Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(4): 1023 – 1038 (2024)
www.ejabf.journals.ekb.eg

# Growth and Physiological Response of the Nile Tilapia (*Oreochromis niloticus*) Fed a Fermented Poultry By-Product Meal

**Abdel Hamid M. S. Eid[1*], Ahmed A. Hashem[2], Mohamed S. Ibrahem[2], Badiaa A. Ali[1], Lobna A. Badawy[3]**

[1]Department of Animal Production and Fish Resources, Faculty of Agriculture, Ismailia, Egypt
[2]Central Lab for Aquaculture Research, Agriculture Research Center
[3]Department of Fish Resources and Aquaculture, Faculty of Environmental Agriculture Sciences, Arish University, El-Arish, Egypt

***Corresponding Author: Abdelhamid_eid@yahoo.com**

## ARTICLE INFO

**Article History:**
Received: May 17, 2024
Accepted: July 2, 2024
Online: July 30, 2024

**Keywords**:
Animal protein,
Feed technology,
Growth performance,
Feed efficiency,
Haematology

## ABSTRACT

A feeding trial was carried out to investigate the effects of a dietary fermented poultry by-product (FPBP) on the growth performance, feed efficiency, body chemical composition, blood biochemical tests and economic efficiency of the Nile tilapia, *Oreochromis niloticus* fingerlings. Poultry by-product was subjected to solid-state fermentation then incorporated into four experimental (Iso-nitrogenous 30% and iso-caloric 4400Kcal/ Kg) diets containing 0, 25, 50 and 75% FPBP instead of soybean meal. Results revealed that the replacement of soybean meal with FBPP had significantly high ($P\leq$ 0.05) growth performance and feed utilization. Moreover, body ash content decreased insignificantly ($P\leq$ 0.05) compared to the control. At a low substitution level of 25% FPBP, a significant increase in body fat content ($P\leq$ 0.05) was recorded compared to the control. Furthermore, body ash and energy contents demonstrated a significant increase ($P\leq$ 0.05) compared with the control. Additionally, biochemical blood tests revealed that FPBP does not have any harmful effects on either liver or kidney function parameters. It could be concluded that the replacement of soybean meal with FPBP at a level of 25% was the best in terms of growth performance and feed utilization under these experimental conditions.

## INTRODUCTION

The aquaculture sector has grown to be a significant industry in many developed and developing nations, generating income, jobs, and nutritious food **(Olsen & Hasan, 2012)**. This has raised attention to an increasing development of aquaculture industry leading to advanced production technologies and culture systems in many parts of the world **(Moss *et al*., 2018)**. Research in fish nutrition focuses on reducing the cost of fish feed, which accounts for 60- 70% of the running cost of intensive system **(Higgs *et al* (1994)**. Therefore, a global priority for finding alternative protein sources to replace expensive/scarce ones in aqua feeds is essential **(Dossou *et al*., 2018a, 2018b, 2019)**. Soybean meal is the most significant source of protein in the diet for the Nile tilapia. However, the price of soybean meal, and subsequently the feed cost, has increased recently. Thus, the replacement of soybean meal by cheaper alternatives is needed **(Plaipetch & Yakupitiyage, 2014)**. Animal protein ingredients are good sources of amino acids with high protein content, free of anti-nutritional factors, nonconventional, total digestible dry matter and energy similar to fish meal **(Bureau *et al.,* 1999, 2000)**, locally available and comparatively less expensive than fish meal **(Bureau *et al.,* 1999; EL-Sayed, 1999; Abdel-Warith *et al.,* 2001)**. Poultry by-product meal, known for its high crude protein content of 58% **(Hill *et al.,* 2019)**, has high digestibility (90%) and contains a proper balance of essential amino acids **(Yang *et al.,* 2006; Shapawi *et al.,* 2007)**.

Because of the high nutritional value, poultry by-product meal (PBM) is used as a protein source in the formulated diets for the tilapia *Oreochromis niloticus* **(Sadiku & Jauncey, 1995; El-Sayed, 1998)**, the European eel *Anguilla anguilla* **(Appelbaum *et al.,* 1996)**, the sea bream *Sparus aurata* **(Nengas *et al.,* 1999)**, the sunshine bass *Morone chrysops* **(Webster *et al.,* 1999)**, the Pacific white shrimp *Litopenaeus vannamei* **(Davis & Arnold, 2000)**, the channel catfish *Ictalurus punctatus* **(Abdel-Warith *et al.,* 2001)**, the rainbow trout *Oncorhynchus mykiss* **(Sevgili, 2004)**, the cobia *Rachycentron canadum* **(Zhou *et al.,* 2011)**, the grouper *Epinephelus ongus* **(Gunben *et al.,* 2014)**, and the sea bass *Dicentrarchus labrax* **(Wang *et al.,* 2015)**. Fermentation is a suitable method to increase the nutritional quality of feed ingredients **(Fagbenro *et al.,* 1994; Sun *et al.,* 2014; Barnes *et al.,* 2015; Hassaan *et al.,* 2018; Jannathulla *et al.,* 2018; Siddik *et al.,* 2019)**, enhance feedstuff palatability **(Fagbenro *et al.,* 1994)**, improve the digestibility of protein, amino acids, fibers and calcium **(Sun *et al.,* 2014; Hassaan *et al.,* 2018)**, and reduce anti-nutritional factors **(Barnes *et al.,* 2015)**.

