromis niloticus* L.)

N. W. Agbo[1*], N. Madalla[2] and K. Jauncey[3]

[1]Department of Fisheries and Watershed Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
[2]Department of Animal Science and Production, Sokoine University of Agriculture, Morogoro, Tanzania.
[3]Institute of Aquaculture, University of Stirling, FK9 4LA, Stirling, UK.

Authors' contributions

This work was carried out in collaboration between all authors. Author NWA designed the study, searched and reviewed literature, performed the statistical analysis and wrote the first draft of the manuscript. Author NM managed and streamlined analyses of the study. Author KJ managed logistics for the experiment and the entire research work. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: This study evaluated the effect of dietary DL-methionine supplementation of diets containing mixtures of oilseed meals (i.e. soybean meal, SBM; cottonseed meal, CSM and groundnut cake, GNC) on the growth and feed utilization of Nile tilapia (*Oreochromis niloticus* L.) of mean initial weight 5.48±0.20g.
Study Design and Methodology: Five isonitrogenous (320g kg^{-1}), isolipidic (100g kg^{-1}) and isoenergetic (18KJ g^{-1}) test diets were formulated in which different mixture combinations of oilseed meal (i.e. EQ50, SBM50, CSM50 and GNC50) proteins enriched with crystalline DL-Methionine (0.5%) replaced fish meal (FM) protein at 50%. The control diet had FM as the major protein source. Fish were fed to satiation from the beginning and later fixed at 4% body weight per day and the study lasted for 56 days. The growth experiment was conducted in plastic tanks in a recirculation system with each dietary

*Corresponding author: Email: nelagbo@gmail.com;

treatment in triplicate.
Results: Growth and feed utilization of fish fed the control diet were significantly higher (*P*<0.05) than for all the oilseed meal-based diets (supplemented with methionine). There were no significant differences in whole-body protein, moisture, lipid and energy contents among diets, with the exception of Diet 4 which had lower protein content. The cost analysis also showed that the control diet was the most cost effective.
Conclusion: Results in the present study demonstrated that utilization of crystalline DL-methionine (0.5%) by Nile tilapia was not effective in improving the growth, feed utilization and cost effectiveness of the diets containing oilseed meal mixtures compared with the fish meal based diet.

Keywords: Oilseed meal mixtures; growth; feed utilization; DL- methionine; supplementation; Nile tilapia.

1. INTRODUCTION

Good quality fish meal is becoming scarce and prices are escalating in recent times. This has generated a lot of interest in the use of alternative protein sources for fish. Plant proteins are the main alternative protein sources normally considered as a solution to the problem and these are mainly from oilseed meals. However, oilseed meal proteins are inferior to fish meal proteins in terms of essential amino acid (EEA) profile required in the diets of cultured fish [1]. The EAA profiles of diets formulated with individual oilseed meals such as soybean meal (SBM), cottonseed meal (CSM) and groundnut cake (GNC) as well as their mixtures in previous studies [2,3,4] showed clear deficiency of one or more EAAs compared to the requirements of Nile tilapia [5]. Crystalline amino acids supplementation in animal diets to enhance EAA profile has been practised successfully in aquaculture but particularly in livestock production for many years [6]. Supplementation with crystalline amino acids is actually an attempt to improve the protein quality of fish feeds by addition of the EAAs that are in deficit in plant proteins [7,8]. EAAs such as methionine and lysine are generally critical in the formulation of fish diets when including plant protein sources [9]. For most EAAs, deficiency is manifest as a reduction in weight gain. However, in some species of fish a deficiency of methionine or tryptophan may lead to pathologies, since these EAAs are not only incorporated into proteins but also used for the synthesis of other compounds [10].

