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Influence of fish meal replacement with graded levels of corn gluten meal on performance, feed efficiency, body chemical analysis and economic revenue of the Nile tilapia fish *Oreochromis niloticus*

Mohamed M. Khadr[1], Sabry A. Shehata[2], Mohamed S. Ebrahim[1], Mohammed A.E. Naiel[2*], Khaled M. Al-Marakby[2]

[1]Department of Fish Nutrition and technology, Central Laboratory for Aquaculture Research, Abbassa, Agriculture Research Center, Giza 12619, Egypt.

[2]Animal Production Department, Faculty of Agriculture, Zagazig University, Egypt.

Corresponding author: mohammednaiel.1984@gmail.com; mnaiel@zu.edu.eg

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ABSTRACT

The current experiment was conducted to inspect the influences of partial replacement of fish meal (FM) with Corn gluten meal (CGM) on tilapia growth, feed utilization, biometric indices, body composition and economic revenue. The experimental groups were divided into five equal groups, each with five replicates. The D_1 fish group was fed a FM-based diet, whereas the other four fish groups were fed FM diets substituted with several levels of CGM, as follows: 15, 30 and 40% from total FM level (D_2, D_3, and D_4, respectively). After 10 weeks of the feeding trial, the growth findings showed that diets containing higher CGM replacement levels (D_3 and D_4) enhanced feed intake, weight gain, and weight gain % significantly ($P < 0.05$) compared to the other diets. Other performance and feed utilization measures showed no statistically significant differences among the tested diets. Weight gain, feed conversion ratio, and FM replacement with CGM showed a strong positive correlation tends; R^2 = 0.98 and 0.92, respectively. The poly-nominal regression indicated that the optimum FM replacement level with CGM is at 45% of the total FM content. Moreover, the biometric indices revealed that tilapia fish fed graded inclusion levels of CGM as a substitute to FM had normal health status. In terms of chemical body composition, fish fed FM diet replaced with a high amount of CGM (D_4) diet had the highest crude protein, ash, and NFE content and the lowest crude fat levels. In conclusion, the current results prove that CGM is a viable feed component for Tilapia. Moreover, it may substitute 45% of the total FM content without affecting the performance or health status of *O. niloticus*.

INTRODUCTION

The Nile tilapia is the most common farmed fish species in Egypt and the world's second biggest farmed fish species after carp **(Ayyat *et al.*, 2020)**. The primary advantage of tilapia fish is its capability to grow in a variety of culture types (**Naiel *et al.*, 2019)**. Aquaculture industry faces several challenges, particularly in developing countries **(Naiel**

***et al*., 2020a)**. Mainly, aquatic feeds which are the major recurrent expenses in aquaculture farms, accounting for approximately 40% to 70% of total essential cost; thus, new unconventional feed component resources are urgently needed (**Naiel *et al*., 2020b)**. Specifically, the major challenge facing the aquaculture sector is the sustainability and availability of fishmeal (FM) as the primary necessary protein source in aquatic diets **(Ayyat *et al*., 2021)**. Nowadays, only few other protein sources have been recommended as FM alternatives (**El-Sayed, 1999; Ding *et al.*, 2015; Wang *et al*., 2019** and **Khafaga *et al*., 2020)**.

One of the effective strategies to achieve long-term output, while keeping fish feed low cost is using appropriate plant feedstuffs as an alternate protein source for FM **(Sivaramakrishnan *et al*., 2021)**. Corn gluten meal (CGM) is a plant-based by-product of the corn-starch industry with a high protein level (**Bulut *et al*., 2014)**. Also, it is well-known that CGM is deficient in lysine and arginine **(Amerio *et al*., 1998).** Thus, CGM is a good alternative to FM because of its low content of anti-nutritional elements and crude fiber, as well as its adequate content of essential amino acids, especially arginine and lysine, which are supplied in adequate amounts **(Pereira & Oliva- Teles, 2003)**.

Recently, CGM has been investigated as a replacer of FM for numerous fish species such as, Asian seabass, *Lates calcarifer* (**Nandakumar *et al*., 2017)**; striped catfish, *Pangasianodon hypophthalmus* (**Güroy *et al*., 2013)**; common carp, *Cyprinus carpio* (**Jahanbakhshi *et al*., 2012)**; puffer, *Takifugu fasciatus* **(Zhong *et al*., 2011)** and rainbow trout, *Oncorhynchus mykiss* **(Gerile & Pirhonen, 2017)** with no harmful effects on growth or general health status of the studied fish. No previous study was conducted on the impact of replacing FM with a graded percentage of CGM on tilapia performance, feed efficiency, chemical body analysis, some biometric indices, and economic revenue, thus the current would be the first to address this issue.