**Dawood *et al.* (2020a)** reported that the incorporation of FPBM in the Nile tilapia diet improve growth performances and feed efficiency. For the Nile tilapia, the suggested dietary FPBM inclusion values are 11.17– 25.14% diet. Fermented PBM has a balance of amino acid profile and high protein content versus un-fermented poultry by-product meal. Furthermore, **Dawood *et al.* (2020b)** reported that the yeast fermented PBM has beneficial effects on the growth, digestive enzymes activity, intestinal morphometry and immune functions of the common carp. Considering the low price of PBM and the beneficial effects of *S. cerevisiae*, the results obtained showed the importance of fermented PBM as dietary supplement in the formulation of feed for the common carp. In addition, **Sathishkumar *et al.* (2021**) postulated that poultry by-product meal can completely replace fish meal protein in the diets of the GIFT tilapia without any negative impact on growth performances, nutrient utilization, blood haematological and biochemical responses.

The study was conducted to determine the influence of dietary levels of fermented poultry by-product (FPBP) as a replacement of soybean on the growth parameters, feed efficiency and body chemical composition in the Nile tilapia *Oreochromis niloticus* diets.

## MATERIALS AND METHODS

**Solid-state fermentation**

A commercially poultry by-product (PBP) was purchased from a local company (Abou Hammad, Sharqia, Egypt) and finely grounded to particle size (< 500µm) by a screen diameter. Three fermented replicates of PBM were performed by the modification method of **Yabaya *et al*. (2009)**. Each replicate comprised 2kg PBM, 60.5mg of commercial dry yeast, *S. cerevisiae*, (Fermipan®, GB ingredients, china) with a cell density of $3 \times 10^6$ cell/ g and 1.1L of distilled water (50% moisture), all of which were homogenized in a Hobart food mixer for 15min. This provided a yeast density of $1 \times 10^6$ cell/g meal. Each replicate lasted for 48h in a 10L glass jar covered with an aluminium foil and incubated at 40˚C, which is the optimal growth temperature for *S. cerevisiae*. The yeast fermented PBM was dried to a constant weight at 70˚C.

**Experimental units**

Twelve glass aquaria (50 x 60 x 70cm$^3$) containing equal amount of water (0.21m$^3$) were used for each experiment. Each glass aquaria were 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**

The Nile tilapia (*Oreochromis niloticus*) fingerlings, all males, reversed sex, were taken from the Central Laboratory for Aquaculture Research, Abbasa Fish Hatchery, Sharkia Governorate, Egypt. A total of 500 fingerlings (weighing approximately 5.00± 0.002g SD), 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 seven equal groups (three replicates per each) in the experimental glass aquaria (20 fish/aquaria). Moreover, they were fed experimental diets till satiation. The experiment lasted for 112 days. Feed was offered two times daily, at 10:00 AM and 14: 00 PM, for 6 days a week. Furthermore, fish per each aquarium were group-weighed every ten days. At the end of the experiment, fish were collected, counted, and group weighed per treatments. 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 formulated is presented in Table (1). Four diets were formulated to contain 30% crude protein and (4438k Ca/ kg) gross energy. Consideration was also given to the equivalence of other components such as fiber. Diet 1 represented the control one, while in diets 2, 3, and 4, the replacement of soybean meal by fermented poultry by-product meal was at graded levels of 25, 50, and 75%, respectively.

**Table 1.** Proximate chemical composition of the ingredients used in the experimental diets

| Ingredient | Fish meal | Soy bean meal | Yellow corn | Wheat bran | Gluten | Fermented poultry by-product |
|---|---|---|---|---|---|---|
| **Dry matter** | 92.00 | 90.00 | 89.00 | 91.60 | 92.90 | 95.95 |
| **Crude protein** | 62.10 | 44.00 | 7.50 | 12.50 | 60.11 | 61.28 |
| **Ether extract** | 7.70 | 3.80 | 3.60 | 3.00 | 8.00 | 15.78 |
| **Crude fiber** | 1.70 | 6.00 | 3.20 | 11.00 | 1.90 | 2.20 |
| **Ash** | 21.80 | 6.50 | 3.00 | 5.00 | 2.28 | 13.37 |
| **NFE** | 6.70 | 38.10 | 82.70 | 68.50 | 27.71 | 7.37 |

## Chemical analysis

Four isonitrogenous and isocaloric diets were formulated from practical ingredients (Table 2). The experimental diets were analyzed to determine the percentage of the moisture, protein, lipid, fiber and ash. Moreover, 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 parameters

***Live body weight***

Fish were weighed to the nearest 0.1g at the beginning of the experiments and every 15 days.

