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Enhancing Nutritive Value of Distillers Dried Grains via Solid-State Fermentation in Diets of the Nile Tilapia, *Oreochromis niloticus* Fingerlings

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ABSTRACT
A feeding trial was carried out to investigate the effects of dietary fermented distillers dried grains (FDDGs) on the growth performance, feed efficiency, body chemical composition, blood biochemical tests and economic evaluation of the Nile tilapia, *Oreochromis niloticus* fingerlings. Distillers dried grains were subjected to solid-state fermentation then incorporated into four experimental (Iso-nitrogenous 30% and iso-Calroric 4400Kcal/Kg) diets containing 0, 25, 50 and 75% FDDGs instead of soybean meal. Results revealed that bioprocessing increases the protein content of DDGs. All growth performance parameters (BW, WG, RGR, DWG, and SGR) demonstrated significant increase with low substitution levels (25 and 50% FDDGs). Survival rate and feed consumption did not differ between all treatments. Feed conversion ratio (FCR), feed efficiency ratio (FER), and protein efficiency ratio (PER) showed significant improvements with low substitution levels (25 and 50% FDDGs). Body dry matter, protein and ash contents did not differ significantly with the control, however, both fat and energy content showed a significant increase for all substitution levels. These results indicate that incorporation of FDDGs meal into tilapia diets at 25 and 50% levels were the best in terms of growth performance, feed utilization and economic evaluation under these experimental conditions.

INTRODUCTION

The global farming of fish and shellfish has been the fastest growing food producing sector in the last few decades and has become an important industry in many countries. Aquaculture industry has become an important industry producing healthy food and providing employment and revenues in many developed and developing countries **(Olsen & Hasan, 2012)**. A promising source of protein is that derived from plant raw materials including secondary materials such as oil seed meals, a residual by-product of the oil extraction industry **(Shchekoldina & Aider, 2014)**.

Numerous researchers have identified several alternatives for the partial or complete replacement of expensive scarce ingredients from the diets of fish **(Tacon & Metian, 2015; Ahmed *et al.*, 2019)**. Unfortunately, the use of plant-derived materials as feed ingredients and/or replacer has been restricted due to deficiencies in the essential amino acids and presence of antinutritional factors (ANFs). These endogenous ANFs reduce feed value unless destroyed or inactivated **(Nuneset al., 2014)**.

Several processing techniques are employed to reduce or eliminate the antinutritional factors (ANFs), with the aim that the nutrient properties of plant ingredients can be enhanced and incorporated appropriately into feed formulations **(Banerjee & Ghosh, 2016)**.

One of the simple methods of bioprocessing is solid state fermentation. It improves the nutritional quality of the original components by reducing the ANFs and improving the bioavailability of nutrients due to the action of enzymes produced by the microorganisms **(Khan & Ghosh, 2012)**. Furthermore, fermentation improves the antioxidant properties in plant materials **(Verniet al., 2019)**. Fermentation with bakers' yeast, Saccharomyces cerevisiae; phytase released from this yeast facilitates degradation of phytic acid **(Nakamura *et al*., 2000; Greiner & Konietzny, 2006)**. Treatment with yeast can also increase the relative levels of crude protein and minerals in the plant meals **(Erukainureet al., 2010)**. Several scientific studies have revealed that fermented plant ingredients at a proper incorporation level may be great nutrient resources pertaining to shrimp **(Molina-Poveda & Morales, 2004)** and fish **(Sun *et al*., 2007; Seoet al., 2011)**.

Distillers dried grain (DDG) is predominantly produced as a by-product of the dry-grind fuel ethanol processing and manufacturing of alcoholic beverages **(Rosentrater & Muthukumarappan, 2006)**. Numerous studies have been investigating the use of DDGS in fish diets, such as in the tilapia, *Oreochromis* sp. **(Tidwellet al.,2000)**, rainbow trout, *Oncorhynchus mykiss***(Cheng & Hardy, 2004a, b; Stone *et al*., 2005)**, sunshine bass, *Moronechrysops*× *Moronesaxatilis***(Thompson *et al*., 2008)**, and catfish, *Ictalurus punctatus* **(Li *et al*., 2010)**. Such studies reported that, up to 40% of DDGs in fish diets did not negatively affect fish performance and feed efficiency.