Tilapias have a requirement for sulphur-containing amino acids (i.e. methionine, cystine and cysteine) which can be met by either methionine alone or a proper mixture of methionine and cysteine [11]. According to Jauncey and Ross [12] dietary cystine can replace up to 50% of the total sulphur-containing amino acid requirement for *Oreochromis mossambicus*. Several studies have indicated that fish utilize crystalline amino acids less efficiently than protein bound forms [13,14]. Jauncey et al. [15] reported difficulty in using purified amino acid test diets with *O. mossambicus*. Possible reasons for the poorer utilization of crystalline amino acids compared with protein bound amino acids, may be attributed to different rates of absorption in the gut, creating amino acid imbalances in the tissues [16] and also to leaching of dietary crystalline amino acid during feeding [10] because these losses occur to a greater degree than those of protein-bound amino acids [17]. However, other studies have reported successful use of crystalline amino acids to supplement amino acid deficient diets in improving tilapia growth and feed utilization efficiency [18-21].

In view of contradictory reports on the efficacy of EAA supplementation of tilapia feeds, further study and economic analysis is required to determine whether or not any improvements in growth justify the use of EAAs and the additional feed cost that this would incur. The objective of this study, therefore, was to investigate the effect of crystalline methionine supplementation in oilseed meal based diets on growth, feed utilization and cost-effectiveness of Juvenile Nile tilapia (*Oreochromis niloticus)*.

2. MATERIALS AND METHODS

2.1 Experimental System and Animals

This study was undertaken at the Institute of Aquaculture, University of Stirling, UK. Fingerlings of Nile tilapia (5.48±0.20g) were stocked in triplicates in 30-L tanks. Fish were distributed randomly in the 30-L tanks at a rate of 20 fingerlings per tank in a recirculation system which was supplied with aerated water at a flow rate of 1L min^{-1}. Fish were subjected to a constant photoperiod of 12 hours Light/12 hours Darkness. Water quality parameters measured every week during the experiment included the following: temperature, 26.97±0.26ºC; pH, 7.29±0.27; ammonia, 0.05±0.03mg.L^{-1}; nitrite, 0.20±0.0mg.L^{-1}; nitrate, 20±0.0mg.L^{-1} and dissolved oxygen, 7.54±0.52mg.L^{-1}.

2.2 Diet Formulation and Preparation

Five isonitrogenous and isoenergetic diets were formulated using a mixture of SBM (crude protein, 500.3 g kg^{-1}), CSM (crude protein, 441.4g kg^{-1}), and GNC (crude protein, 430.5g kg^{-1}) as protein sources. Composition of the different oilseed meal mixtures used for diet formulation is presented in Table 1 and designation of diets shown correspondingly. FM (crude protein, 716.3g kg^{-1}) was substituted with different mixtures of SBM, CSM and GNC at 50% of total protein as presented in Table 2. Diets containing different mixtures of oilseed proteins were supplemented with 0.5% DL-methionine (M9500, 99.0% TLC; Sigma) to meet the minimum requirement for Nile tilapia, which is 2.7% of dietary protein [4]. In this study only methionine was supplemented because this was deemed more critical for Nile tilapia [11].

Table 1. Specification of dietary protein levels (%) in the experimental diets fed to fish in this study

Diet No.	Designation	Percentage of total protein contributed by various ingredients in the diets			
		Fish meal	Soybean meal	Cottonseed meal	Groundnut cake
1	Control	100.00	-	-	-
2	EQ50	50.00	16.67	16.67	16.67
3	SBM50	50.00	25.00	12.50	12.50
4	CSM50	50.00	12.50	25.00	12.50
5	GNC50	50.00	12.50	12.50	25.00

EQ50 = equal contribution of protein from test ingredients to mixture, SBM50=50% contribution from soybean meal to mixture, CSM50 = 50% contribution from cottonseed meal to mixture, GNC50=50% contribution from groundnut cake to mixture

Preparation of experimental diets was similar to previous methods by Agbo et al. [2]. The diets were stored at -20ºC until fed. Fish were hand-fed three times a day (09:30, 13:00 and 16:00) up to satiation for the first three weeks and 4% of body weight for subsequent weeks with the experiment lasting for 8 weeks. Diets were dispensed in small portions to ensure prompt consumption and avoid amino acid leaching as recommended by Lovell [10].

