

Original Research Article

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

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 ± 0.20 g.

Study design and Methodology: Five isonitrogenous (320 g kg^{-1}), isolipidic (100 g kg^{-1}) and isoenergetic (18 KJ 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 treatment in triplicate.

Results: Growth and feed utilization of fish fed the control diet were significantly higher at 5% level than for all the oilseed meal based diets (supplemented with methionine). There were no significant differences at 5% level 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 compared with the fish meal based diet.

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

1. INTRODUCTION

The scarcity of good quality fish meal and escalating prices in recent years has lead to renewed interest in the use of alternative protein sources for fish. A possible solution to this problem is being sought by using plant proteins, mainly oilseed meals. However, apart from fish meal,

there are few animal or plant protein products available for formulation of fish feeds with an essential amino acid (EAA) profile approximating the dietary requirements 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] showed clearly deficiency of one or more EAAs compared to the requirements of Nile tilapia [4]. Supplementing crystalline amino acids to diets in order to optimize the amino acid profile has been commonplace in the terrestrial livestock industry for decades with good results [5] and to some extent in aquaculture. 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 [6,7]. Some EAAs, such as methionine and lysine, are generally critical in the formulation of fish diets when incorporating inexpensive plant protein sources [8]. For most EAAs, deficiency is manifest as a reduction in weight gain. In some species of fish, however, a deficiency of methionine or tryptophan leads to pathologies, because these EAAs are not only incorporated into proteins but also used for the synthesis of other compounds [9].

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 [10]. Dietary cystine can replace up to 50% of the total sulphur-containing amino acid requirement for *Oreochromis mossambicus* [11]. Several studies have indicated that fish utilize crystalline amino acids less efficiently than protein bound forms [12,13]. Jauncey *et al.* [14] reported difficulty in using purified amino acid test diets with *O. mossambicus*. Possible reasons for the poorer utilization of free compared with protein bound amino acids, may firstly be attributed to different rates of absorption in the gut, creating amino acid imbalances in the tissues [15] and secondly to leaching of dietary crystalline amino acid during feeding [9] because these losses occur to a greater degree than those of protein-bound amino acids [16]. However, crystalline amino acids have been reported to be successfully used to supplement amino acid deficient diets, improving tilapia growth and feed utilization efficiency [17,18,19,20].

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*).

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70 2. MATERIALS AND METHODS

71 2.1 Experimental System and Animals

72 This study was undertaken at the Institute of Aquaculture, University of Stirling, UK. Fingerlings
73 of Nile tilapia of average weight 5.48 ± 0.20 g were stocked in triplicate in 30-L tanks. Each tank

was randomly stocked with 20 fingerlings in a recirculation system which was supplied with aerated water at a flow rate of 1 L min⁻¹ with temperature maintained at 27 ± 1° C. 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 ± 0.26 °C; pH, 7.29 ± 0.27; ammonia, 0.05 ± 0.03 mg.L⁻¹; nitrite, 0.20 ± 0.0 mg.L⁻¹; Nitrate, 20 ± 0.0 mg.L⁻¹ and dissolved oxygen, 7.54 ± 0.52 mg.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, 441.4 g kg⁻¹), and GNC (crude protein, 430.5 g 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 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 2.70% of dietary protein [4]. In this study only methionine was supplemented because this was deemed more critical for Nile tilapia [10].

Table 1. Specification of dietary protein levels (%) in experimental diets used in this study

Diet No.	Designation	Percentage of total protein contributed by various sources 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 -20°C until fed. Fish were hand-fed three times a day (09:30, 13:00 and 16:00) to satiation for the first three weeks and 4% of body weight for subsequent weeks with the experiment duration of 8 weeks. Diets were dispensed in small portions to ensure prompt consumption and avoid amino acid leaching as recommended by Lovell [9].

Table 2. Composition of diets fed to juvenile *O. 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	

¹Carboxymethyl cellulose (Sigma, C5013), ²Contained (as g kg⁻¹ of diet): MgSO₄·7H₂O, 20.40; NaCl, 8.00; KCl, 6.04; Fe SO₄·7H₂O, 4.00; ZnSO₄·4H₂O, 0.88; MnSO₄·4H₂O, 0.41; CuSO₄·5H₂O, 0.13; CoSO₄·7H₂O, 0.08; CaO₃·6H₂O, 0.05; CrCl₃·6H₂O, 0.02 (according to Jauncey and Ross 1982). ³Contained (as mg kg⁻¹ of diet): Thiamine (B₁), 85.00; Riboflavin (B₂), 60.00; Pyridoxine (B₆), 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 (B₁₂), 0.03; Retinol palmitate(A), 20.00; Tocopherol acetate (E), 140.00; Ascorbic acid (C), 750.00; Menadione (K), 30.00; Cholecalciferol (D₃), 0.08 (according to Jauncey and Ross [11]. ⁴(Sigma, M9500) Sigma-Aldrich Chemie, Germany.