The price of soybean meal, the primary protein source in the Nile tilapia diets, has recently increased, leading to higher feed costs. Replacement of soybean meal by cheaper alternatives is therefore needed **(Saha & Ghosh, 2013; Plaipetch & Yakupitiyage, 2014)**.

The study aimed to determine the influence of dietary levels of fermented distiller's dried grains (FDDGs) as a replacement of soybean on the growth parameters, feed efficiency and body chemical composition.

MATERIALS AND METHODS

Solid-state fermentation

A commercially distiller's dried grains with soluble DDGS was purchased from local company (Abouhammad, Sharqia, Egypt) and finely grounded to a particle size (< 500µm) by a screen diameter. Three fermented replicates of DDGs were conducted using a modification method based on the study of **Yabaya *et al*. (2009)**. Each replicate comprises 2kg DDGS, 60.5mg of commercial dry yeast & *S. cerevisiae*, (Fermipan®, GB ingredients, china) with a cell density of 3×10^6 cell/g; 1.1L of distilled water (50% moisture) was homogenized in a Hobart food mixer for 15min. This provided a yeast density of 1×10^3 cell/g meal. Each replicate lasted for 48h in a 10L glass jar covered with aluminium foil and incubated at 40°C, which is the optimal growth temperature for *S.cerevisiae*. The yeast fermented DDGs was dried to a constant weight at 70°C.

Experimental units

Twelve glass aquaria (50 x 60 x70cm^2) containing equal amount of water (0.21m^3) were used for each experiment. Each glass aquaria was supplied with compressed air via air pumps for satisfying the oxygen requirement by fish, and water supply was provided from the tank storage of water.

Experimental fish

Fingerlings of the Nile tilapia (*O. niloticus*), which were sex reversed (all-male) were provided by the Fish Hatchery of Central Laboratory for Aquaculture Research at Abbassa, Sharkia Governorate, Egypt. 500 fingerlings (weighing approximately 5.00±0.002g), after an adaptation period for two weeks under normal laboratory conditions, were randomly distributed into the glass aquaria. Fish were randomly divided after that into four equal groups (three replicates per each) in the experimental glass aquaria (20 fish/aquaria). The fish were fed experimental diets up to satiation. The experiment lasted for 112 days, during which feed was offered two times daily, at 10:00 AM and 14:00 PM, for 6 days a week. Fish per each pond were group-weighed every ten days. At the end of the experiments, fish were collected, counted, and group weighed per treatments. The parameters of growth and feed utilization were calculated as follows. A weight of 300g of fish was frozen at –20ºC for further proximate chemical analysis.

Experimental diets preparation and feeding regimen

The proximate composition of the ingredients used in the diets is presented in Table (1). Four diets were formulated to contain 30% crude protein. A consideration was also given to the equivalence of other components such as fiber. In diet 1, the control diet, in diets 2, 3 and 4, replacements of soybean by fermented distiller's dried grains with soluble meal were at graded levels of 25, 50 and 75%.

Chemical analysis

The experimental diets were analyzed to determine the percentage of the moisture, protein, lipid, fiber, and ash. Also, the proximate composition including crude protein, crude fat, crude ash and moisture of body composition was determined using the standard procedures of **AOAC (2019)**.

Growth and feed utilization parameters

Live body weight

Fish were weighed to the nearest 0.1g at the beginning of the experiments and every 15 days, and the amount of feed given was adjusted in accordance with the new measured biomass.

Body weight gain

Body weight gain was calculated by subtracting the two successive live weights at different experimental periods (weight gain (g/fish) = final weight – initial weight).