Table 2. Composition of diets fed to juvenile *Oreochromis niloticus* using oilseed meal mixtures (g.kg^{-1} of diet) supplemented with DL-Methionine

Ingredients	Control	EQ50	SBM50	CSM50	GNC50	Price of ingredients ($kg^{-1})
	1	2	3	4	5	
Soybean Meal	-	100.2	150.4	75.2	75.2	0.432
Cottonseed Meal	-	113.5	85.2	170.4	85.2	0.162
Groundnut Cake	-	116.4	87.4	87.4	175.0	0.360
Fish Meal	420.0	210.0	210.0	210.0	210.0	1.053
Wheat Grain	208.0	211.0	210.5	211.0	210.2	0.090
Sunflower Oil	57.0	47.0	53.8	51.7	35.4	0.450
α- Cellulose	30.0	10.9	12.5	7.0	14.5	0.045
Corn Starch	205.0	106.0	105.2	102.3	109.5	0.090
Binder CMC[1]	20.00	20.00	20.00	20.00	20.00	0.225
Mineral Premix[2]	40.0	40.0	40.0	40.0	40.0	1.350
Vitamin Premix[3]	20.0	20.0	20.0	20.0	20.0	1.305
DL-Methionine[4]	0.0	5.0	5.0	5.0	5.0	22.50
Diet cost, $kg^{-1}	0.504	0.486	0.495	0.477	0.486	

[1]Carboxymethyl cellulose (Sigma, C5013), [2]Contained (as g kg^{-1} of diet): $MgSO_4,7H_2O$, 20.40; NaCl, 8.00; KCl, 6.04; Fe $SO_4,7H_2O$, 4.00; $ZnSO_4,4H_2O$, 0.88; $MnSO_4,4H_2O$, 0.41; $CuSO_4,5H_2O$, 0.13; $CoSO_4,7H_2O$, 0.08; $CaIo_3,6H_2O$, 0.05; $CrCl_3,6H_2O$, 0.02 (according to Jauncey and Ross [12]). [3]Contained (as mg kg^{-1} of diet): Thiamine (B_1), 85.00; Riboflavin (B_2), 60.00; Pyridoxine (B_6), 25.00; Pantothenic acid, 105.00; Inositol, 500.00; Biotin, 1.80; Folic acid, 20.00; Ethoxyquin, 4.00; Choline, 1481.00; Nicotinic acid (Niacin), 250.00; Cyanocobalamin (B_{12}), 0.03; Retinol palmitate(A), 20.00; Tocopherol acetate (E), 140.00; Ascorbic acid (C), 750.00; Menadione (K), 30.00; Cholecalciferol (D_3), 0.08 (according to Jauncey and Ross [12]) . [4](Sigma, M9500) Sigma-Aldrich Chemie, Germany. (Price of ingredients are presented in US Dollars)

2.3 Analytical Techniques

Ingredients, diets and carcass were analysed in triplicates for proximate composition according to standard methods [22]. Energy was determined using an Adiabatic Autobomb Calorimeter (Parr 6100, USA) with benzoic acid as a standard. Amino acid content was analysed using LKB 4151 Alpha-Plus Amino Acid Analyser (LKB Biochrom Ltd, UK). Phosphorus was measured following the method by Stirling [23] using a spectrophotometer (Cecil Elegant Technology–Aquarius-P). Some antinutritional factors (ANFs) such as phytic acid, trypsin inhibitors and saponin were analysed following earlier methods used by Agbo et al. [24].

2.4 Chemical Composition of Diets

Chemical composition of the diets used in this experiment is presented in Table 3. Crude protein, CL and energy were similar for all diets as formulated. Ash and phosphorus contents of the control diet were higher than for the plant-based diets. Diet 4 (CSM50) had the highest fibre content reflecting higher inclusion level of cottonseed meal (50% of plant mixture). The ANFs are much lower for the control (Diet 1) compare to Diets 2, 3, 4 and 5 (Table 3). The diets met the EAA requirements of Nile tilapia [5] and exceeded this in most cases with the exception of threonine which was slightly deficient for all the diets (Table 3).