2.3 Analytical Techniques

Ingredients, diets and carcass were analysed in triplicates for proximate composition according to standard methods [21]. 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 [22] using a spectrophotometer (Cecil Elegant Technology–Aquarius-P). Some antinutritional factors such as phytic acid, trypsin inhibitors and saponin were analysed following earlier methods used by Agbo *et al.* [23].

2.4 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:

$$WG (\%) = \frac{\text{final body weight} - \text{initial body weight}}{\text{initial body weight}} \times 100$$

$$SGR (\% \text{ day}^{-1}) = 100 \times [\ln(\text{final body weight}) - \ln(\text{initial body weight})] / \text{no. of days}$$

$$FI (g) = \text{Total feed intake per fish} / \text{no. of days},$$

$$FCR = \text{feed intake} / \text{live weight gain}$$

$$PER = \text{live weight gain} / \text{crude protein intake}$$

$$ANPU (\%) = 100 \times (\text{final fish body protein (g)} - \text{initial fish body protein (g)}) / \text{crude protein intake (g)}$$

$$ER (\%) = 100 \times (\text{final fish body energy} - \text{initial fish body energy}) / \text{gross energy intake}$$

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

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140 **2.5 Cost effectiveness of diets and statistical analysis**

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

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

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151 **3. RESULTS**

152 **3.1 Chemical Composition of Diets**

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

160 **3.2 Growth performance and feed utilization**

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

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173 **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
Methionine+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 (g kg ⁻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

174 ¹Essential amino acid requirements for tilapia [4], ²Values of methionine and phenylalanine are
 175 the requirements in the presence of cystine and tyrosine of the diet respectively.
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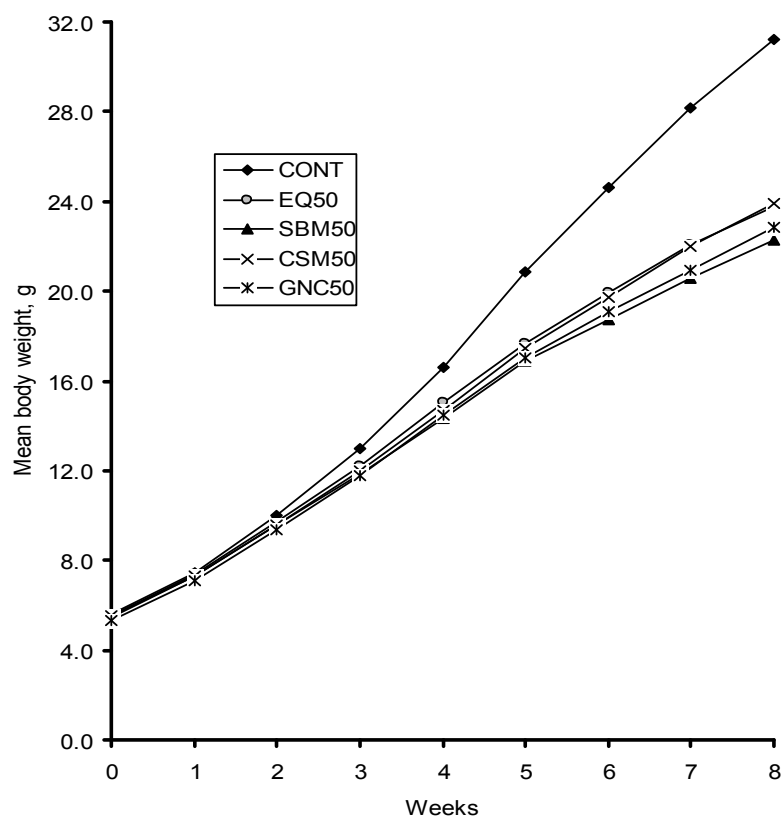


Fig 1. Growth response of fish fed oilseed based diets with DL-methionine supplementation for eight weeks

Table 4. Growth 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 values within the same row with different letters are significantly different at P=0.05. The prices of ingredients used in this study are presented in Table 2. Sale price of tilapia is 1.80 \$kg⁻¹.

192

193 3.3 Body Composition

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

199

200 **Table 5. Whole body proximate composition (% wet weight) of Nile tilapia fed diets**
201 **containing oilseed meal mixtures 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

202 *MC = moisture content, CP = crude protein, CL = crude lipid, CF = crude fibre, GE = gross*
203 *energy (kJ.g⁻¹). Values are means ± SD of three replicates, and values within the same row with*
204 *different letters are significantly different at P=.05.*

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206 3.4 Cost-effectiveness Analysis of Diets

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

212

213 4. DISCUSSION

214 Results from the present study indicated that there was significantly lower growth performance
215 and feed utilisation (Table 4) in Nile tilapia fed oilseed meal based diets supplemented with
216 methionine compared with the control diet (fish meal based diet). However, ER of fish fed Diets
217 2, 4 and 5 were not significantly different from the control diet (Table 4). Amongst the oilseed
218 meal based diets, Diets 2 and 4 gave better growth and feed utilisation even though this was
219 not significantly different from the other diets. Despite the fact that growth and feed utilization of
220 fish fed test diets were lower than that of the control in this study, they could be considered as
221 showing improvements (particularly, FCR, PER and ANPU). Values are significantly higher than
222 in previous studies using the same oilseed meals [2,3] at similar plant protein levels and
223 comparable to those of various researchers who reported improved growth of fish with amino
224 acid incorporation at similar inclusion levels of plant protein [19,20,24,25].