***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).

***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***

The specific growth rate (SGR) was calculated according the following equation:

SGR = [ln (final fish weight) – ln (initial fish weight)] X 100 / period (day).

## Feed utilization parameters

### *Feed conversion ratio*

The 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,

$N_t$ = 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

At the end of the experimental period (112 days), five fish per glass aquaria were randomly chosen and anesthetized with 120mg/ l amino-benzoic acid (Sigma-Aldrich) before the drawing of blood. The blood was extracted from the caudal vein and divided in one set of tubes. One set was left with no anticoagulant in order to clot at 4ºC and centrifuged at 5000rpm for 5min at room temperature. The uric acid was measured using the enzymatic determination method according to **Barham and Trinder (1972)**. Creatinine was measured by the colorimetric method as described by **Henery (1974)**. Aspartate amino transferase (AST) and alanine amino transferase (ALT) activities were determined colorimetrically by transaminases kites (Boehringer Manmheim kit).

## 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 daily. Ammonia nitrogen ($NH_3$-N) and nitrite ($NO_2$) values were detected on a weekly 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 weekly monitored by titration with sulphuric acid till pH point reached 4.5 **(APHA, 1998)**.

**Table 2.** Ingredient formulation (%) and proximate composition of the experimental diets

| Ingredient % | Control | 25% FPBP | 50% FPBP | 75% FPBP |
|---|---|---|---|---|
| Fish meal | 5.00 | 5.00 | 5.00 | 5.00 |
| Soybean meal (SM) | 44.00 | 33.00 | 22.00 | 11.00 |
| FPBP | 0.00 | 8.16 | 16.32 | 24.48 |
| Corn | 32.00 | 35.14 | 37.98 | 39.82 |
| Wheat bran | 10.00 | 11.00 | 11.00 | 13.00 |
| Corn gluten | 7.00 | 6.00 | 6.00 | 5.00 |
| Soybean oil | 1.30 | 1.00 | 1.00 | 1.00 |
| Vit. & Min. Premix[1] | 0.70 | 0.70 | 0.70 | 0.70 |
| Proximate Analysis% | | | | |
| Dry matter | 89.21 | 89.88 | 90.66 | 91.19 |
| Crude protein | 30.97 | 30.71 | 30.91 | 30.67 |
| Ether extract | 5.33 | 5.97 | 6.94 | 6.86 |
| Crude fiber | 4.98 | 4.69 | 4.03 | 4.08 |
| Ash | 5.57 | 6.07 | 6.53 | 7.04 |
| NFE[2] | 53,15 | 52.56 | 51.32 | 50.35 |
| G E( Kcal/Kg([3] | 4437.90 | 4459.57 | 4511.57 | 4544.99 |
| P/E ratio[4] | 69.78 | 68.66 | 67.58 | 67.50 |

[1] each Kg vitamin & mineral mixture premix contained Vitamin A, 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; Nicotinic acid, 8g; Folic acid, 0.4g Biotin, 20mg, Mn, 22g; Zn, 22g; Fe, 12g; Cu, 4g; I, 0.4g, Selenium, 0.4g and Co, 4.8mg.

[2]Nitrogen free extract = 100 – (%Protein + %Fat + %Fiber + %Ash).

[3]Gross energy based on protein (5.65 Kcal/g), fat (9.45 Kcal/g) and carbohydrate (4.11Kcal/g). **(NRC, 2011)**.

[4] P/E ratio= mg crude protein/ kcal GE.

## Economical evaluation

The economical evaluation 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 (2007)** 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. Differences between treatments were tested at the 5% probability level **(Duncan, 1955)**.

## RESULTS

### Growth performance

Growth performance parameters, related to the influence of incorporation of FPBP in the Nile tilapia diets instead of soybean meal (BW, BWG, DG, SGR, RGR)**,** showed primitive results (Table 3). All substitution levels recorded a significant increase in all growth performance parameters compared to the control. The treatments could be discernibly ordered as 25, 50, and 75% FPBP, with significant differences among all treatments. Survival rates were not influenced by the replacement processes. Therefore, FPBP did not compromise fish survival and welfare.

### Feed utilization

Feed efficiency parameters, including feed intake (FI), feed conversion ratio (FCR), feed efficiency ratio (FER) and protein efficiency ratio (PER), are illustrated in Table (4). The feed consumption of the Nile tilapia decreased significantly compared to the control in the diet containing the lowest substitution level (25% FPBP), while 50% FPBP recorded an insignificant decrease compared to the control. The feed conversion ratio (FCR) and feed efficiency ratio (FER) demonstrated significant enhancement at all substitution levels compared to the control. Among the treatments, low substitution levels (25% and 50% FPBP) showed the best FCR and FER, followed by 75% FPBP. The protein efficiency ratio (PER) also showed significant improvement compared to the control, especially at low substitution levels (25% and 50% FPBP). Although protein productive value (PPV) recorded an increase at all substitution levels, it did not differ significantly from the control statistically.