MATERIALS AND METHODS

1. Experimental groups and rearing condition

The experimental work was assigned in the wet laboratory belonging to the Department of Fish Nutrition and Technology, Central Laboratory for Aquaculture Research, Abbassa. Apparently healthy tilapia fish (37.09±0.02 g) were obtained from a governate fish hatchery belonging to the central laboratory for aquaculture research. Fish were acclimatized to lab conditions and fed a basal diet for the first two weeks. The fish used in the feeding trial were randomly allocated into four equal groups as follow; D_1, fed fish meal-based diet (control group); D_2, fed CGM-based diets (replace 15% of total FM content with CGM); D_3, fed CGM-based diets (replace 30% of total FM content with CGM); D_4, fed CGM-based diets (replace 45% of total FM content with CGM). Each group has five replicates, with ten fish per 100 L aquarium. The aquaria were continuously supplied with continuous aeration through air diffuser stones. Throughout the feeding trial, about 40% of the water in the aquarium was syphoned daily and refilled with dechlorinated clean water. Fishes were fed to apparent satiation twice daily (10.00 and 16.00) then after 30 min, uneaten diets were collected and dried to determine the actual consumed feed. The water quality criteria were measured biweekly and found to be in adequate range as ascribed by **Boyd & Tucker, (2012)** throughout the feeding trial (water temperature, dissolved oxygen, pH and total ammonia-N were 27±2°C, 5.5-6.5 mg/L, 7.5-7.8 and 0.12 mg/L ,respectively). The fish were kept in a natural photoperiodicity (12 L: 12 D).

2. Preparing formulated diets

Four isolipidic (8%) and isonitrogenous (32%) diets were prepared to determine the feasibility of CGM as a potential component to replace fish meal. The studied meals were manufactured by replacing a particular portion of fish meal with corn gluten meal on a weight-for-weight basis at 0% (control), 15%, 30%, and 45 %. **Table (1)** shows the chemical analysis of FM and CGM, whereas **Table (2)** illustrates the composition of the tested diets and their chemical components. Methionine and lysine deficiencies were repaired by including methionine and lysine supplements in all CGM-based meals except the control diet. In a micropulverizer, the coarse feed materials were crushed and sieved through a 0.3-mm sieve. Using an electronic blender, all of the prepared materials were mixed and homogenized. The prepared diet was turned into soft dough by adding the required amount of water, and then steam baked for 10 min, chilled, and pelletized using a 2.0-mm die in a small-scale laboratory extruder (Diamond America Co.). The cold extruded pelleted diets were dried in an oven at 50 °C until the moisture percentage reached below 10%. The oven-dried tested diets were packaged in airtight bags and preserved inside refrigerator until use.

Table (1): Chemical analysis (%) of fish meal (FM) and corn gluten meal (CGM).

Parameters	Fish meal (FM)	Corn gluten meal (CGM)
Dry matter	89.48	91
Organic matter	75.1	88.9
Crude protein	59.9	60.4
Crude fat	10.8	1.8
Crude fiber	0.8	1.5
Carbohydrate	3.6	25.2
Ash	14.38	2.1
Gross energy*	454.59	461.22

*Gross energy calculation based on values of CP, EE and NFE, 5.64, 9.44 and 4.11 kcal/g respectively. According to **NRC (1993)**

Table (2): Ingredients, formulation and chemical analysis of the tested diets

Items	Experimental diets			
	D_1	**D_2**	**D_3**	**D_4**
Diets formulation				
Fish meal	20	17	14	11
Corn gluten meal	0	3	6	9
Soy bean meal	37.5	37.5	37.5	37.5
Yellow corn	20.5	20.5	20.5	20.5
Wheat flour	15	13	11	7
Oil fish	3	3	3	3
Vegetable oil	2	2	2	2
Premix [a]	2	2	2	2
Methionine	0	0.25	0.5	1
Lysine	0	1.25	2.5	5
Threonine	0	0.5	1	2
Total	**100**	**100**	**100**	**100**
Proximate composition %				
Dry matter	100	100	100	100
Organic matter	96.06	96.42	96.79	97.16
Crude protein	31.98	31.99	32.01	32.03
Ether extract	8.94	8.67	8.4	8.13
Crude fiber	3.56	3.56	3.61	3.63
Nitrogen free extract	37.84	38.49	39.13	39.79
Ash	3.94	3.58	3.21	2.84
GE(kcal / kg diet) [b]	4203	4204	4205	4209