Table1. Ingredient formulation (%) and proximate composition of the experimental diets

Ingredient %	**Control**	**25%FDDGs**	**25%FDDGs**	**25%FDDGs**
Fish meal	5	5	5	5
Soybean meal (SM)	44	33	22	11
FDDGs	0	15.94	31.88	47.82
Corn	32	29.36	24.42	18.48
Wheat bran	10	8	8	8
Corn gluten	7	7	7	8
Soybean oil	1.3	1	1	1
Vit. & Min. Premix[1]	0.7	0.7	0.7	0.7
Proximate analysis%				
Moisture	10.79	10.26	9.61	8.90
Crude protein	30.97	30.52	30.13	30.27
Ether extract	5.33	5.64	6.23	6.85
Crude fiber	4.98	5.21	5.59	5.96
Ash	5.57	5.42	5.31	5.18
NFE[2]	53,15	53.21	52.74	51.74
G E(Kcal/Kg)[3]	4437.9	4444.2	4458.6	51.74

[1]Each Kgvitamin&mineralmixturepremix containedVitaminA, 4.8 million IU,D3, 0.8 million IU; E, 4g; K, 0.8g; B1,0.4g;Riboflavin,1.6g; B6,0.6g, B12,4mg;Pantothenic acid,4g; Nicotinicacid,8g;Folic acid,0.4g; Biotin,20mg;,Mn, 22g;Zn, 22g;Fe,12g; Cu, 4g;I,0.4g,Selenium, 0.4gandCo, 4.8mg.
[2]Nitrogen freeextract = 100 – (%Protein+%Fat+ %Fiber+%Ash).
[3]Gross energy based on protein (5.65Kcal/g), fat (9.45Kcal/g) and carbohydrate (4.11Kcal/g).(**NRC,2011)**.
P/E ratio= mg crude protein/ kcal GE.

Average daily gain (ADG)
(ADG) = $W_2 – W_1 / T$
Where,
W_2= final weight, W_1= initial weight and T= time.

Relative growth rate (RGR)
RGR= $W_2 – W_1 / W_1 X 100$
Where,
W_1= the initial weight (g), W_2 = the final weight (g), and T = the feeding period (days).

The specific growth rate
Specific growth rate (SGR) was calculated according the following equation:
SGR = [ln (final fish weight) – ln (initial fish weight)] X 100 / period (day).
Feed conversion ratio
Feed conversion ratio (FCR) was calculated according to the following equation: FCR = cumulative feed delivered to aquarium/fish biomass gain.

$$\mathbf{FCR} = \frac{\mathbf{Feed\ intake\,(g)}}{\mathbf{Weight\ \ gain\,(g)}}$$

Feed efficiency ratio (FER)
FER= body weight gain (g) / (DM) feed intake (g) X 100

Protein efficiency ratio (PER)
PER= body weight gain (g) / protein intake (DM) (g) X 100

Protein productive value (PPV)
PPV= $P_2 – P_1 / P_f$
Where,
P_1= the protein content in fish carcass at the start of the experiment (g).
p_2= the protein content in fish carcass at the end of the experiment
p^f= the protein intake (g) during the experiment (on DM basis).

Survival rate (%):
SR=Nt x 100/N0
Where,
Nt = Total number of fish survived in tank at the end of the experiment.
N_0 = Total number of fish in tank at the beginning of the experiment.

Biochemical parameters

The activities of aspartate aminotransferases (AST) and alanine aminotransferase (ALT) enzymes were measured in accordance with the method of **Bergmeyer *et al.* (1978)**. Total serum protein was evaluated by following the instructions of **Yatzidis (1987)**. Additionally, the method of **Doumas *et al*. (1971)** was implemented to measure the levels of serum albumin. To assess kidney function, serum levels of urea, creatinine, and uric acid levels were tested. According to **Henry *et al.* (1974)** and **Patton and Crouch (1977)**, colorimetric methods were used to measure the concentrations of creatinine and urea, respectively. The technique described by **Whitehead *et al*. (1991)** was used to measure uric acid in the blood.