225 Supplementing crystalline amino acids in fish diets has had variable success. According to
226 Shiau *et al.* [26], male tilapia (*O. niloticus* x *O. aureus*) fed diets in which 100% of the fishmeal
227 was replaced with SBM either with or without methionine supplementation had significantly
228 lower weight gain, FCR and protein digestibility than in groups fed diets containing fishmeal as
229 the sole source of protein. Andrews and Page [27] stated no improvement in growth of channel
230 catfish when L-methionine was supplemented to a soybean meal based diet and Teshima [28]
231 also reported similar observation for Nile tilapia when he supplemented SBM with methionine,
232 and therefore concluded that it was unnecessary. Davis and Stickney [29] and El-Saidy and
233 Gaber [19] reported feeding blue tilapia and Nile tilapia respectively with 100% SBM (with
234 methionine supplementation in the first instance and methionine and lysine in the second) with
235 no significant effect on growth and feed utilization.

236 In contrast, Shiau *et al.* [30] reported improved growth of tilapia with addition of supplemental
237 methionine and Murai *et al.* [31] also reported that the nutritional value of soy flour was
238 improved by addition of 0.4% crystalline L-methionine. In other studies partial replacement of
239 fish meal was achieved using a combination of plant proteins supplemented with amino acids. A
240 mixture of plant proteins (corn gluten, wheat gluten, extruded peas, rapeseed meal and sweet
241 white lupin) balanced with EAAs could provide between 50 - 75% of protein in diets fed to
242 gilthead sea bream, *Sparus aurata* without significantly affecting performance [32]. A sizeable
243 proportion of the fish meal in diets for juvenile turbot, *Psetta maxima* could be replaced by a
244 mixture of plant proteins from lupin, corn gluten and wheat gluten meal supplemented with
245 amino acids without affecting growth and nutrition [33].

246 Even though supplementation of diets with DL-methionine in the present study resulted in
247 improvements in feed utilization compared to previous studies [2,3], the oilseed meal based
248 diets did not produce growth and feed utilization equivalent to that of fish fed the fish meal
249 based diet. The superiority of fishmeal in this respect may be attributed to the absence of any
250 known antinutritional factors (Table 3), higher protein levels and to the generally higher
251 availability of amino acids in fish meal protein [34]. Reduced efficacy of crystalline-amino acid
252 compared to protein-bound-AA was also observed in different fish species [13,16,35,36]. This
253 was attributed to differences in amino acid absorption rates and the leaching of dietary
254 crystalline amino acid during feeding of fish. In the present study in order to avoid leaching of
255 amino acids, an attempt was made to feed fish more frequently with smaller quantities of feed
256 as recommended by Lovell [9].

257 Carcass composition was little affected by dietary treatments at the termination of the feed trial.
258 Total crude protein and energy contents of Nile tilapia were not significantly different between
259 dietary treatments and the control with the exception of CP of fish fed Diet 4 which was
260 significantly lower than the control. However, there was significant increase in protein and fat in
261 comparison with the initial carcass values in all the dietary treatments. Similar results were

262 reported by Polat [25] in *T. zillii*, El-Saidy and Gaber [19] in Nile tilapia and Mukhopadhyay and
263 Ray [24] in rohu.

264 Cost effectiveness analysis of diets in this study revealed that the oilseed meal based diets with
265 methionine supplementation had slightly lower cost per kilogram compared to the control diet
266 (Table 2). Nonetheless, PI for the control diet was higher indicating that the control was more
267 profitable than the oilseed meal based diets supplemented with DL-methionine. The result
268 indicated that DL-methionine supplementation of tilapia diets in this study did not lead to
269 improved cost-effectiveness. This appears to concur with concerns raised by Jauncey [9] about
270 EAA supplementation in tilapia feeds and whether any improvements in growth justify the
271 additional costs. The cost of the methionine used in this study might be higher than other
272 commercial ones on the market since it was based on feed grade price in the USA (MP
273 Biomedicals, Solon, USA). It is therefore likely that if cheaper sources of methionine are found
274 cost effectiveness could improve substantially, especially for Diets 2 and 4.

275 **4. CONCLUSIONS**

276 To conclude, the present study demonstrated that utilization of crystalline DL-methionine (0.5%)
277 by Nile tilapia was not effective in improving the nutritive value and cost effectiveness of the
278 diets containing oilseed meal mixtures (SBM, CSM and GNC replacing 50% FM protein)
279 compared with the fish meal based diet. However, FCR, PER and ANPU improved compared to
280 previous studies where there was no methionine supplementation. The lower performance of
281 fish fed the oilseed based diets compared to the control may be attributed to poor utilization of
282 the crystalline methionine and the presence of various antinutritional factors, among others in
283 the selected oilseed meals.

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285 **COMPETING INTERESTS**

286 Authors have declared that no competing interests exist.

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