[a]Vitamin premix supplied the diet with (mg/ kg dry diet): retinol (VA) 10,000 international units (IU); cholecalciferol (VD) 1,500 IU; tocopherol (VE) 2500 IU; menadione (VK), 40; thiamin (VB1), 1; riboflavin (VB2), 9; pyridoxine (VB6),3; cyanocobalamin (VB12), 0.1 folicacid, 1.5; anti scorbic acid (VC),60.

[a] Mineral premix consisted of (mg/kg dry diet): 30000 Mg Copper, 250 Iodine, 300 Selenium, 50000 Manganese, 400 Cobalt, 60000 Zinc and 3000 Gm\ 30Kg CaCo3.

[b]: Gross energy calculation based on values of 5.64 kcal/g CP, 9.44 kcal/g EE and 4.11kcal/g NFE. According to **NRC (1993)**

3. Performance and feed efficiency parameters

The fish were weighed at the beginning and end of the trial to estimate the initial (IW) and final (FW) weights. For calculated consumed diet, the subsequent live body weight was recorded biweekly. Growth and feed efficiency measurements were computed as listed below:

- **Weight gain, WG (g) = W_F - W_I**
- **Weight gain percent, WG % = {(W_F - W_I)/ W_I}* 100**
- **Feed conversion ratio, FCR = FI/WG**
- **Specific growth rate, SGR (g day-1) = ((Ln W_F-Ln W_I)/ T) x100**

- **Feed efficiency ratio FER (g/g) = WG/FI**
- **Protein efficiency ratio, PER (g/g) = WG/PI**
- **Survival rate SR = $\{(N_I - N_F)/ N_I\}$ *100**

Where:

W_F is Final weight (g);
W_I is Initial weight (g);
FI is feed intake, is the total consumed diet (g);
T is the feeding trial period (days);
PI is protein intake, is the amount of protein consumed (g);
N_I is fish number at the starting of experiment;
N_F is fish number at the end of experiment

4. Chemical analysis of fish flesh and diet samples

The proximate analysis of the tested diets, as well as the total body chemical composition of fish samples, were carried out in accordance with standard **AOAC (2012)** methods. Three fish from each tank were taken at the end of the feeding experiment for whole chemical body analysis. Prior to assessing the whole-body composition, fish were killed using an overdose of anaesthetic. The fish samples were freshly weighed and then dried at 105 °C for 24 hr to estimate moisture content. The dried specimens were gathered and analyzed.

Crude protein (CP) was estimated using Kjeldahl as ascribed by **Sader *et al*. (2004)**. Crude lipids (CL) were determined by a Soxhlet system (SOCS, Pelican, India), using petroleum ether extraction method. The total ash was measured after 6 hrs of ignition of sample at 600 °C in a muffle furnace. In addition, following acid and alkali digestion and mass loss by burning at 600 °C for 3 hrs, crude fiber was estimated following **Nandakumar *et al*. (2017)** protocol. The Nitrogen-free extract (NFE) was calculated according to the following formula; NFE= 1000 − (CP + CL + CF + Ash). All chemical examinations were performed using five replicates, and the findings were evaluated on a wet weight basis.

5. Body indices measurements

At the end of the feeding trial, fish were anaesthetized using clove oil at a concentation of 0.5 ml L^{-1} then the total length and weight of each fish were recorded. Hence, the condition factor (CF) was calculated using the following formula:

$$CF= l00W/L^3;$$

Where: **W**, is the weight of the fish body (g); and L is the length of fish (cm). Five fish from each aquarium were randomly collected to determine the biometric indices. The liver and viscera of fish were dissected out and weighed for calculating the hepatosomatic index (HSI) and viscerosomatic index (VSI) as ascribed by **Syed *et al*. (2015)**. Furthermore, the total length of the intestinal tract was measured to the nearest cm.