Water quality parameters
A digital thermometer was used to measure the water's temperature and dissolved oxygen content (DO), and a Milwaukee-PH600 pH meter was used to assess the water's pH once a week. Ammonia nitrogen (NH_3-N) and nitrite (NO_2) values were detected on a biweekly basis using water analysis and via a photometer and test kits, and nitrate (NO_3) was weekly determined. While, alkalinity (expressed as $Ca_2\ CO_3$) was biweekly monitored by titration with sulfuric acid till pH point reached 4.5 **(APHA, 1998)**.

Economical evaluation
The cost of feed to raise unit biomass of fish was estimated by a simple economic analysis. The estimation was based on local retail sale market price of all the dietary ingredients at the time of the study. These prices (in LE/kg) were as follows: herring fish meal, 60.0; poultry by-product meal, 20.0 ; wheat bran, 11.40 : corn gluten, 47.0; soybean meal, 31.50; corn meal, 13.30; soybean oil, 42.0; premix, 100 **(Eid & Mohamed, 2008)**.

Cost/kg diet (LE) = Cost per Kg diet L.E
Consumed feed to produce 1kg fish (kg) = Feed intake per fish per period/ final weight per fish Kg/ Kg
Feed cost per kg fresh fish (LE) = Step 1x step 2

Relative%of feed cost/ kg fish= Respective figures for step3/ highest figure in this step
Feed cost/ 1Kg gain (LE) = Feed intake per Kg gain x step 1
Relative% of feed cost of Kg gain= Respective figures for step 5/ highest figure in this step

Statistical analysis The data were statistically analyzed by a completely randomized design with **SPSS (V16.0)** through the following model: $Y_{ij}= \mu + T_i + E_{ij}$, where μ is the overall mean; T_i is the fixed effect of i^{th} treatments, and E_{ij} is the random error. Difference between treatments was tested for significant differences using orthogonal comparison.

RESULTS

Growth performance

Growth performance parameters (BW, BWG, DG and SGR) influenced by the incorporation of fermented distillers dried grains in the Nile tilapia fed diets instead of soybean meal (Table 2) demonstrated significant improvement with the incorporation of 25% FDDGs, followed by a significant difference of 50% FDDGs. Although 75% FDDGs recorded a slight decrease, it did not differ significantly compared to the control. The survival rates were not influenced by the replacement processes; therefore, FDDGs did not compromise the survival of the fish.

Feed utilization

Feed efficiency parameters means: feed intake (FI), feed conversion ratio (FCR), feed efficiency ratio (FER) and protein efficiency ratio (PER) are illustrated in Table (3).Feed intake showed insignificant decrease compared to the control for all substitution levels. Feed conversion ratio (FCR) and feed efficiency ratio (FER) both showed significant improvementswith theincorporation of 25 and 50 FDDGs, respectively. 75% FDDGs was comparable to the control. Moreover, protein efficiency ratio (PER) also showed a significant improvement compared to the control when soybean was replaced by 25 and 50% FDDGs. However, 75% FDDGs did not differ significantly with the control. Protein productive value (PPV) did not record any detrimental effects compared with the control.