2.5 Analysis of Biological Parameters

Weight gain (WG), specific growth rate (SGR), feed intake (FI), feed conversion ratio (FCR), protein efficiency ratio (PER), apparent net protein utilization (ANPU) and energy retention (ER) were used to evaluate growth and feed utilization as follows:

WG (%) = (Final body weight – initial body weight)/ Initial body weight x 100
SGR (% day^{-1}) = 100 × [ln (Final body weight) – ln (Initial body weight)]/no. of days
FI (g) = Total feed intake per fish/no. of days,
FCR = feed intake/live weight gain
PER = live weight gain/crude protein intake
ANPU (%) = 100 × (Final fish body protein - Initial fish body protein)/crude protein intake
ER (%) = 100 × (Final fish body energy - Initial fish body energy)/gross energy intake.

Whole body composition was determined where whole body samples were analyzed for moisture, crude protein, crude lipid and ash. Results were expressed as percentage of live weight.

Table 3. Biochemical composition of diets fed to Nile tilapia in this study

Proximate composition (g kg^{-1} as-fed)		Diets				
		Control	EQ50	SBM50	CSM50	GNC50
		1	2	3	4	5
Dry matter		976.7	971.8	973.0	958.9	973.7
Crude protein		333.4	342.7	342.1	337.2	343.6
Crude lipid		110.3	111.4	107.8	109.4	112.6
Crude fibre		22.8	28.2	26.6	31.9	25.5
Ash		97.8	89.1	88.3	89.7	89.1
Nitrogen free extract		412.4	400.5	408.1	390.7	402.9
Gross energy, (kJ g^{-1})		18.36	18.77	18.75	18.74	18.81
Essential amino acid composition (% of dietary protein)						
Arginine	4.20[1]	5.01	6.11	5.97	6.23	6.14
Isoleucine	3.10	3.96	3.71	3.84	3.66	3.63
Leucine	3.40	6.41	6.08	6.24	6.03	5.98
Lysine	5.10	6.23	5.43	5.55	5.41	5.34
Methione+Cystine[2]	2.70	2.72	3.63	3.62	3.66	3.59
Phenylalanine+Tyrosine[2]	3.80	5.26	5.90	5.96	5.89	5.85
Threonine	3.80	3.23	2.93	2.97	2.97	2.86
Valine	2.80	4.94	4.59	4.69	4.57	4.52
Phosphorous and antinutritional factors (gkg^{-1})						
Phosphorus		8.30	7.01	7.33	7.53	7.77
Phytic acid		0.5	7.6	7.1	8.5	7.1
Trypsin inhibitors		0.0	1.8	2.4	1.5	1.6
Gossypol		0.0	0.6	0.5	1.0	0.5
Saponin		1.1	3.4	3.3	3.4	3.5

[1]Essential amino acid requirements for tilapia [5], [2]Values of methionine and phenylalanine are the requirements in the presence of cystine and tyrosine of the diet respectively

2.6 Cost Effectiveness of Diets and Statistical Analysis

Cost effectiveness of diets was assessed using Profit Index (PI) as follows; *PI = value of fish/cost of feeding.* The value of fish and cost of diets were calculated using market prices in Ghana but presented in US Dollars.

Each experimental diet was fed to three groups of fish in a completely randomized design. Statistical analyses in this study were conducted using SPSS Statistical Package (Version 16.0, SPSS Inc., Chicago, IL). Data were subject to one-way ANOVA and the Tukey's Multiple Comparison Test applied to evaluate differences between means at P=.05. All percentages were arcsine transformed before analysis.

3. RESULTS

3.1 Growth Performance and Feed Utilization

Data on growth performance and feed utilization of Nile tilapia fed the different experimental diets is presented in Table 4 and growth responses are also shown in Fig. 1. All experimental diets fed to fish were well accepted and no pathological signs were observed during the trial. FW, WG, SGR, FCR, PER and ANPU in Nile tilapia were significantly higher for the control diet when compared to all the oilseed meal-based diets (supplemented with methionine). Feed intake of fish fed the control (Diet 1), Diets 4 and 5 was significantly higher than that of fish fed Diets 2 and 3 (Table 4). Fish fed Diet 3 (SBM50) had significantly lower energy retention than the control diet.

