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Effect of Replacement of Fish Meal by Corn by Product Meal on Growth Performance For Nile Tilapia (*Oreochromis Niloticus*)

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Abstract

THE current trial investigates the impacts of replacing fish meal (FM) with corn gluten meal (CGM) on tilapia fish's productive performance and economic efficacy. A 12-week feeding experiment was conducted to examine the impact of substituting FM with CGM on 360 fingerlings of Nile tilapia (with initial weight = 3.01 ± 0.01 g). The experimental fish were randomly divided into six equal groups, with triplicates in each group (20 fish per replicate). The control group was administered FM-based diets (CGM0) with 20% FM. Whereas, CGM was employed to substitute 20%, 40%, 60%, 80%, and 100% of dietary FM protein in the other five isonitrogenous (crude protein: 32.85%) and isoenergetic (17.60 MJ kg-1 dry matter) formulated diets. Meanwhile, the findings showed a significant ($p<0.05$) decrease in performance markers (final biomass, weight gain and weight gain percent) for the group that received a high replacement amount of FM with CGM (80 or 100%) compared to control and other treated groups. Compared to the control group, substituting FM with 20, 40%, or 60% CGM significantly ($p<0.001$) increased protein efficiency measures. Furthermore, specific growth rate, feed conversion rate, feed efficiency, and survival rate reported no significant effect at any replacement level. Meanwhile, incorporating CGM in tilapia fish diets as an alternative to fish meals with high levels (80-100%) significantly increased serum levels from protein constituents, thyroid agents, and triglyceride content. Moreover, the replacement of FM with CGM is more economical. In conclusion, incorporating CGM instead of FM up to the level of 60% does not negatively impact the fish performance, but also improves the economic efficiency of Nile tilapia feed.

Keywords: Fish meal, Corn gluten, Growth performance, Digestibility, Health, Economically.

Introduction

Egypt ranked first in Africa and sixth in the world in aquaculture for the year 2018, according to the statistics of the Food and Agriculture Organization [1]. In 2019, fish production exceeded 2 million tons, with aquaculture contributing to 80% of total production, and tilapia is considered one of the main economic farmed fish species cultivated in Egypt [2]. As aquaculture grows increasingly important for feeding the world's expanding population, so do the natural resources necessary

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to generate aquaculture feed ingredients [3]. Tilapia are warm-water fish with a light flavor, high yield, and tolerance to poor water quality [4-6]. Economically, Nile tilapia is one of the most significant freshwater fish species. It is extensively cultivated because it is adaptable to many different environmental conditions,is a mixed-feeding species, grows fast, and reproduces easily [7].

The feed cost in fish farms is about 50-80% of the production cost. Furthermore, the aquaculture sector's sustainability strongly depends on a continual supply of feed protein and oil resources [8]. Fish meal (FM) is widely employed as a primary protein source in aquafeeds due to its high crude protein content, balanced amino acid profile, and palatability [9]. Only limited fish species are a source of FM and these species are relatively stable [10]. In addition, they revealed that FM is the main source of animal protein in processed fish feed [11]. With an increasing demand for FM and the restrictions governments impose to reduce poaching, its availability is decreasing, and its price is increasing [12]. This increased cost of using FM drives the ongoing search for unconventional protein sources, including CGM [13]. Aquatic organisms prefer to use protein for energy, which is the most important and valuable component of aquatic diets. Additionally, fishmeal (FM) is also essential in fish feed as a source of protein [14].

The CGM is a vegetable residue from the corn starch industry [15,16]. CGM is a protein concentrate that contains low concentrations of several antinutrients commonly found in other plant-derived ingredients [17,18]. Thus, it is a good alternative due to its high protein (40-60%) and low dietary inhibitors and fiber content, except for the high content of arginine and lysine [19]. Currently, CGM is utilized as an alternative to FM and has no adverse effects on the growth and efficiency of many fish species that consume feed. For example, substituting 60% of the FM with CGM had no significant effect on sea bream growth performance [20]. Besides, Wu et al. [21] reported that CGM could replace 75% of dietary FM (equal to 16.2% of CGM inclusion level in diet) without reducing the growth performance of abalone (Haliotis discus hannai) significantly. Besides, Hermawan et al. [22] reported that CGM could be incorporated into the Nile tilapia feed diet.The economic evaluation indicated that incorporating CGM into fish feed might lower feeding costs by 5-6 times compared to FM-based diets.

Therefore, the current trial aimed to evaluate the impacts of replacing FM with graded levels of CGM (20%, 40%, 60%, 80%, and 100%) on the growth, feed efficiency, blood biochemical and hematological indices, nutrient digestibility, economic efficiency and flesh chemical composition of the Nile tilapia fish. It delivers basic information for applying CGM in the formulated diet for Tilapia.

Experimental

This study was conducted at the Animal Production Department, Faculty of Agriculture, Zagazig University, Egypt. The experimental work was conducted at the Central Laboratory for Aquaculture Research, Abbassa, Abu-Hammad, Sharkia Governorate, Egypt.