Table2. Effect of different dietary FDDGs on growth performance of the Nile tilapia*(Oreochromisniloticus*) fingerlings fed experimental diets

Treatment	Control	Fermented distiller dried grains		
		25% FDDGs	50% FDDGs	50% FDDGs
IW (g/fish)	5.1±0.20	5.07 ±0.25	5.06 ±0.30	5.09±0.27
FBW (g/fish)	34.33 ±1.61^c	49.17 ±1.69^a	41.48 ±0.75^b	33.90 ±1^c
BWG (g/fish)	29.24 ±1.61^c	44.44 ±1.68^a	36.41 ±0.07^b	28.82 ±1^c
RGR %	574 ±31^c	873 ±33^a	717 ±1.9^b	568 ±19^c
DG (g/fish)	0.27 ±0.01^c	0.40 ±0.02^a	0.33 ±0.01^b	0.26 ±0.01^c
SGR (%/d)	1.73 ±0.04^c	2.06 ±0.03^a	1.91 ±0.02^b	1.73 ±0.01^c
SR %	90 ±0.00	90 ±0.00	93 ± 4.41	90 ±0.00

Means in the same row having different super script letters are significantly different ($P< 0.05$).

Table 3. Effect of different dietary FDDGs on feed utilization of the Nile tilapia *(Oreochromis niloticus*) fingerlings fed experimental diets

Treatment	Control	Fermented distiller dried grains		
		25% FDDGs	50% FDDGs	50% FDDGs
FI (g/fish)	53.27 ±1.11	48.47±1.49	48.70 ±0.66	51.76 ±1.59
FCR	1.83 ±0.07^{a}	1.10 ±0.29^{c}	1.34 ±0.02^{b}	1.80 ±0.02^{a}
FER	0.55 ±0.03^{c}	0.91 ±0.01^{a}	0.75 ±0.01^{b}	0.56 ±0.01^{c}
PER	1.98 ±0.11^{c}	3.33 ±0.04^{a}	2.77 ±0.03^{ab}	2.02 ±0.02^{c}
PPV	28.98 ±1.72	31.08 ±3.0	31.46 ±1.87	30.87±1.21

Means in the same row having different super script letters are significantly different ($P< 0.05$).

Whole body composition

The body chemical compositions of the Nile tilapia are illustrated in Table (4). Neither the body dry matter nor the protein contents recorded any significant variation between all treatments compared to the control. Body ash content demonstrated an insignificant decrease compared with the control. On the other, body fat and calculated energy contents exhibited a significant increase for all treatments compared to the control.

Table 4. Effect of different dietary FDDGs on body chemical composition of the Nile tilapia *(Oreochromisniloticus*) fingerlings fed experimental diets

Treatment	Control	Fermented distiller dried grains		
		25% FDDGs	50% FDDGs	50% FDDGs
DM	26.88±0.35	26.79±0.93	27.19±0.68	27.88±0.42
CP	62.39±0.35	62.16±0.76	61.35±1.57	60.68±0.93
EE	20.32±0.28^{b}	23.57±0.48^{a}	24.38 ±0.24^{a}	24.91±0.58^{a}
Ash	17.29±0.42^{a}	14.27±0.67^{b}	14.26 ±1.58^{b}	14.42 ±0.35^{b}

Means in the same row having different super script letters are significantly different ($P<0.05$).

Biochemical parameters

Values for ALT, AST, urea and creatinine were affected by the dietary levels of FDDGS meal (Table 5). No significant differences were observed for the values of ALT and AST, as the replacement of SBM with FDDGS increased from 0 to 75% ($P> 0.05$). Significant differences were observed in urea values as the replacement level of SBM with FDDGs meal.

Table 5. Effect of different dietary FDDGs on biochemical analysis of the plasma of the Nile tilapia *O. niloticus* fed different experimental diets

Treatment	Control	Fermented distiller dried grains		
		25% FDDGs	50% FDDGs	50% FDDGs
ALT	15.9± 0.17	15.67± 0.23	16.17± 0.49	15.70± 0.26
AST	28.72± 0.31	29.69± 0.27	29.43± 0.28	29.67± 0.32
Urea	14.50± 0.17[a]	13.90± 0.40[ab]	14.00± 0.15[ab]	13.60± 0.21[b]
Creatinine	0.157± 0.03	0.197± 0.04	0.193± 0.01	0.203± 0.03

Values are means ± SD. Values in the same row with different superscripts are significantly different ($P < 0.05$).