**Table 3.** Effect of different dietary FPBP on growth performance of the Nile tilapia (*Oreochromis niloticus*) fingerlings fed experimental diets

| Treatment | Control | Fermented PBP | | |
|---|---|---|---|---|
| | | 25% FPBP | 50% FPBP | 75% FPBP |
| IW (g/fish) | 5.10±0.20 | 5.07 ±0.25 | 5.06 ±0.30 | 5.09±0.27 |
| FBW (g/fish) | 34.33 ±1.61$^{d}$ | 50.36 ±1.11$^{a}$ | 45.60 ±0.75$^{b}$ | 39.22 ±0.53$^{c}$ |
| BWG (g/fish) | 29.24 ±1.61$^{d}$ | 45.28 ±1.12$^{a}$ | 40.53 ±0.73$^{b}$ | 34.16±0.54$^{c}$ |
| RGR % | 574.00 ±31$^{d}$ | 891.00 ±22$^{a}$ | 799.00 ±13$^{b}$ | 675.00 ±11$^{c}$ |
| DG (g/fish) | 0.26±0.01$^{d}$ | 0.41 ±0.01$^{a}$ | 0.37 ±0.01$^{b}$ | 0.31 ±0.01$^{c}$ |
| SGR (%/d) | 1.73 ±0.04$^{d}$ | 2.08 ±0.02$^{a}$ | 1.99 ±0.02$^{b}$ | 1.86 ±0.01$^{c}$ |
| SR % | 90.00 ±0.00 | 90.00 ±0.02 | 93.00 ± 2.89 | 90.00 ±0.00 |

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

**Table 4.** Effect of different dietary FPBP on feed utilization of the Nile tilapia (*Oreochromis niloticus*) fingerlings fed experimental diets

| Treatment | Control | Fermented PBP | | |
|---|---|---|---|---|
| | | 25% FPBPM | 50% PBPM | 50% FPBPM |
| FI (g/fish) | 53.27 ±1.11$^{a}$ | 48.44±1.07$^{b}$ | 51.73 ±0.86$^{ab}$ | 55.80 ±2.69$^{a}$ |
| FCR | 1.83 ±0.07$^{a}$ | 1.07 ±0.02$^{d}$ | 1.27 ±0.01$^{c}$ | 1.63 ±0.05$^{b}$ |
| FER | 0.55 ±0.03$^{d}$ | 0.93 ±0.01$^{a}$ | 0.78 ±0.01$^{b}$ | 0.61 ±0.02$^{c}$ |
| PER | 1.99 ±0.11$^{c}$ | 3.39 ±0.02$^{a}$ | 2.83 ±0.01$^{b}$ | 2.19 ±0.06$^{c}$ |
| PPV | 28.98 ±1.72 | 32.66 ±1.59 | 30.87 ±2.04 | 31.78±3.16 |

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 (5). Neither body dry matter nor protein contents recorded any significant variation between all treatments compared to the control. Body ash content demonstrated an insignificant decrease compared to the control. On the other hand, the low substitution level of 25% FPBP recorded a significant increase in body fat content compared to the control, while the level of 50 and 75% FPBP recorded an insignificant increase compared with the control. Both body ash contents demonstrated a significant increase compared with the control.

**Table 5.** Effect of different dietary FPBP on body chemical composition of the Nile tilapia *(Oreochromis niloticus*) fingerlings fed experimental diets

| **Treatment** | **Control** | **Fermented PBP** | | |
|---|---|---|---|---|
| | | **25% FPBPM** | **50% FPBPM** | **50% FPBPM** |
| **DM** | 26.88±0.35[a] | 27.38 ±0.48[a] | 27.69±0.18[a] | 27.89±0.29[a] |
| **CP** | 62.39±0.35[a] | 61.70 ±1.65[a] | 61.18 ±0.86[a] | 62.75±1.97[a] |
| **EE** | 20.32±0.28[b] | 24.50±1.65[a] | 24.29 ±0.42[ab] | 23.15±1.59[ab] |
| **Ash** | 17.29±0.42[a] | 13.80±0.04[b] | 14.52±0.45[b] | 14.10 ±1.02[b] |

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

## Biochemical parameters

Table (6) lists the average values for the blood serum components: urea, creatinine, AST and ALT in the blood serum of *O. niloticus*. The results in Table (6) reveal that the replacement of soybean meal with FPBP had not any deleterious effects on either liver (ALT and AST) or kidney (Urea and Creatinine) function parameters after 112 days of trial.