Table 4. Growth performance and feed utilization of Nile tilapia fingerlings fed diets containing oilseed meal mixtures with DL-methionine supplementation for eight weeks

	Control	EQ50	SBM50	CSM50	GNC50
	1	**2**	**3**	**4**	**5**
IW	5.59 ±0.27	5.50 ±0.28	5.47 ±0.02	5.50±0.19	5.32±0.17
FW	31.20±0.99^{a}	23.80±0.92^{b}	22.29 ±1.16^{b}	23.88±1.97^{b}	22.90±1.07^{b}
WG	458.63±28.60^{a}	333.12 ±23.95^{b}	307.65±20.14^{b}	333.78±21.46^{b}	330.34±6.84^{b}
SGR	3.07±0.09^{a}	2.62±0.10^{b}	2.51±0.09^{b}	2.62±0.09^{b}	2.61±0.03^{b}
FCR	1.34±0.05^{a}	1.82±0.09^{b}	1.99±0.13^{b}	1.84±0.16^{b}	1.94±0.10^{b}
FI	34.31±0.07^{a}	33.22±0.11^{b}	33.42±0.03^{b}	34.09±0.28^{a}	34.12±0.04^{a}
PER	2.24±0.08^{a}	1.61±0.08^{b}	1.47±0.10^{b}	1.60±0.16^{b}	1.50±0.08^{b}
ANPU	32.68±1.16^{a}	24.00±1.13^{b}	21.75±1.4^{b}	23.10±2.28^{b}	23.26±1.20^{b}
ER	26.70±1.03^{a}	20.37±2.73^{ab}	19.91±0.90^{b}	22.46±4.36^{ab}	20.48±1.16^{ab}
S	100.00	100.00	100.00	100.00	100.00
PI	2.66	2.04	1.82	2.04	1.90

IW (g) = Initial weight, FW (g) = Final weight, WG (%) = Weight gain, SGR (%.day^{-1}) = Specific growth rate, S = Survival (%), FCR = Feed conversion ratio, FI (g) = Feed intake, PER = Protein efficiency ratio, ANPU (%) = Apparent net protein utilization, ER (%) = Energy retention, PI=Profit index. Values are means ± SD of three replicates, and means within the same row with different letters are significantly different at P=.05. The prices of ingredients used in this study are presented in Table 2 (all prices are in US Dollars; Sale price of tilapia is 1.80 \$kg^{-1})

3.2 Body Composition

At the end of the growth study there were no significant differences in whole-body protein, moisture, lipid and energy contents among diets, with the exception of Diet 4 which resulted in lower protein content (Table 5). These values were, however, higher than for initial whole-body composition. Ash contents of fish fed the control diet were significantly higher than those of fish fed the plant-based diets.