6. Economic analysis

The costs of consumed feed and the pricing of harvested fish were used to determine the economic impact of the experimental diets. The cost of the examined diets was estimated in Egyptian Pounds (L.E.) and then adjusted to US Dollars ($) using the following formulae, as ascribed by **Abo-Taleb *et al*. (2021)**:

Incidence cost = the income of the harvested fish (102.11 US$) + the cost of consumed feed to harvest 1000 fish (6)

Income from fish = the cost of 1000 fish (102.11 US$) x Survival percentage (7)

Profit rate = income from fish /cost of feed intake (1000 fish) (8)

Economic conversion rate (ECR) = consumed diet (g)/gain of weight (g) (9)

The cost is for 1 kg of each of D_1, D_2, D_3 and D_4 which were 0.81, 0.71, 0.69, and 0.66 US$, respectively.

7. Statistical Analysis

Data were statistically examined for significant differences between treatments applying one-way analysis of variance (ANOVA), whereas Tukey's range tests were operated to identify the significance letters between the means of the treatment. The collected data were analyzed using SPSS version 22.0 software. All data were presented as mean ± SE.

RESULTS

1. Performance and efficiency of feed

During the 10 weeks of the feeding trial period, no mortality was recorded for tilapia fish fed the examined diets with or without CGM inclusion. Growth and feed utilization of fish fed the FM (D_1) or diets containing CGM as fish meal replacers (D_2, D_3, and D_4) are illustrated in **Table (3)**. Significantly ($p<0.05$) higher feed intake, weight gain and weight gain percent were observed for fish fed either D_3 or D_4 diets similar to D_1 diets compared to the other diets. The other growth and feed utilization parameters such as FCR, SGR, PER and FER showed no significant differences between all experimental diets.

The relation between WG, FCR, and high FM replacement concentrations with CGM revealed line polynomial regression trends with strong correlation R^2 = 0.98 and 0.92, respectively, which proved that the most propionate replacement level of FM with CGM could be specifically at 45% according to tested diets (**Fig. 1**).

2. Whole fish body chemical analysis

The whole-fish-body chemical analysis of tilapia fish fed the Fm based diet and CGM as FM replacer is shown in **Table (4)**. Amongst all tested diets, the tilapia fish fed the diet D4 attained the highest significant ($p<0.05$) body proximate compositions of CP, NFE, and ash levels, as well as they showed the lowest significant ($p < 0.05$) level of CF. Also, there were no significant changes in moisture and OM % between fish groups given FM or CGM-based diets **(Table 4)**.

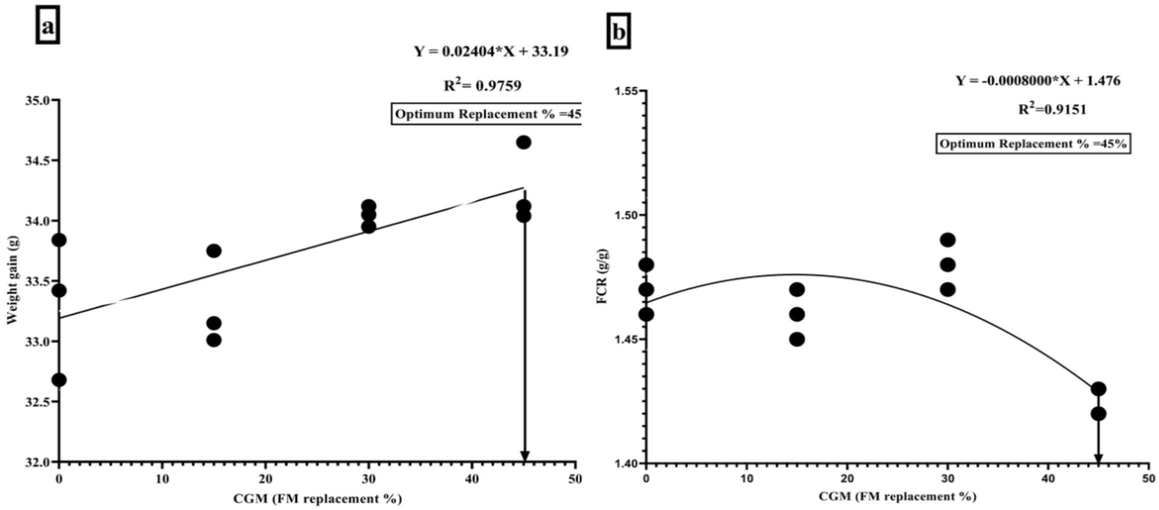

Fig. (1). Poly-nominal regression of different weight gain (a) and feed conversion ratio (b) in tilapia fish diets influenced by fish meal substitution % with Corn Gluten meal (CGM)