Economic evaluation

The results of economic evaluation including feed costs of one kg gain in weight and its ratio to that of the controlgroup are presented in Table (6). Data show that the cost of one kg of the diet for FDDGS meal in T1, T2, T3, and T4 were 26.79, 25.84, 24.94, and 24.37LE, respectively. Costs of one kg gain in weight were 49.03, 28.43, 33.43, and 43.87LE for control, 25, 50, and 75% FDDGS, respectively. These results indicate that incorporation of FDDGs meal into tilapia diets reduced the price of one kg diet to 42.02, 31.84 and 10.51% for the 25, 50, and 75%FDDGs, respectively, compared to the control group (100% of theprice).

Table 6. Effect of different dietary FDDGsmeal levels on the economic efficiency of the Nile tilapia*(Oreochromisniloticus*) fingerlings

Treatment	Control	Fermented distiller dried grains		
		25% FDDGs	50% FDDGs	50% FDDGs
Feed costs (L.E)/KG	26.79	25.84	24.94	24.37
Relative to control %	100.00	96.45	93.09	90.98
FCR	1.83	1.10	1.34	1.80
Feed costs (L.E/kgweight gain)	49.03	28.43	33.42	43.87
Relative to control (%)	100.00	57.98	68.16	89.49
Decrease in Feed costs(L.E/kg weight gain%)	0.00	42.02	31.84	10.51

[1]Feed cost X feed intake.
[2]Value of each treatment feed intake cost /highestvalue x100.
[3]Feed conversion ratio.
[4]Feed cost/ kg gain = FCR x Feed cost/Kg EGP.
[5]Feed cost /kg fresh fish EGP value for each treatment/ highest value x100.

DISCUSSION

Several studies have dealt with the potential of DDGs in diets for several species with importance in aquaculture, such as channel catfish **(Li *et al.*, 2011)**, rainbow trout **(Overland *et al.*, 2013; Welker *et al.*, 2014)**, and the Nile tilapia **(Suprayudi*et al.* 2015)**. **Zhou *et al.* (2010)** concluded that, DDGs (at least at levels up to 30%) appear to be suitable for replacing soybean meal and corn meal in hybrid catfish diets; the same trend was reported by **Robinson and Li (2008)**. Moreover, **Diógenes *et al.* (2018)** reported that, the total replacement of SBM by DDGS in diets for gilthead seabream did not compromise growth performance, voluntary feed intake, feed efficiency, and protein & energy retention. More recently, **Oliveira*et al.* (2020)** reported that, the inclusion of DDGs as a plant protein source in diets for *P. mesopotamicus* in total replacement of soybean meal improved fish production and reduced the environmental impact. Additionaly, no significant differences were found between the experimental groups regarding growth performance (final weight, weight gain and SGR), when DDGs replaced 0, 10, 20 and 30% of soybean and wheat corn for the European catfish (*Silurus glanis*) **(Sandor *et al.*,2021)**.

Fermentation of plant by-products with beneficial microorganisms has been adopted to improve the nutritional quality of feed stuffs by the action of enzymes from bacteria, yeasts, and molds. **Plaipetch and Yakupitiyage (2014)** demonstrated that growth performance parameters did not record any significant differences between treatments when soybean meal was replaced with yeast-fermented (*Saccharomyces cerevisiae*) canola for the Nile tilapia. Moreover, **Wattanakul *et al.* (2021)** studied the replacement of soybean meal (SBM) with fermented palm kernel meal in diets for the red tilapia. The obtained results revealed that the nutritive value of palm kernel meal was improved by solid-state fermentation, and growth performance did not show any significant differences between all treatments.