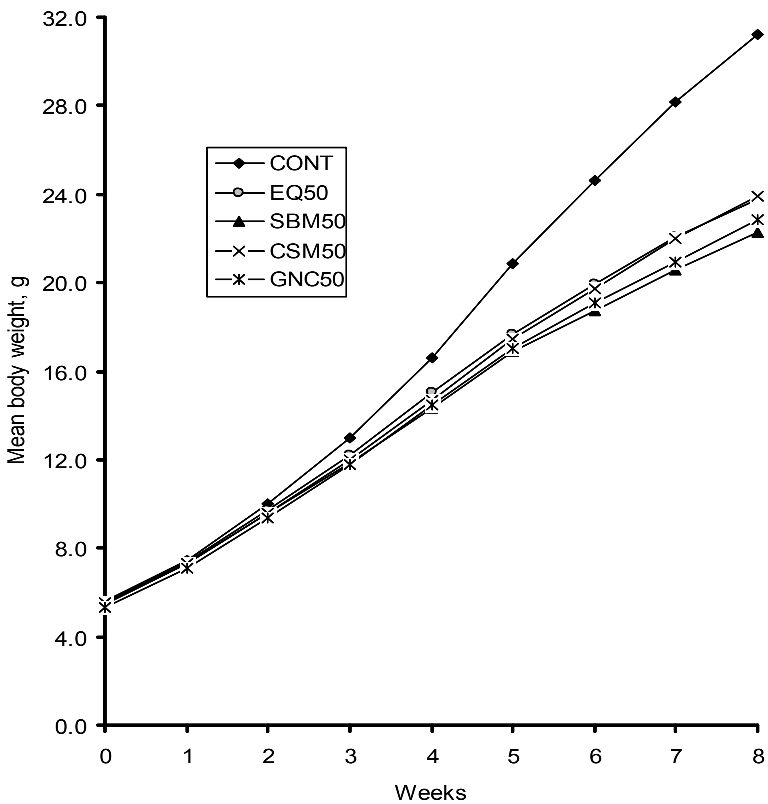

Fig. 1. Growth response of fish fed oilseed meal-based diets with DL-methionine supplementation for eight weeks

Table 5. Whole body composition (% wet weight) of Nile tilapia fed oilseed meal-based diets with DL-methionine supplementation for eight weeks

	Initial	Control	EQ50	SBM50	CSM50	GNC50
		1	2	3	4	5
MC	75.48	72.66±0.61	72.44±1.07	71.61±0.20	70.85±1.36	70.98±0.27
CP	13.85	14.45±0.17[ab]	14.66±0.06[ab]	14.56±0.24[ab]	14.27±0.45[b]	15.13±0.43[a]
CL	5.73	7.78±0.75	8.43±1.19	9.13±0.42	9.93±1.58	8.89±0.37
Ash	3.90	4.31±0.05[a]	3.57±0.16[b]	3.77±0.11[b]	3.83±0.12[b]	3.78±0.16[b]
GE	5.41	6.36±0.27	6.57±0.48	6.93±0.10	7.22±0.63	7.00±0.08

MC = moisture content, CP = crude protein, CL = crude lipid, CF = crude fibre, GE = gross energy ($kJ.g^{-1}$). Values are means ± SD of three replicates, and means within the same row with different letters are significantly different at P=.05

3.3 Cost-effectiveness Analysis of Diets

The costs of ingredients used in this analysis are presented in Table 2. The cost per kilogram of experimental diets varied little with the control having the highest ($0.504kg^{-1}$) and Diet 4 (CSM50) the least ($0.477kg^{-1}$) (Table 2). The cost analysis however, showed that the highest profit was obtained by the control diet and the lowest by Diet 3 (SBM50) (Table 4). Among the oilseed meal-based diets, Diets 2 and 4 were the most profitable.

4. DISCUSSION

Results from the present study indicated that there was significantly lower growth performance and feed utilization in Nile tilapia fed oilseed meal-based diets supplemented with methionine compared with the control diet (fish meal-based diet). However, ER of fish fed Diets 2, 4 and 5 were not significantly different from the control diet. Amongst the test diets, Diets 2 and 4 gave better growth performance and feed utilization even though this was not significantly different from the other diets. Despite the fact that growth and feed utilization of fish fed oilseed meal-based diets were lower than that of the control in this study, they showed considerable improvements particularly in FCR, PER and ANPU compare to earlier studies. Values are significantly higher than in previous studies using the same oilseed meals [2,3,4] at similar plant protein levels and comparable to those of various researchers who reported improved growth of fish with amino acid incorporation at similar inclusion levels of plant protein [20-26].

Crystalline amino acids supplementation in fish diets has had variable success. According to Shiau et al. [27], male tilapia (*O. niloticus* x *O. aureus*) fed diets in which 100% of the fishmeal was replaced with SBM either with or without methionine supplementation had significantly lower weight gain, feed utilization and protein digestibility than in groups fed diets containing fishmeal as the sole source of protein. Andrews and Page [28] observed no improvement in growth of channel catfish when L-methionine was supplemented to a soybean meal-based diet. Teshima [29] also reported similar observation for Nile tilapia when he supplemented SBM with methionine, and concluded that it was unnecessary. Davis and Stickney [30] and El-Saidy and Gaber [20] reported that feeding blue tilapia and Nile tilapia respectively with 100% SBM, firstly with methionine supplementation and secondly with methionine and lysine, had no significant effect on growth parameters and feed utilization.