Table (3): Effect of fish meal replacement with corn gluten meal on growth performance and feed utilization indices of tilapia fish**.**

Measurements	Experimental diets				*P* value
	D_1	D_2	D_3	D_4	
IW (g)	37.10±0.01	37.09±0.01	37.11±0.02	37.09±0.02	0.852
FW (g)	70.94±0.43	70.84±0.58	71.06±0.79	71.13±0.95	0.054
FI (g/fish)	50.08±0.94^{ab}	49.28±0.84^{b}	50.58±0.51^{a}	48.33±0.88^{b}	0.016
WG (g)	33.84±1.00^{a}	33.75±0.67^{ab}	33.95±0.49^{a}	34.04±0.67^{a}	0.012
WG %	912.13±2.08^{a}	909.94±1.68^{b}	914.85±1.38^{a}	917.76±2.08^{a}	0.015
FCR (%)	1.48±0.38	1.46±0.16	1.49±0.64	1.42±0.92	0.048
SGR (g day^{-1})	0.93±1.08	0.92±0.86	0.93±0.58	0.93±1.14	0.112
PER (g/g)	2.11±0.85	2.14±1.12	2.10±0.16	2.20±0.81	0.162
FER (g/g)	0.67±0.96	0.68±0.18	0.67±0.36	0.70±1.64	0.051
SR (%)	100	100	100	100	0.552

IW, initial weight; FW, final weight; FI, feed intake; WG, weight gain; WG%, weight gain percentage; FCR, feed conversion ratio; SGR, specific growth rate; PER, protein efficiency ratio; FER, feed efficiency ratio; SR, survival rate. Values are means ± SE. Means in the same row with different superscript are significantly ($p<0.05$) different.
D_1, fish group fed fish meal-based diets; **D_2**, fish group fed fish meal replacement with 15% corn gluten meal diets; **D_3,** fish group fed fish meal replacement with 30% corn gluten meal diets; **D_4,** fish group fed fish meal replacement with 45% corn gluten meal diets.

3. Biometrics indices

The biometric measurements of the CF, HIS, VSI and intestine total length of tilapia fish exhibited normal fish health status that fed the basal diet (D1) or FM replacement level with 30% CGM (D3). The fish fed FM replacement with graded levels of CGM recorded high significance differences ($p<0.001$) in HSI values. The low HSI values were found to be correlated with the D_3 fish group fed CGM and FM based diet. Other body biometric indicators, such as CF, VSI, and total intestinal length, revealed no statistically significant differences between all examined groups **(Table 5)**.

4. Economic revenue

The economic–profit analysis of tilapia fish fed FM replacement with graded levels of CGM is represented in **Table (6)**. In the compartment with the FM based diet group, the obtained results showed that the lowest cost of feed (1.357 US$ 1000 fish^{-1}), incidence cost (103.47 US$ 1000 fish^{-1}), and the maximum profit index (75.25 US$) were recorded with fish fed D4 **(Table 6)**. There were no significant differences in the other estimated economic characteristics between the FM based diet and the other CGM based diet. However, the ECR was enhanced by increasing the CGM substituting level of FM from 15 to 30% by 9.1% and 8%, respectively.

Table (4): Effect of fish meal replacement with corn gluten meal on whole chemical body composition of Nile tilapia fish (DM % basis).