Aquaria and water

Three hundred and sixty fingerlings of Nile tilapia were assigned randomly into six treatments (60 fish per treatment). All treatments contained three replicates (20 fish/replicate), with an average weight of 3.01±0.01g. The feeding trial period was extended to 12 weeks. The experimental fish were acclimatized in a 300 L fiberglass tank for two weeks before the feeding trial experiment. Aquaria was supplied with dechlorinated water from the storage tank. Air pumps were used to provide air to the glass aquariums. Fish waste was removed daily by siphoning one-third of the aquarium volume and replacing it with clean water. The water samples were collected biweekly from each aquarium to monitor the water quality measurements. The water temperature was determined daily using a thermometer. The following water quality parameters values were under optimal levels for tilapia culture: the dissolved oxygen, pH, ammonia, nitrite, nitrate and total hardness was 5.5 mg/L, 7.5, 0.2 mg/L, 0.05 mg/L, 10 mg/L and 185 mg/L, respectively. The average water temperature varied from 25 to 31 °C during the experimental period.

Experimental diets and Feeding regimes

Six tested diets were formulated to be isonitrogenous and isocaloric. The FM was replaced by five graded percentage levels of CGM (0, 20, 40, 60, 80 and 100% Kg^{-1} diet). The chemical analysis of FM and CGM are shown in Table 1. Also, the formulation and chemical composition of experimental diets are shown in Table 2. Adding CGM rather than FM increased organic matter, crude protein, crude fibre, nitrogen-free extract, and gross energy. Increasing the CGM level in the diets decreased ether extract and ash content. Fish were hand-fed twice daily, at 10:00 a.m. and 2:00 p.m., until apparent satiation. Small quantities of the diets were supplied until 1-2 feed pellets remained on the bottom of the aquarium for 20-30 minutes without being consumed. Feed supply was calculated as a percentage of live fish biomass (3% of fish body weight).

Digestibility trial

The digestibility trial began at the end of the growth experiment, with fish weighing 19.2±1.2 g selected from each treatment group and transported in triplicate into glass aquaria (10 fish/aquarium; dimensions = 60x50x40 cm). The digestibility study was extended to a maximum of thirty days. The fecal collection began four days following the feed-ingest meals to enable the discharge of all previously ingested feedstuff. Daily, the aquaria were drained to remove any uneaten feed and the water in each glass aquaria was fully replaced with new clean fresh water. The manual fecal collection was accomplished by siphoning and filtering through a fine-meshed net [23]. Fecal matter gathering from each aquarium was pooled and dried under 50 °C for 5h. The specimens were analyzed in triplicates to determine the nutrients (dry matter, crude protein, ether extract and nitrogen-free extracts) following the procedure by AOAC [24]. Chromic oxide in the faeces was estimated according to the procedure of Furukawaand Tsukahara [25]. The method included the digestion of the sample by highly concentrated nitric acid and oxidizing chromic oxide with 70% perchloric acid [26]. Chromic oxide was computed employing the following formula:

Chromic oxide (%) = (absorbance − 0.0032 ÷ 0.2089) ×100 ÷ sample weight. The measurement of chromium was estimated in feces samples at Zagazig University, Faculty of Technology and Development Central Lab for Soil, Food and Feedstuff (CLSFF) laboratory (ISO 17025/2017).

The apparent digestibility coefficient (ADC) of the formulated diets was computed as follows:

ADC (%) = [1- (dietary Cr level / fecal Cr level) × (fecal nutrient / dietary nutrient)] 100 ×. The apparent digestibility of dry matter (DM %) in all diets was calculated from the following equation:

DM% = (% indicator in feces - % indicator in feed)/ % indicator in feces × 100.

Growth and feed utilization parameters

Total feed intake (FI) = the total weight of the offered diet during the experiment of survived fish.

Body weight gain (BWG) = The final average body weight (g) - The initial average body weight (g).

Weight gain percent, (WG %) or relative growth rate (RGR) = BWG 100× / initial weight [27].

Specific growth rate (SGR) = (Ln final body weight – Ln initial body weight) 100× ÷ Time (day) [28].

Feed conversion ratio (FCR) = total consumed feed (g)/ weight gain (g).

Feed efficiency ratio FER (g/g) = BWG (g) / total feed intake (g).

Protein efficiency ratio (PER) = BWG/ protein intake (PI, g).

Protein intake PI = dry matter feed ×protein ratio in the diet.

Protein productive value (PPV) = protein retention 100×/ PI.

Protein retention (PR) = final fish body protein (g) - initial fish body protein (g) [29].

Survival rate (SR) = (numbers of survived fingerlings/numbers of initial fingerlings) × 100.

Analysis of formulated diets and whole-fish body composition

The chemical analysis of formulated diet and fish specimens has been analysed and estimated total moisture content, dry matter, organic matter, crude protein, ether extract, crude fiber, and ash content using AOAC [30] technique. Five fish from each treatment group were dried at 65 °C for 72 hours or until the weight was stable in the oven drier, and then fully dried at 105 °C for 3 hours for further chemical analysis. On the other hand, diet analysis was done in triplicate for every single meal tested.