**Table 6.** Effect of different dietary FPBP on biochemical analysis of the plasma of the Nile tilapia *(Oreochromis niloticus*) fed different experimental diets

| **Treatment** | **Control** | **Fermented PBP** | | |
|---|---|---|---|---|
| | | **25% FPBP** | **50% FPBP** | **75% FPBP** |
| **ALT** | 15.90± 0.17 | 15.90± 0.23 | 16.07± 0.15 | 16.07± 0.15 |
| **AST** | 28.72± 0.31 | 29.80± 0.32 | 29.67± 0.40 | 29.76± 0.31 |
| **Urea** | 14.50± 0.17 | 14.30± 0.21 | 13.96± 0.09 | 13.83± 0.35 |
| **Creatinine** | 0.16± 0.03 | 0.18± 0.04 | 0.19± 0.04 | 0.19± 0.04 |

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 control group are presented in Table (7). Data in Table (7) clarify that the costs of one kg of the diet for fermented PBP meal in experimental diets were 26.79, 24.31, 22.70 and 20.70 LE, for control diet, at a level of 25, 50 and 75% FPBP, respectively. Costs of one kg gain in weight were 49.03, 26.01, 28.82, and 33.74 LE for control, in T1, T2 and T3, respectively. These results indicate that incorporation of fermented PBP meal into the tilapia diets reduced the price of one kg diet to 46.94, 41.22 and 31.18% for the 25, 50 and 75% FPBP, respectively, compared to the control group (100% of the price).

**Table 7.** Effect of different dietary FPBP levels on the economic efficiency of the Nile tilapia *(Oreochromis niloticus*) fingerlings

| **Treatment** | **Control** | **Fermented PBP** | | |
|---|---|---|---|---|
| | | **25% FPBP** | **50% FPBP** | **75% FPBP** |
| Feed costs (L.E)/Kg | 26.79 | 24.31 | 22.70 | 20.70 |
| Feed intake | 53.27 | 48.44 | 51.73 | 55.80 |
| Feed intake cost (LE)[1] | 1427 | 1177 | 1174 | 1155 |
| Relative to control %[2] | 100.00 | 90.74 | 84.70 | 77.26 |
| FCR[3] | 1.83 | 1.07 | 1.27 | 1.63 |
| Feed costs (L.E/kg weight gain)[4] | 49.03 | 26.01 | 28.82 | 33.74 |
| Relative to control (%)[5] | 100.00 | 53.06 | 58.78 | 68.82 |
| Decrease in feed costs (L.E/kg weight gain %) | 0.00 | 46.94 | 41.22 | 31.18 |

[1]Feed cost X feed intake.
[2]Value of each treatment feed intake cost /highest value 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

The influence of *Saccharomyces cerevisiae*-fermented poultry by-product meal (PBM) on growth performance, micromorphological, and immunological changes in the common carp demonstrated a significant improvement on fish growth performance parameters (final body weight, weight gain and specific growth rate) **(Dawood, *et al*., 2020b)**. The same results were reported in the studies of **Sathishkumar *et al*. (2021)**, **Abbass *et al.* (2023)** and **Hendam *et al.* (2023)**, who concluded that poultry by-product meal, either in bioprocessed (fermented by *Saccharomyces cerevisiae and Lactobacillus casei*) or in non-processed condition, can replace fish meal protein completely in the diets of the GIFT tilapia in floating net cages, without recording any negative impact on growth performances, nutrient utilization, blood haematological and biochemical responses. Furthermore, they recommended the bioprocessing (fermentation) for achieving higher growth performances. **Dawood *et al*. (2020a)**, **Marwa *et al.* (2023)**, **Mirghaed *et al.* (2023)** and **Ragab *et al.* (2023)** studied the effects of dietary inclusion of alternative ingredients of plant and animal protein including fermented poultry by-product meal (FPBM) on growth performance of the Nile tilapia (*Oreochromis niloticus*). Diets were produced by the inclusion of 10, 20, 30, or 40% FPBM. Regarding to feed efficiency utilization namely feed intake and feed conversion ratio, feed consumption of fish fed diets containing 10, 20 and 30% FPBM did not differ significantly compared with the control, while the high inclusion level of 40% FPBM decreases significantly the feed intake. Fish fed diets containing 10 and 20% FPBP showed a significant improvement in FCR compared with the control; however, high inclusion level of FPBP (30 and 40%) did not differ significantly with the control. The findings are in agreement with the obtained results of **Dawood *et al.* (2020b)**, they revealed that the inclusion of *Saccharomyces cerevisiae*-fermented poultry by-product meal (PBM) had a significant improvement on fish final body weight (FBW), weight gain (WG), specific growth rate (SGR), and feed intake (FI) and feed conversion ratio (FCR) of the common carp (*Cyprinus carpio*).

**Dawood *et al.* (2020b)** investigated the effects of *Saccharomyces* cerevisiae-fermented poultry by-product meal (PBM) on growth performance, and the whole body composition of the common carp. The results revealed that the inclusion of fermented PBM had a significant improvement on growth performance parameters. Whole body composition of fish did not vary significantly between different dietary treatments ($P$> 0.05). Following various feeding trials, fish health status can be assessed using blood biochemical indices **(Badrey *et al.*, 2019)**. Moreover, fish health and physiological status can be broadly determined by biochemical indicators **(Zhou *et al.*, 2005)**. The results in Table (7) reveal that the replacement of soybean meal with FPBP have not any deleterious effects on either liver (ALT and AST) or kidney (Urea and Creatinine) function parameters.