Parameters	Experimental diets				*P value*
	D_1	**D_2**	**D_3**	**D_4**	
Moisture	72.53±0.41	74.92±1.51	72.96±2.56	74.25±1.50	0.587
OM	82.03±1.08	80.25±1.73	81.58±2.99	79.97±1.28	0. 632
CP	46.02±0.79^{c}	47.36±0.36^{bc}	47.92±2.38^{ab}	48.82±1.34^{a}	0.002
CF	27.45±1.34^{a}	25.60±2.80^{ab}	23.46±1.97^{b}	21.07±0.90^{c}	0.012
NFE	8.42±1.70^{b}	10.32±3.51^{a}	7.46±2.53^{c}	9.71±1.69^{a}	0.042
Ash	17.97±1.08^{c}	19.75±1.73^{b}	18.42±2.99^{c}	24.03±1.28^{a}	0.023

OM, organic matter; DM, dry matter; CP, crude protein; CF, crude fat; NFE, nitrogen free extract Values are means ± SE. Means in the same row with different superscript are significantly ($p<0.05$) different.

D_1, fish group fed fish meal-based diets; **D_2,** fish group fed fish meal replacement with 15% corn gluten meal diets; **D_3**, fish group fed fish meal replacement with 30% corn gluten meal diets; **D_4**, fish group fed fish meal replacement with 45% corn gluten meal diets.

Table (5): Effect of fish meal replacement with corn gluten meal on some body indices of Nile tilapia fish

Item	Experimental diets				*P value*
	D_1	D_2	D_3	D_4	
CF	1.76±0.14	1.81±0.08	1.84±0.13	1.84±0.15	0.056
HSI, %	9.64±2.91^b	13.27±3.16^a	8.97±1.02^b	12.28±4.40^a	0.001
VSI, %	4.67±0.72	4.54±0.76	5.08±1.08	4.57±0.66	0.613
IL, cm	41.6±1.36	40.98±2.03	41.32±1.91	40.81±1.26	0.064

CF, condition factor; HSI, hepato-somatic index; VSI, viscera somatic index; IL, intestine length. Values are means ± SE. Means in the same row with different superscript are significantly (p<0.05) different.
D_1, fish group fed fish meal-based diets; **D_2**, fish group fed fish meal replacement with 15% corn gluten meal diets; **D_3**, fish group fed fish meal replacement with 30% corn gluten meal diets; **D_4**, fish group fed fish meal replacement with 45% corn gluten meal diets.

Table (6): Cost–profit analysis of tilapia fish fed fish meal replacement diets with corn gluten meal**.**

Item	Experimental diets			
	D_1	D_2	D_3	D_4
FP (US$ 1000 fish^{-1})	102.11	102.11	102.11	102.11
FC (US$ 1000 fish^{-1})	1.411	1.416	1.435	1.357
IC (US$)	103.52	103.53	103.55	103.47
ICR (%)	100	99.99	99.98	100.1
PI (US$)	72.37	72.11	71.16	75.25
PR (%)	100	100.4	101.3	94.56
ECR	1.91	1.75	1.62	1.63
ECRR (%)	100	109.1	108	99.39

FP, Fish price; FC, feed cost; IC, incidence cost; ICR, incidence cost rate; PI, profit index; PR, profit rate; ECR, economic conversion rate; ECRR, economic conversation rate ratio.
D_1, fish group fed fish meal-based diets; **D_2**, fish group fed fish meal replacement with 15% corn gluten meal diets; **D_3**, fish group fed fish meal replacement with 30% corn gluten meal diets; **D_4**, fish group fed fish meal replacement with 45% corn gluten meal diets.

DISCUSSION

The findings showed that fish meal might be substituted with a specified level of CGM in tilapia diets without affecting growth performance, feed efficiency, body composition, or any biometric indices. Numerous research has been carried out, with different degrees of success, to investigate the nutritional benefits of various plant protein sources like rice polish (**Khan *et al*., 2013)**, soy protein **(Chen *et al*., 2019)**, corn gluten meal (**Gerile &Pirhonen, 2017)** as replacements for fish meal in tilapia. Based on the existing results, CGM may be substituted 30 up to 45 % of FM in the diet. Furthermore, when CGM was raised beyond 30%, fish feed intake and FCR improved significantly. The polynomial regression proved that a high partial replacement level of FM with CGM is associated with the maximum weight gain and the lowest FCR. The obtained results coincide with **Al-Thobaiti *et al*. (2017)** who reported that CGM may replace up to 20%