Blood sample collection and body-somatic index

After a 24-hour fasting period, five fish from each treatment group were randomly selected and anesthetized with 50 l of clove solution to obtain blood samples. The blood samples were obtained from the caudal vein and separated into two equal parts. The first aliquot was heparinized for hematological determination, while the other aliquot was allowed to coagulate for 30 min at room temperature. After coagulating the specimens, they were centrifuged at 3000 rpm for 15 min at 4 °C to obtain serum, which was kept at -20 °C for subsequent biochemical investigation. The total length and final weight of each fish were recorded to calculate the condition factor (K) as follows: K = (body weight (g)/ body length (cm)^3) × 100. Whereas, the liver and viscera of fish were dissected out and weighed for calculation of Hepatosomatic index (HSI) and Viscera-somatic index (VSI) as follows: Hepato-somatic index = [liver weight (g) / body weight (g)]×100, while viscera-somatic index = (visceral weight, g/ body weight, g) × 100 [31]. In addition, intestinal weight, length, and spleen and gas bladder weight were measured to determine other body somatic indices.

Blood Haematological and biochemical assessment

The serum total protein, albumin, triglycerides and liver enzyme activities (Aspartate Amino Transferase AST, Alanine Amine Transferase ALT) content was determined using Bio-diagnostic commercial kits (Cairo, Egypt) as described by many authors [32- 35] techniques, respectively. Meanwhile, hemoglobin (Hb), total red blood cells (RBC), and packed cell volume (PCV) counts were determined according to Witeska et al. [36] procedure. The globulin values were calculated by subtracting the albumin value from the total protein content. The thyroid activity (T_3 and T_4) was carried out by enzyme-linked fluorescent assay employing commercial kits (mini VIDAS®- bioMérieux) following manufacturer instructions.

Economical study

The economical feed efficiency was calculated from the cost of one kg feed in Egyptian pounds (L.E) and the weight gain of fish from the equation:

Profit per one fish (L.E.) = Selling price - (total feed cost per fish + initial fish price).

Statistical analysis

Data was subjected to One-way analysis of variance (ANOVA) statistical analysis using SPSS program version 22.0 software for Windows. The obtained results are expressed as means ± standard error (SE). Differences among means were evaluated by using Duncan's multiple-range tests [37].

Results

Fish performance and Survival rate

The results presented in Table 3 showed significant improvement in some growth performance indices such as, the final body weight (FBW), total weight gain (TWG), weight gain percent (WGP), average relative growth rate (RGR), and specific growth rate (SGR) up to 60% CGM. In addition, the incorporation of CGM into tilapia diets did not induce any significant alterations in Total feed intake (TFI), feed conversion ratio, feed efficiency (FE) and survival rate between all treatments (P > 0.05). Conversely, FBW, TWG, WGP, RGR, and SGR significantly (P<0.05) decreased with an elevation of CGM with 80, and 100 % compared with those in the control diet.

Protein efficiency ratio (PER), and protein productive value (PPV)

The inclusion level of CGM within the fish diet led to an improvement in protein efficiency ratio (PFR), and protein productive value (PPV) with increasing CGM up to 60% in the tested diets for tilapia (Oreochromis niloticus) fingerlings (Table 4).

Digestibility of nutrients

Table 5 presents the results of the digestibility assessment. The replacement of FM with CGM has no harmful impact on the nutritional digestibility of Nile tilapia. Substituting FM with CGM over 20% significantly improved all estimated nutrient digestibility (P < 0.05). The greater crude protein, dry matter, ether extract, and nitrogen-free extract values were reported in the fish group given 20% CGM, followed by 40 and 60% CGM as a substitute for the entire FM content.

Whole body composition

The body analysis findings revealed a considerable rise (P<0.05) in CP and EE concentrations in fish given diets containing 20,40 or 60% CGM as a substitute for FM, whereas ash content was significantly lowered (Table 6). However, the moisture content was unaffected by the CGM replacement proportion. Replacement FM with 20% CGM recorded the highest CP content and the lowest EE content. Meanwhile, when dietary CGM levels rose, whole fish body lipids increased modestly.

Blood parameters

Some blood characteristics showed significant variation after replacing FM with graded amounts of CGM (P<0.05). In contrast, there were no significant differences between any experimental groups in total protein, aspartate aminotransferase

(AST), and Alanine aminotransferase (ALT) values (Table 7). While, albumin, globulin, A/G ratio, triglyceride, $_{T3}$, and T_4 levels rose remarkably as CGM substitution levels increased in the fish diet, in which haemoglobin, RBCs, and PCV count declined significantly (P<0.001).

Biological indices

The condition factor (K), hepatosomatic index (HSI), total intestinal length (IL), and viscera-somatic index (VSI) (Table 8) revealed that there was no significant difference between the control and experimental diets containing graded levels of CGM up to 60%.

Economic efficiency

Table 9 shows the economic feed efficiency of the experimental diets. The feed cost was computed using the local market values at the start of the experiment (August 2021). The economic study found that diets substituted with CGM over 40% replacement level had a lower feed cost per kg than the control group. The highest feed cost kg^{-1} of growth occurred at CGM replacement levels of 100%, 80%, 60%, and 40%, respectively. Meanwhile, the relative feed cost per kg growth was highest in the 60% CGM substituted group (155%), then followed by 20% and 100% CGM (150%), and finally was 144.44% at the 40% and 80% CGM fish group.

Discussion

The inclusion of CGM instead of FM increased organic matter, crude protein, crude fibre, nitrogen-free extract, and total energy. On the contrary, the ether extract and ash contents were decreased by raising the level of CGM in the diet. Because CGM is considered a vegetable residue that contains fibre, and the percentage of protein in it is higher than the percentage of protein in FM, and it also contains a percentage of NFE that is higher than FM, so its content of mineral salts is less.