The results of economic evaluation showed that diets containing FPBP showed that the cost of one ton of feed mixture reduced gradually with the increase of substitution levels (Table 8). Additionally, feed cost/Kg weight gain decreased gradually with the increase of the substitution levels of FPBP, especially for 25 and 50% FPBP, respectively. These results coincide with the findings of **Arunlertaree and Rakyuttithamkul (2006)**, **Hassaan *et al.* (2018)**, **Davies *et al.* (2020)** and **Samad *et al.* (2022)** who elucidated that the replacement of fish meal with fermented feather in the diet of the hybrid clarias cat fish at levels of 25, 50, 75 and 100% of fish meal diet reduced feed costs.

## CONCLUSION

The present study highlights the importance of finding novel ingredients and using new feed technology to achieve the sustainability of aquaculture industry. The current trial concluded that replacement soybean meal with FPBP at a level of 25% was the best in terms of growth performance and feed under this experimental conditions

## REFERENCES

**AOAC** (2019). Association of official analytical chemists, official methods of analysis.16Th edition, AOAC, Arlington, VA. 1832.Aquacult. Rep., 16 (2020), Article 100255

**APHA** (1998). Standard methods for the examination of water and wastewater, 20pp.

**Abbas, E.; Ahmed Said Al-Souti; Zaki Z. Sharawy; Ehab El-haroun, and Mohamed Ashour** (2023). Impact of Dietary Administration of Seaweed Polysaccharide on Growth, Microbial Abundance, and Growth and Immune-

Related Genes Expression of The Pacific Whiteleg Shrimp (*Litopenaeus vannamei*). Life 13, 344

**Abdel-Warith, A. A.; Russell, P. M. and Davies, S. J.** (2001). Inclusion of a commercial poultry by-product meal as a protein replacement of fish meal in practical diets for African catfish *Clarias gariepinus* (Burchell 1822). Aquaculture Research, 32:296–305.

**Appelbaum, S.; Birkan, V. and Prilutzly, A.** (1996). Use of chicken meal as a substitute for fish meal in the diet of young eels. *Arch. Pol. Fish*. 4: 141-145.Aquaculture. 179:13–23.

**Arunlertaree, C. and Rakyuttithamkul, E.** (2006). Utilization of Fermented Feather Meal as a Replacement of Fish Meal in the Diet of hybrid Clarias Catfish. Kasetsart J. (Nat. Sci.) 40: 436 – 448.

**Badrey, A.A.; Osman, A.; Farrag, M.S.; Toutou, M.M. and Moustafa, M.A.** (2019). Influences of diets supplemented with pomegranate peel on haematology, blood biochemistry and immune status in monosex Nile tilapia, Oreochromis Nilotic's. Egyptian Journal of Aquatic Biology and Fisheries, 23(2): 133-144.

**Barham, D. and Trinder, P.** (1972). an improved colour reagent for the determination of blood glucose by the oxidase system. Analyst, 97 (1151): 142-145.

**Barnes, M. E; Brown, M. L. and Neiger, R.** (2015). Comparative performance of two rainbow trout strains fed fermented soybean meal. *Aquaculture International*, *23*(5), 1227–1238.

**Bureau, D.; harris, A. and Cho, C.** (1999). Apparent digestibility of rendered animal protein ingredients for rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, *180*(3–4), 345–358.

**Bureau, D.P. ; harris, A.M. ; Bevan, D.J. ; Simmons, L.A. ; Azevedo, P.A. and Cho, C.Y.** (2000). Feather meals and meat and bone meals from different origins as protein sources in rainbow trout *(Oncorhynchus mykiss*) diets. Aquaculture 181, 281– 291.

**Davis, D.A. and Arnold C.R,** (2000). Replacement fishmeal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. Aquaculture, 185:291-298.

**Davies, S.J. ;Guroyd, G. ; hassaan, M. ;El-Ajnaf, S.M. and Ehab E.** (2020). Nutritional evaluation of a novel co-fermented apple-pomace, molasses and formic acid generated sardine based fish silages as ingredients in diets for juvenile European sea bass *(Dicentrachus labrax)* Aquaculture, 521, 735087

**Dawood, M.O.; Magouz, F.I.; Mansour, M.; Saleh, A.A.; Asely, A.M., Fadl, S.E; Ahmed, h. A; Al-Ghanim, K.A.; Mahboob, S. and Al-Misned, F.** (2020a). Evaluation of Yeast Fermented Poultry By-Product Meal in Nile Tilapia (*Oreochromis niloticus*) Feed: Effects on Growth Performance, Digestive Enzymes

Activity, Innate Immunity, and Antioxidant Capacity. Front. Vet. Sci. 6:516. doi: 10.3389/ fvets. 2019. 00516

**Dawood, M. A.; Magouz, F. I.; Essa, M., and Mansour, M.** (2020b). Impact of yeast fermented poultry by-product meal on growth, digestive enzyme activities, intestinal morphometry and immune response traits of common carp (*Cyprinus carpio*). Annals of Animal Science, 20(3), 939–959.