of the FM content without affecting tilapia health. Furthermore, **Metwalli (2013)** investigated that partial replacement of FM with CGM up to 75% might be applied in tilapia diets with no adverse impacts on performance, the efficiency of consumed feed, or blood characteristics. Hence, the FM replacement level with a high level of CGM in the diet of juvenile Japanese flounder is estimated to be 40 up to 60%, when the diet is complemented with essential amino acids **(Kikuchi, 1999)**. It should be highlighted that both cereals and their by-products contain low levels of essential amino acids like lysine and methionine (**Gatlin *et al*., 2007)**. The amino acids were supplied in the current feeding trial to prevent the common deficiency of certain amino acids of CGM, particularly lysine. Many investigations have been performed on the role of supplemented amino acids in the diets of several fish species, including *Clarias gariepinus* **(Fasakin *et al*., 2006)**, *Paralichthys olivaceus* (**Kikuchi, 1999)**, and *Oncorhynchus mykiss* **(Davies & Morris, 1997)**, which demonstrated that CGM enriched levels could be raised up to 16–29%. Furthermore, there are many variables that may influence the high level of replacement across different fish species, such as the fish's ability to maintain critical amino acid requirements, digestibility, and diet formulation **(Kamalam *et al*., 2017)**.

The condition factor (CF) represents physical and biological status, as well as modification in food reserves, and is therefore an indication of overall fish general health status. In addition, the hepatosomatic index (HSI) is an important indicator of an animal's energy supplies, particularly in fish **(Chellappa *et al*., 1995)**. A substantial reduction in the hepatosomatic index indicated numerous hepatocytes disorders, including cytoplasmlysis and severe degeneration of proliferating hepatocytes **(Mehana *et al*., 2020)**. According to our results, body biometric indices like condition factor (CF), total intestinal length (IL), and viscerasomatic index (VSI) showed no significant difference between the fish fed FM based diet and fish group fed FM replacement diet with graded levels of CGM. Moreover, the HSI values revealed significant improvements in cooperation with increasing CGM (45%) in the fish diet. Similarly, the obtained HSI values in this feeding trial were similar to those found in tilapia **(Metwalli, 2013)**, hybrid red tilapia **(Abdel &Atallah, 2016)** and *Tilapia zillii* **(Ibrahim *et al*., 2008)**.

The crude protein, NFE, and ash levels of tilapia were significantly promoted with increasing inclusion levels of CGM in the diet, while the crude fat level was decreased substantially with rising CGM levels in the experimental diets. The obtained results agree with several recent findings in *Dicentrarchus labrax* **(Ballestrazzi *et al*., 1994** and **Dias *et al*., 2005)** and *Oncorhynchus mykiss* **(Yamamoto *et al*., 1995)** postulated that the partial replacement of FM with CGM markedly increased the fat and protein retention levels of the entire fish body composition. In contrast to the HSI values observed in the experiment, the total lipid level of tilapia muscle from fish fed a high level of CGM-based diet was significantly lower than values found in fish fed other diets, a situation that is likely related to CGM's inability to promote bile acid secretion throughout the gut **(Potter, 1995)**. Another attribution, this impact may be attributed to an increase in hepatic apo B/E receptor activity, which increases hepatic absorption of very low-density lipoprotein (VLDL), as well as the fact that VLDL in fish contains more cholesterol than VLDL in mammals **(Dias *et al*., 2005)**.

In our feeding experiment, the cost–profit findings indicate that fish given D_4 had the lowest ECR, feed cost, and profit index when compared to fish fed FM (D_1). Despite showing the same tendencies as D_4 in terms of performance, feed efficiency, and whole-body chemical analysis, D_3 finished second to D_4 in terms of economic assessment with a small margin. These results showed that a 30 up to 45 % substitution of FM with CGM (D_3 and D_4) is the best FM alternative resource for tilapia. In accordance with the present results, **El-Ebiary (2005)** reported that replacing up to 25% from FM with a different protein source in the tilapia diet significantly decreased the price of the formulated diet while keeping normal growth performance. Furthermore, one of the primary goals of FM replacement is to retain the cost-efficiency of the formulated diet while preserving the biological and environmental elements as a positive approach.

CONCLUSION

The sustainability of fish meal is one of the most significant problems facing the aquaculture sector. Until recently, there has been no viable diet for tilapia based on corn gluten meal (CGM) supplemented by necessary amino acids as a complete or partial replacement for fish meal. Based on the findings of this research, CGM may be considered a useful protein source for tilapia. It has the potential to replace up to 45% of dietary FM while improving growth performance, feed consumption, chemical composition and the economic revenue of *O. niloticus*.

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