The results showed an improvement in growth performance, FI, FBW, BWG, WGP, SGR, RGR, FE and FCR at the end of the experiment, even to a level of 60%. In addition, the CGM replacement indicated no significant differences in feed conversion ratios between all treatments (P > 0.05). However, FI, BWG, WGP, RGR, and SGR significantly (P<0.05) decreased with an elevation of CGM levels in the diets containing 80% and 100 % of CGM compared with those in control. The improvement by CGM supplementation agrees with Allam et al. [38]. They illustrated improving growth performance and feed consumption of Nile tilapia when replacing up to 45% of dietary FM with CGM. Also agrees with Sadek et al. [39], who mentioned that a diet containing 75% FM and 25% CGM gave the best FCR, PER, and PPV. In addition, suggested that up to 25% of the fish meal protein could be substituted with CGM in the tilapia fingerlings (Oreochromis niloticus) diet without affecting fish growth or nutrient composition. Also, Metwalli [40] demonstrated that incorporating CGM instead of FM up to 50% in Nile tilapia (Oreochromis niloticus) fish diets improved all growth parameters without inducing any significant effects. Besides, it was found that including the CGM in tilapia meals increased body weight. Also, they observed that fed tilapia fish with meals containing CGM resulted in higher growth and improved FCR values than fishmeal-based diets [29].

In addition, the survival rate results indicated that no statistically significant differences were found among all treatments. These results are consistent with what was suggested by El-Ebiary [29]. They revealed that incorporating CGM into Nile tilapia feed up to 45% instead of fishmeal did not significantly affect the survival rate. Moreover, Khalifa et al. [41] demonstrated that up to 25% of fishmeal protein might be substituted with CGM in fingerling tilapia (Oreochromis niloticus) diet without reducing survival, growth and feeding rates.

The investigation demonstrated that increasing CGM content in fish feed by up to 60% enhanced PFR and PPV values in tilapia fish (Oreochromis niloticus). This result agrees with El-Ebiary [29], who mentioned that a diet containing 75% FM and 25% CGM gave the best PER and PPV. Metwalli [40] exhibited that there were no significant differences in the values of both PER and PPV (P<0.05) between diets containing 0, 50, and 75% CGM instead of FM, respectively.

The nutritional digestibility findings demonstrated that FM may be replaced with considerable amounts of CGM in the diet of Nile tilapia without affecting digestive efficiency. The results indicate that CGM is a good dietary component for Nile tilapia and can be included in tilapia diets up to 60% of the diet without compromising digestibility. Pereiraand Oliva-Teles [19], and Nandakumar et al. [42] showed that the utilization of apparent digestion in dry matter, protein, and energy digestion of seabass diets and similar species was high with the increase of

CGM substitution level. While in white shrimp, there was a substantial improvement in nutrient digestion with increasing the amount of CGM replacement ($P < 0.05$) [43]. The variation in the utilization rate of increasing the amount of CGM in meals is attributable to the different breeds of fish, the degree of amino acid balance, and the number of dietary inhibitors included.

The results showed that moisture and dry matter were not affected by increased FM substitution by CGM in tilapia diets. At the same time, there was a significant increase ($P < 0.05$) in the CP content at the 20% level only, and it decreased at the rest of the levels. The ash content also decreased significantly in the body chemical analysis due to increased replacement. Meanwhile, OM and EE increased significantly with increasing substitution levels. These results are consistent with what was suggested by El-Ebiary [29], who explained that the body composition of the fish was significantly affected ($P < 0.05$), as both body water and fat percentage increased at the level from 25 to 50%, unlike protein and ash, where both protein and ash decreased with an increase in the substitution level. Metwalli [40] suggested that the contents of DM, CP, crude fat, and ash in whole fish body analysis did not change significantly regarding different dietary treatments. However, the percentage of fish body fat was slightly increased by increasing dietary CGM levels in the diets.

Blood characteristics results indicated that the replacement of FM by CGM indicated no remarkable effects on blood constituents ($P<0.05$) between the experimental groups. The A/G ratio T_3 was significantly lower in control compared to 80% and 100% CGM. On the other hand, RBCs and PCV significantly increased. These results agree with those recorded in tilapia by Metwalli [40], and Shalaby [44].

The condition factor (K) indicates the overall general health status of the fish. Also, the hepatosomatic index (HSI) is an important indicator of energy supply in fish [45]. A substantial reduction in the HSI indicated numerous hepatocyte disorders, such as cytoplasm lysis [46]. Our results showed no significant difference between body biometric indices like K, HSI, total intestinal length (IL), and visceral somatic index (VSI) in fish-fed FM-based (control) diets and experimental diets containing graded levels of CGM up to 60%. These results agree with the results of several previous reports [17, 47, 48]. Moreover, the HSI values revealed significant improvements with increasing CGM up to (60%) in the fish diet. Similarly, the obtained HSI values in this feeding trial were similar to those found in tilapia [40].