**Dossou, S.; Koshio, S.; Ishikawa, M.; Yokoyama, S.; Dawood, M. A. O.; El Basuini, M. F.; El-hais, A.M. and Olivier, A.** (2018a). Effect of partial replacement of fish meal by fermented rapeseed meal on growth, immune response and oxidative condition of red sea bream juvenile, *Pagrus major*. Aquaculture 490: 228–235.

**Dossou, S.; Koshio, S.; Ishikawa, M.; Yokoyama, S.; Dawood, M. A. O.; El Basuini, M. F., Olivier, A. and Zaineldin, A.I.,** (2018b). Growth performance, blood health, antioxidant status and immune response in red sea bream *(Pagrus major*) fed *Aspergillus oryzae* fermented rapeseed meal (RM-Koji). Fish Shellfish Immunol. 75: 253–262.

**Dossou S. ; Koshio S. ; Ishikawa M. ; Yokoyama S. ; El Basuini M.F. and Zaineldin A.I., *et al*** (2019). Effects of replacing fishmeal with fermented and non-fermented rapeseed meal on the growth, immune and antioxidant responses of red sea bream (*Pagrus major*). Aqua Nutr. 25:508–17.

**Duncan, D. B.** (1955). Multiple range ad multiple F- test. Biometrics, 11: 1- 42.

**Eid A. h. and Mohamed K. A.** (2008). Effect of using probiotic as growth promoters in commercial diets monosex Nile tilapia (*Oreochromis niloticus)* fingerlings. 8th International symposium on tilapia in aquaculture

**El-Sayed, A.M.** (1998). Total replacement of fish meal with animal protein sources in Nile tilapia, *Oreochromis niloticus (L.)* feeds. Aquaculture Research, 29: 275-285.

**El-Sayed, A.M.** (1999). Alternative dietary protein sources for farmed tilapia, Oreochromis spp. Aquaculture, 179:149-168.

**Fagbenro, O.; Jauncey, K. and haylor,G.** (1994). Nutritive value of diet containing dried lactic acid fermented fish silage and soybean meal for juvenile *Oreochromis niloticus* and *Clarias gariepinus*. *Aquatic Living Resources*, *7*(2), 79–85.

**Gunben, E. M. ; Senoo, S. ;Yong, A. and Shapawi, R.** (2014). high potential of poultry by-product meal as a Main Protein Source in the formulated feeds for a commonly cultured grouper in Malaysia (*Epinephelus fuscoguttatus*). Sains Malaysiana. 43: 399- 405.

**hassaan, M. S.; Soltan, M. A.; Mohammady, E. Y.; Elashry, M. A. El-haroun, E. R. and Davies, S. J.** (2018) .Growth and physiological responses of Nile tilapia, *Oreochromis niloticus* fed dietary fermented sunflower meal inoculated with *Saccharomyces cerevisiae* and *Bacillus subtilis*. Aquaculture 495: 592–601.

**Henry, R.; Cannon, D. and Winkleman, J.;** (1974).Automated determination of serum and urine creatinine. Clinical chemistry, principles and techniques. Harper and Row, New York, pp. 552–555.

**Hendam, M. M. ; Moaheda E., Ehab E. ; Hien v. D. ; Thian H.C. and El-Sayed H. E.** (2023). Effects of water additive probiotic, Pediococcus acidilactici on growth performance, feed utilization, hematology, gene expression and disease resistance against Aspergillus flavus of Nile tilapia *(Oreochromis niloticus*). Animal Feed Science and Technology 303: 115696

**Higgs D.A.; Prendergast A.F.; Dosanjh B.S.; Beames D.M.; Deacon G. and Hardy R.W.,** (1994).Canola protein offers hope for efficient Salmon production. Proceedings of an International Fish physiology symposium held July 16-21, 1994, organized and edited by Don McKinlay. 23-28 p

.

**Hill J.C.; Alam M.S.; Watanabe W.O.; Carroll P.M.; Seaton P.J. and Bourdelais A.J.** (2019) Replacement of menhaden fish meal by poultry by-product meal in the diet of juvenile red porgy. N Am J Aquac. 81:81–93.

**Jannathulla, R. ; Dayal, J. S. ; Ambasankar, K. and Muralidhar, M.** (2018) Effect of *Aspergillus niger* fermented soybean meal and sunflower oil cake on growth, carcass composition and haemolymph indices in *Penaeus vannamei* Boone, 1931. *Aquaculture, 486*, 1–8.

**Marwa, A; Elashry, M. ;Mohammady, E., Soaudy, M. ; El-Garhy, H., E. ; Mustafa A. ; Ragaza, J. ; Ehab E., and Hassaan, M**. (2023).Dietary Alpha-Monolaurin for Nile Tilapia (*Oreochromis niloticus*): Stimulatory Effects on Growth, Immune hematological Indices, and Immune-Related Gene Express Aquaculture Research, doi.org/10.1155/2023/3155447

**Mirghaed, A.,T. ; Seyed S.M. ; Melika G.R. ;Abbasali A. M. ;Ehab E. and Seyyed M. H.** (2023). Effects of dietary lactic acid supplementation on growth performance, hemato-immunological parameters, and calcium and phosphorus status of common carp, *Cyprinus carpio.* Aquaculture Reports 29, 101499

**Moss, A. S.; Koshio, S.; Ishikawa, M.; Yokoyama, S.; Nhu, T. H.; Dawood, M. A. O. and Wang, W.** (2018). Replacement of squid and krill meal by snail meal (*Buccinum striatissimum*) in practical diets for juvenile of kuruma shrimp (*Marsupenaeus japonicus*). Aquacult. Res., 49: 3097–3106.