In contrast, Shiau et al. [31] reported that the growth of tilapia was improved with addition of supplemental methionine and Murai et al. [32] also reported improvement in the nutritional value of soy flour by addition of 0.4% crystalline L-methionine. In other studies partial replacement of fish meal was achieved using a combination of plant proteins supplemented with amino acids. A mixture of plant proteins (corn gluten, wheat gluten, extruded peas, rapeseed meal and sweet white lupin) balanced with EAAs could provide between 50-75% of protein in diets fed to gilthead sea bream, *Sparus aurata* without significantly affecting performance [33]. A sizeable proportion of the fish meal in diets for juvenile turbot, *Psetta maxima* could be replaced by a mixture of plant proteins from lupin, corn gluten and wheat gluten meal supplemented with amino acids without affecting growth and nutrition [34].

Although supplementation of diets with DL-methionine in the present study resulted in improvements in feed utilization compared to previous studies [2-4], the oilseed meal-based diets did not do well in terms of growth and feed utilization compared to fish fed the fish meal-based diet. The superiority of fishmeal in this respect may be attributed to the absence of any known antinutritional factors (Table 3), higher protein levels and to the generally higher availability of amino acids in fish meal protein [35]. Reduced efficacy of crystalline-amino acid compared to protein-bound-amino acid was also observed in different fish species [14,17,36,37]. This was attributed to differences in amino acid absorption rates and the leaching of dietary crystalline amino acid during feeding of fish. In the present study in order to avoid leaching of amino acids, an attempt was made to feed fish more frequently with smaller quantities of feed as recommended by Lovell [10].

Whole body composition of fish was little affected by dietary treatments at the end of the feed trial. Total crude protein and energy contents of Nile tilapia were not significantly different between dietary treatments and the control with the exception of CP of fish fed Diet 4, which was significantly lower than the control. However, there was significant increase in protein and lipid in comparison with the initial carcass values in all the dietary treatments. Similar results were reported by Polat [26] in *Tilapia zillii*, El-Saidy and Gaber [20] in Nile tilapia and Mukhopadhyay and Ray [25] in rohu.

Cost effectiveness analysis of diets in this study revealed that the oilseed meal based diets with methionine supplementation had slightly lower cost per kilogram compared to the control diet. Nonetheless, PI for the control diet was higher indicating that the control was more profitable than the oilseed meal-based diets supplemented with DL-methionine. The result showed that DL-methionine supplementation of tilapia diets in this study did not lead to improved cost-effectiveness. This appears to concur with concerns raised by Jauncey [38] about EAA supplementation in tilapia feeds and whether any improvements in growth justify the additional costs. The cost of the methionine used in this study might be higher than other commercial ones on the market since it was based on feed grade price in the USA (MP Biomedicals, Solon, USA). It is therefore likely that if cheaper sources of methionine are found cost effectiveness could improve substantially, especially for Diets 2 and 4.

5. CONCLUSIONS

To conclude, the present study demonstrated that utilization of crystalline DL-methionine (0.5%) by Nile tilapia was not effective in improving the nutritive value and cost effectiveness of the diets containing oilseed meal mixtures (SBM, CSM and GNC replacing 50% FM protein) compared with the fish meal based diet. However, FCR, PER and ANPU improved compared to previous studies where there was no methionine supplementation. The lower performance of fish fed with the oilseed meal-based diets compared to the control diet may be attributed to poor utilization of the crystalline methionine and the presence of various antinutritional factors, among others in the selected oilseed meals. Since this study was conducted under laboratory conditions, further research is recommended under field conditions (particularly in semi-intensive system commonly used for tilapia production in earthen ponds) to confirm the utilization of crystalline DL-methionine supplementation in oilseed meal-based diets on growth and feed utilization of Nile tilapia. There is the possibility of achieving better and practical results which would directly be beneficial to farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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