Thecost–profit findings indicate that the feed cost was calculated according to the local market prices at the beginning of the experiment (August 2021). The economic analysis revealed that the feed cost per kg of gain in the diets supplemented with CGM was lower than that of their counterparts without CGM supplementation. The best-feed cost kg^{-1} of gain was 100%, 80%, 60% and 40% CGM, respectively, while the worst was control. Relative feed cost per kg of gain of 100% CGM was higher than that of 0% CGM. Elevating the inclusion level of CGM in Nile tilapia diets to 100% positively impacted the cost of the growth unit. From the economic study, the profit was for 60% CGM (155.56%), 20% and 100% CGM (150%), then 40% and 80% CGM (144.44%). This results in agreement with

Khadr et al. [49]. They revealed that including CGM up to 45% of tilapia diets improved the economic efficiency of the diet. Following the present results, El-Ebiary [29] reported that replacing up to 25% of FM with a different protein source in the tilapia diet significantly decreased the price of the formulated diet while keeping normal growth performance. In addition, one of the primary goals of FM replacement is to retain the cost-efficiency of the formulated diet.

Conclusion

The substitution of FM with CGM at 20, 40, and 60% rates had no negative impacts on growth performance, nutrition utilization, body chemistry analysis, or estimated blood parameters. Furthermore, FM substitution with 60% CGM resulted in the largest relative economic profit compared to the control group. Finally, it was proven that FM could be replaced with 60% CGM in tilapia diets without impacting performance or production. Thus, CGM might be identified as a possible alternative protein source for Nile tilapia, and more research is required to increase the efficacy of incorporating CGM into the tilapia diet by up to 100% without negatively impacting fish health and productivity.

Conflicts of interest

The authors have declared no conflict of interest.

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Ethical approval statement

The animal ethics guidelines were followed and approved by the Zagazig university animal ethics committee (No: ZU-IACUC/2/F62/2019).

Author contribution

All authors have an equal contribution to the conceptualization, implementation, and outputs of this research work presented in this manuscript.

TABLE 1. Proximate composition of fish meal and corn gluten meal.

Items	DM	OM	CP	CL	CF	NFE	Ash	GE*
FM	89.49	75	59.8	10.8	0.8	3.6	14.49	454.02
CGM	90.9	88.6	60.1	1.8	1.5	25.2	2.3	459.53

FM, fish meal; CGM, corn gluten meal; DM, dry matter; OM, organic matter; CP, crude protein; CL, crude lipids; CF, crude fiber; NFE, nitrogen free extract.

*GE, Gross energy calculation based on values of 5.64 kcal/g CP, 9.44 kcal/g EE and 4.11kcal/g NFE.

TABLE 2. Formulation and chemical composition of the formulated diets.

Ingredients	Corn gluten meal as % of fish meal					
	0%	20%	40%	60%	80%	100%
Fish meal	20	16	12	8	4	0
Corn gluten meal	0	4	8	12	16	20
Soy bean meal	40	40	40	40	40	40
Yellow corn	18	18	18	18	18	18
Wheat flour	15	15	15	15	15	15
Oil fish	3	3	3	3	3	3
Vegetable oil	2	2	2	2	2	2
Premix [a]	2	2	2	2	2	2
Total	100	100	100	100	100	100
Proximate composition (% on dry matter)						
Crude protein	32.83	32.84	32.85	32.87	32.88	32.89
Ether extract	8.88	8.52	8.16	7.80	7.44	7.08
Crude fiber	3.74	3.77	3.80	3.83	3.86	3.88
Nitrogen free extract	36.81	37.68	38.54	39.41	40.27	41.13
Ash	4.12	3.63	3.14	2.66	2.17	1.68
GE (kcal / kg diet) [b]	4202.75	4204.95	4207.16	4209.36	4211.56	4213.77

[a] Each 3kg premix contain: 1,200,000 International units (IU) Retinol (VA); 300,000 IU Cholecalciferol (VD3); 700 mg Tocopherol (VE); 500 mg Menadione (VK3); 500 mg Thiamin (VB1); 200 mg Riboflavin (VB2); 670 mg Calcium pantothenate (VB5); 600 mg Pyridoxine (VB6); 600 mg Biotin (VB7); 300 mg Folic acid (VB9); 3000m g Cyanocobalamin (VB12); 450 mg Anti ascorbic acid (VC); 3000 mg Nicotinamide; 3000 mg Copper sulfate, 1000 mg Choline chloride, 3000 mg Magnesium sulfate, 3000 mg Cupper sulfate, 10,000 mg Iron sulfate,180 mg Zinc sulfate , and 300 mg Cobalt sulfate; Methionine 3000 mg. [b] Gross energy calculation based on values of 5.64 kcal g^{-1} CP, 9.44 kcal g^{-1} EE and 4.11kcal g^{-1} NFE.

TABLE 3. Effect of experimental diets on performance of Nile tilapia fish.