The findings of **Gabr *et al.* (2013)** demonstrated that there were no significant differences in feed intake among different DDGs levels. On the other hand, the FCR improved significantly with increasing level of DDGs up to 16%. **Fouda *et al.* (2018)** replaced yellow corn by DDGs in diets for tilapia. The results showed a non-significant decrease in feed intake, FCR and PER as the level of DDGs were increased, while there was a significant increase in PPV and EU. Moreover, **Sandor*et al.* (2021)** concluded that, DDGs is a promising feedstuff for the European catfish (*Silurus glanis*), and that 30% of DDGs can be included in the diet of the European catfish, without compromising the growth performance and nutrient utilization (FCR, PER, and PPV).

The fermentation process has been reported to improve the nutritional quality of different protein sources **(Dossou*et al.*, 2019)**. Fermented plant protein meals displayed a better nutrient efficiency and could improve the nutritional value of aquafeed **(Dossou *et al.*, 2018a, b; Dossou *et al.*, 2019)**. **Sun *et al.* (2016)** introduced 25, 50, 75 and 100% of fermented cotton seed meal (FCM) instead of fish meal (FM) in diets for juvenile *Litopenaeus vannamei*. Concerning feed utilization efficiency and daily feed consumption, there were no significant differences among all treatments. FCR and PER did not differ significantly with fish fed with the low substitution levels (25 and 50% FCM); on the other hand, the high levels of substitution (75 and 100% FCM) decreased significantly compared to the control.

Gabr *et al*. (2013) reported that dry matter and crude protein of fish body decreased significantly with increasing DDGs levels. In addition, crude protein significantly differed among treatments. Crude fat increased significantly with increasing DDGS levels up to 16% compared to the control diet. The findings of **He *et al*. (2021)** revealed that, no significant differences in body composition, in terms of crude protein, crude ash, and moisture, were observed among treatments, when fermented rice protein replaced fish meal with fermented rice protein in diets for hybrid groupers (*Epinephelus fuscoguttatus*♀×*Epinephelus lanceolatus*♂).Furthermore, **Plaipetch and Yakupitiyage (2014)** evaluated the replacement of soybean with yeast-fermented (*Saccharomyce scerevisiae*) canola for the Nile tilapia. The results showed a significant difference in the body composition of ether extract and ash for all fish fed with the test diets, except for the crude protein.

The results (Table 5) revealed that the replacement of soybean meal with FDDGs did not show any deleterious effects on either liver (ALT and AST) or kidney (Urea and Creatinine) function parameters. **Sandor *et al*. (2021)** reported that, plasma biochemical parameters, such as glucose, phosphatase, Ca, total protein, globulin, alanine aminotransferase, alkaline phosphatase, cholesterol, triglyceride and amylase were not differing significantly upon using DDGs instead of soybean and wheat corn for the European catfish (*Silurus glanis*). The same trend was reported for rainbow trout, *Oncorhynchus mykiss* **(Overland *et al*., 2013)**. **Sun *et al*. (2016)** recorded no significant difference ($P > 0.05$) in plasma protein, albumin, triglyceride levels and SOD, ALT, AST activity among the treatments upon substituting fish meal with fermented cotton seed meal in the juveniles' *Litopenaeus vannamei* diets up to 100%.

The diets containing FDDGs showed that the cost of one ton of feed mixture was reduced gradually with increasing the substitution levels (Table 6). Moreover, feed cost/Kg weight gain decreased gradually with the increase of substitution levels of FDDGs, especially for 25 and 50% FDDGs, respectively. **Gabr *et al*. (2013)** indicated that total outputs, net return, economic efficiency and relative economic efficiency were gradually increased with increasing the level of DDGs. Furthermore, **Rahman *et al.* (2016)** concluded that, DDG is a cost-effective feed ingredient to replace soybean meal and wheat flour and can be used in diets for freshwater snail and juvenile abalone.

CONCLUSION

It could be concluded that FDDGs meal can be used instead of soybean meal at percentages of25 and 50% in the Nile tilapia fingerlings' diets based on the outcomes of the growth performance, feed utilization, and economic analysis under experimental conditions.

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