Items	Corn gluten meal as % of fish meal						
	0%	20%	40%	60%	80%	100%	*P* value
Initial body weight (g)	3.01±00	3.01±0.003	3.01±0.003	3.01±0.003	3.01±0.003	3.01±00	0.840
Total feed intake (g)	29.64±0.51[bc]	31.20±0.52[a]	30.28±0.42[b]	30.12±0.22[b]	28.92±0.66[bc]	28.44±0.18[c]	0.003
Final body weight (g)	18.90±0.10[c]	20.51±0.13[a]	19.60±0.22[b]	19.58±0.23[b]	18.58±0.31[cd]	18.10±0.06[d]	<0.001
Total weight gain (g)	15.89±0.10[c]	17.50±0.13[a]	16.59±0.21[b]	16.57±0.23[b]	15.56±0.30[cd]	15.09±0.06[d]	<0.001
Weight gain percent (%)	528.02±3.16[c]	581.39±4.89[a]	551.05±6.62[b]	550.50±7.34[b]	517.06±9.76[cd]	501.33±2.11[d]	<0.001
Average relative growth rate	88.01±0.53[c]	96.80±0.82[a]	91.74±1.10[b]	91.65±1.22[b]	86.08±1.63[b]	83.56±0.35[d]	<0.001
Specific growth rate (%/d)	2.53±0.07	2.68±0.07	2.63±0.01	2.57±0.03	2.48±0.09	2.42±0.01	0.054
Feed conversion ratio (g/g)	1.86±0.022	1.82±0.017	1.83±0.003	1.81±0.013	1.87±0.034	1.88±0.003	0.112
Feed efficiency (g/g)	0.54±0.006	0.55±0.006	0.55±0.001	0.55±0.003	0.54±0.012	0.53±0.001	0.196
Survival rate (%) *	100±0.00	98.33±0.10	98.33±0.10	98.33±0.20	100±0.00	100±0.00	0.084

[a, b, c, and d]: means in the same row with different superscripts differ significantly (P<0.05). Data were presented as Mean ± SE.

TABLE 4. Effect of experimental diets on protein efficiency ratio (PER) and protein productive value (PPV) of Nile tilapia fish.

Items	Corn gluten meal as % of fish meal						
	Zero%	20%	40%	60%	80%	100%	P value
Final fish body protein (%)	62.15±.0.03[a]	62.13±0.25[a]	62.03±0.38[a]	62.06±0.11[a]	61.46±0.11[b]	61.38±0.04[b]	0.051
Final fish body weight	18.90±0.10[c]	20.51±0.13[a]	19.60±0.22[b]	19.58±0.23[b]	18.58±0.31[cd]	18.10±0.06[d]	<0.001
Final fish body protein (g)	11.75±0.06[bc]	12.74±0.07[a]	12.16±0.18[b]	12.16±0.16[b]	11.42±0.18[cd]	11.11±0.04[d]	<0.001
protein retention (g)	9.82±0.06[bc]	10.81±0.07[a]	10.23±0.18[b]	10.23±0.16[b]	9.49±0.18[cd]	9.18±0.04[d]	<0.001
Protein intake (g)	8.51±0. 15[bc]	9.20±0.15[a]	8.76±0.12[b]	8.70±0.06[b]	8.40±0.19[bc]	8.23±0.05[c]	0.003
Total weight gain (g)	15.89±0.10[c]	17.50±0.13[a]	16.59±0.21[b]	16.57±0.23[b]	15.56±0.30[cd]	15.09±0.06[d]	<0.001
PER (%)	1.87±0.023[ab]	1.90±0.017[a]	1.89±0.003[ab]	1.91±0.013[a]	1.85±0.034[ab]	1.83±0.007[b]	0.111
PPV (%)	115.39±1.28[abc]	117.58±1.51[a]	116.77±0.59[ab]	117.58±0.95[a]	112.98±1.78[bc]	111.63±0.41[c]	0.016

PER, protein efficiency ratio. PPV, Protein productive value.

[a, b, c, and d]: means in the same row with different superscripts differ significantly (P<0.05). Data were presented as Mean ± SE

TABLE 5. Effect of experimental diets on digestibility of nutrients.

Items	Corn gluten meal as % of fish meal						
	0%	20%	40%	60%	80%	100%	*P* value
Dry matter	77.29±0.33^{b}	80.49±0.20^{a}	78.38±0.40^{b}	76.90±0.62^{b}	73.65±0.53^{c}	71.96±1.13^{c}	<0.001
Crude protein	90.60±0.08^{a}	90.14±0.32^{a}	88.18±0.38^{b}	87.09±0.53^{b}	83.75±0.14^{c}	81.18±0.62^{d}	<0.001
Ether extract	85.69±0.54^{ab}	88.00±0.34^{a}	86.10±0.88^{ab}	85.65±1.18^{ab}	84.62±0.47^{b}	84.18±1.40^{b}	0.116
Nitrogen free extract	90.53±0.51^{c}	92.82±0.24^{ab}	92.98±0.13^{ab}	93.97±0.40^{a}	92.02±0.58^{b}	86.93±0.45^{d}	<0.001

[a, b, c, and d]: means in the same row with different superscripts differ significantly (P<0.05). Data were presented as Mean ± SE.

TABLE 6. Effect of experimental diets on chemical composition of whole Nile tilapia fish body.

Items	Corn gluten meal as % of fish meal						
	0%	20%	40%	60%	80%	100%	*P* value
Moisture	76.57±0.12	76.35±0.22	75.08±0.42	74.2±0.11	74.38±0.32	73.72±0.21	0.524
Dry matter	23.43±0.24	23.65±0.31	24.92±0.11	25.8±0.22	25.62±0.42	26.28±0.34	0.078
Organic matter	84.57±0.12^{c}	85.00±0.28^{bc}	85.16±0.08^{bc}	86.00±0.34^{b}	86.75±0.19^{a}	87.04±0.14^{a}	<0.001
Crude protein	62.15±.0.04^{a}	62.13±0.25^{a}	62.03±0.38^{ab}	62.06±0.10^{ab}	61.40±0.12^{bc}	61.33±0.05^{c}	0.041
Ether extract	22.11±0.13^{c}	22.36±0.15^{bc}	22.57±0.33^{bc}	23.38±0.32^{b}	24.72±0.26^{a}	25.06±0.23^{a}	<0.001
Crude fiber	0.41±0.04	0.51±0.14	0.56±0.08	0.56±0.03	0.63±0.08	0.65±0.09	0.114
Ash	15.43±0.12^{a}	15.00±0.28^{ab}	14.84±0.08^{b}	14.00±0.34^{bc}	13.25±0.19^{c}	12.96±0.14^{d}	<0.001

[a, b, and c]: means in the same row with different superscripts differ significantly (P<0.05). Data were presented as Mean ± SE.

TABLE 7. Effect of experimental diets on blood parameters of Nile tilapia fish.

Items	Corn gluten meal as % of fish meal						*P* value
	0%	20%	40%	60%	80%	100%	
ALT (IU/L)	15.30±0.35	16±0.58	15.60±0.52	15.66±0.34	15.01±0.28	15.01±0.49	0.259
AST (IU/L)	11.41±0.05	11.56±0.04	11.52±0.05	11.44±0.08	11.32±0.17	11.32±0.11	0.168
T.P (g/dL)	4.64±0.02	4.68±0.01	4.59±0.03	4.57±0.01	4.60±0.11	4.58±0.04	0.201
Albumin (g/dL)	1.97±0.01^{b}	1.96±0.01^{b}	2.06±0.02^{a}	2.07±0.01^{a}	2.06±0.44^{a}	2.07±0.01^{a}	<0.001
Globulin (g/dL)	2.67±0.45^{a}	2.72±0.12^{a}	2.53±0.71^{b}	2.50±0.04^{b}	2.54±0.02^{b}	2.51±0.11^{b}	<0.001
A/G	0.74±0.54^{c}	0.72±0.36^{c}	0.81±0.01^{ab}	0.83±0.01^{a}	0.81±0.14^{b}	0.83±0.02^{ab}	<0.001
Triglyceride (mg/dL)	305.77±2.17^{a}	296.90±1.27^{b}	293.40±1.27^{b}	306.80±1.56^{a}	306.00±1.39^{a}	306.30±2.42^{a}	<0.001
T_3 (µg/dL)	98.87±0.39^{b}	99.00±0.28^{b}	99.18±0.60^{b}	99.70±0.55^{b}	103.27±0.69^{a}	103.15±0.57^{a}	<0.001
T_4 (µg/dL)	7.25±0.03^{ab}	7.15±0.03^{b}	7.05±0.03^{b}	7.35±0.03^{ab}	7.60±0.07^{a}	7.57±0.05^{a}	<0.001
Haemoglobin (g/dl)	8.85±0.09^{a}	8.80±0.06^{a}	8.55±0.03^{a}	8.50±0.06^{a}	8.61±0.25^{a}	8.05±0.03^{b}	0.001
RBCs (10^6 /µL)	2.62±0.58^{a}	2.63±0.54^{a}	2.31±0.03^{b}	2.24±0.10^{b}	2.25±0.22^{b}	2.28±0.01^{b}	<0.001
PCV (%)	20.85±0.03^{a}	21.01±0.06^{a}	19.40±0.25^{b}	19.35±0.03^{b}	19.50±0.06^{b}	19.40±0.09^{b}	<0.001

A/G ratio, albumin-to-globulin ratio; AST, aspartate aminotransferase; ALT, alanine aminotransferase, T.P, total protein, RBCs, red blood cells Erythrocytes, PCV, Packed cell volume haematocrit, T_3, Triiodothyronine, T_4, tetra iodothyronine thyroxin.

[a, b, and c]: means in the same row with different superscript differ significantly (P<0.05). Data were presented as Mean ± SE.

TABLE 8. Effect of experimental diets on the condition factor and hepatosomatic index of Nile tilapia fish.

Item	Corn gluten meal as % of fish meal						*P* Value
	0%	20%	40%	60%	80%	100%	
Condition factor (K)	1.80±0.05[ab]	1.84±0.08[a]	1.72±0.05[ab]	1.69±0.05[b]	1.73±0.04[ab]	1.68±0.06[b]	0.006
Hepatosomatic index (HSI)	4.55±1.05b[c]	3.48±0.65[c]	3.67±0.91[c]	5.49±0.76a[bc]	6.68±1.01[a]	5.85±0.43[ab]	0.014
Viscera-somatic index (VSI)	2.63±.63	2.09±0.19	2.36±0.08	1.93±0.28	2.55±62	2.06±0.33	0.195
Intestine length/fish length	4.13±0.28	3.99±0.25	4.53±0.23	3.98±0.05	4.52±0.35	4.42±0.22	0.467
Intestine length/fish weight	2.05±0.21	2.02±0.08	2.21±0.15	2.18±0.03	2.24±0.22	2.26±0.20	0.827
Spleen weight /fish weight	0.46±0.06[a]	0.30±0.04[ab]	0.34±0.12[ab]	0.25±0.05[b]	0.46±0.08[a]	0.27±0.09[ab]	0.004
Spleen weight /fish length	0.71±0.17[ab]	0.60±0.07[ab]	0.69±0.23[ab]	0.46±0.07[b]	0.92±0.12[a]	0.53±0.17[b]	0.015
Gall bladder weight/ fish weight*100	1.33±0.27	1.02±0.07	1.20±0.04	1.04±0.28	1.26±0.33	1.06±0.17	0.242

K, Condition factor; HSI, Hepatosomatic index; VSI, Viscera somatic index.

[a, b, and c]: means in the same row with different superscript differ significantly ($P<0.05$). Data were presented as Mean ± SE.

TABLE 9. Effect of experimental diets on feed cost (LE) / kg gain.

Items	Corn gluten meal as % of fish meal					
	0%	20%	40%	60%	80%	100%
Initial fish weight (g)	3.01±0.01	3.01±0.01	3.01±0.01	3.01±0.01	3.01±0.01	3.01±0.01
Initial fish price (LE)[a]	0.4	0.4	0.4	0.4	0.4	0.4
Total/ Feed input/ fish (g)[b]	29.64±0.51	31.20±0.52	30.28±0.42	30.12±0.22	28.92±0.66	28.44±0.18
Total feed cost/ fish[c]	0.42	0.42	0.38	0.36	0.32	0.29
Final weight (g)[d]	18.90±0.17[c]	20.51±0.22[a]	19.60±0.38[b]	19.58±0.40[b]	18.58±0.53[cd]	18.10±0.11[d]
Selling price (LE)[e]	1	1.09	1.04	1.04	0.98	0.96
Profit (LE)[f]	0.18	0.27	0.26	0.28	0.26	0.27
Relative profit %[g]	100	150.00	144.44	155.56	144.44	150.00

a, Initial fish price x 0.4 LE (cost of one fish, price 2022). b, 72 day (actual feed input for 12 weeks, 6 days/one week). c, b x cost of diets (14.25, 13.45, 12.65 11.85 11.05, and 10.25LE/kg of control 0, 20, 40, 60, 80, and 100% corn gluten, respectively. The cost of one kg corn gluten and fish meal is 15.00 and 35 LE, respectively). e, Final weight of corn gluten treatment x 100 / Final weight of control (the selling price (LE) / one fish). f, e - (c + a). g = profit of corn gluten treatment / profit of control x 100.

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تأثير استبدال مسحوق السمك بمسحوق جلوتين الذرة فى علائق اسماك البلطى النيلى على أداء النمو

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الهدف الرئيسى من الدراسة هو تقييم آثار استبدال مسحوق السمك بمسحوق جلوتين الذرة على الأداء الإنتاجي لأسماك البلطي وعائدها الاقتصادى. حيث تم إجراء تجربة تغذية مدتها 12 أسبوعًا لفحص تأثير استبدال مسحوق السمك بمسحوق جلوتين الذرة على 360 إصبعية من البلطي النيلي (الوزن الأولي = 3.01 ± 0.01 جم حي). حيث تم تقسيم الأسماك التجريبية بشكل عشوائي إلى ست مجموعات متساوية، مع وجود ثلاث مكررات في كل مجموعة (20 سمكة لكل حوض). غذيت المجموعه الكنترول على عليقة تحتوى على 20% مسحوق سمك , اما المجموعات التجريبية الاخرى تم فيها استخدام جلوتين الذرة لاستبدال 20% و40% و60% و80% و100% من بروتين مسحوق السمك بحيث كانت العلائق متساوية النيتروجين (البروتين الخام: 32.85%) ومتساوية الطاقة (17.60 ميجا جول كجم-1 مادة جافة). أظهرت النتائج انخفاضًا كبيرًا (P<0.05) في الأداء (الكتلة الحيوية النهائية وزيادة الوزن ونسبة زيادة الوزن) للمجموعة التي تلقت كمية استبدال عالية من مسحوق السمك مع جلوتين الذرة 80) أو 100٪) مقارنةً بالمعاملة الكنترول وغيره من المعالجات. مقارنةً بالمجموعة الكنترول، أدى استبدال مسحوق السمك بـ 20 أو 40% أو 60% من جلوتين الذرة بزيادة مقاييس كفاءة البروتين معنويا بشكل ملحوظ (P <0.001) . علاوة على ذلك، فإن معدل النمو النوعي، ومعدل تحويل العلف، وكفاءة استهلاك العلف، ومعدل البقاء على قيد الحياة لم يظهر أي تأثير معنوي عند أي مستوى استبدال. وفي الوقت نفسه، أدى دمج جلوتين الذرة في وجبات أسماك البلطي كبديل مسحوق السمك عند المستويات العالية (100-80٪) إلى زيادة كبيرة في مستويات مصل الدم من مكونات البروتين وهرمونات الغدة الدرقية ومحتوى الجليسيريدات الثلاثية. علاوة على ذلك، فإن استبدال مسحوق السمك بـجلوتين الذرة يعد أكثر كفاءة اقتصاديه. في الختام، فإن دمج جلوتين الذرة بدلاً من مسحوق السمك حتى مستوى 60% لا يؤثر سلبًا على أداء الأسماك، بالاضافة الى انه يحسن من العائد الاقتصادي لتغذية البلطي النيلي.

الكلمات الدالة: اداء النمو ,الهضم , العائد الاقتصادى , جلوتين الذرة ,مسحوق السمك.