**Nengas, I. ; Alexisand M.N. and Davies, S.J.** (1999). High inclusion levels of poultry meals and related by products in diets for gilthead sea bream, (*Sparus aurata L).* Aquaculture, 179: 13-23.

**NRC (National Research Council).** (2011). Nutrient requirements of fish. Committee on Animal Nutrition. Board on Agriculture. National Research Council. National Academy Press. Washington DC, USA.

**Olsen, R.L. and hasan, M.R.** (2012). A limited supply of fishmeal: Impact on future increases in global aquaculture Production. Trends in Food Science & Technology (27) 120-128.

**Plaipetch, P. and Yakupitiyagez, A.** (2014) Effect of replacing soybean meal with yeast-fermented canola meal on growth and nutrient retention of Nile tilapia, *Oreochromis niloticus* (Linnaeus 1758). Aquaculture Research, 45: 1744–1753.

**Ragab, S; Seyed h. h. ; hien V. D. and Ehab E.** (2023). Evaluation of distiller's dried grains with solubles in aquafeeds: A review. Annals of animal science DOI: 10.2478/aoas-2023-0051

**Sadiku, S. E. and Jauncey K.** (1995). Soybean flour-poultry meat meal blend as dietary protein source in practical diets of *Oreochromis niloticus* and *Clarias gariepinus*. Asian Fisheries Science, 8: 159-167.

**Samad, S. O.; Ayub Y A. ; Ehab, R. E. and Simon, J. D.** (2022). Preliminary assessment of a novel Fermented Wheat Protein Concentrate from a bio-distillation source as a dietary ingredient contribution for tilapia *(Oreochromis niloticus).* **Aquaculture report.** 101101

**Sathishkumar, G.; Felix, N. and Prabu, L.** (2021). Effects of dietary protein substitution of fish meal with bioprocessed poultry by-product meal on growth performances, nutrient utilization, and whole-body composition and haemato-biochemical responses of ƐIFT tilapia reared in floating cases. Aquaculture Research, 52: 5407–5418.

**Sevgili, h. and Ertürk, M.M.** (2004**)** Effect of replacement of fish meal with poultry by-product meal on growth performance in practical diets for rainbow trout, *Onchorynchus Mykiss*. Akdeniz Üniv Zir Fak Dergisi, 17:161-167.

**Shapawi, R.; Ng, W.K.; and Mustafa, S.** (2007). Replacement of fish meal with poultry by-product meal in diets formulated for the humpback grouper, *Completes altivelis*. *Aquaculture*, *273*(1), 118–126.

**Siddik, M. A. ; Chungu, P.; Fotedar, R., and howieson, J.** (2019) Bioprocessed poultry by-product meals on growth, gut health and fatty acid synthesis of juvenile barramundi, *Lates calcarifer* (Bloch). PLoS One, 14(4), e0215025.

**SPSS (Statistical Packages for Social Sciences)** (2007). Statistical packages for social sciences (version 17.0) (Chicago, IL, USA: SPSS Inc.).

**Sun, Y.; Chang, A. K. ; Wen, Z. ; Li, Y. ; Du, X. and Li S**. (2014). Effect of replacing dietary fish meal with silkworm (*Bombyx mori* L) caterpillar meal on growth and non-specific immunity of sea cucumber *Apostichopus japonicus* (Selenka). *Aquaculture Research*, *45*(7), 1246–1252.

**Wang, Y.; Wang, F.; Ji, W. X.; han, h. and Li, P.** (2015). Optimizing dietary protein sources for Japanese sea bass (*Lateolabrax japonicus*) with an emphasis on using poultry by-product meal to substitute fish meal. Aquaculture. Res., 46: 874–883.

**Webster, C. D.; Tiu, L. G.; Morgan, A. M., and Ɜannam, A. (**1999**).** Effect of partial and total replacement of fish meal on growth and body composition of sunshine bass Morone chrysops× M. saxatilis fed practical diets. J World Aquac Soc. 30:443–53.

**Yabaya, A.; Akinyanju, J. and Jatau, E.** (2009). Yeast enrichment of soybean cake. World J. Dairy Food Sci. 4: 141–144.

**Yang, Y. Xie, S.Q. ; Cui, Y.B. ; Zhu, X.M. ; Lei, W. and Yang, Y.X.** (2006). Partial and total replacement of fishmeal with poultry by-product meal in diets for gibel carp, Carassius auratus gibelio Bloch. Aquaculture Research. 37: 40–48.

**Zhou, Q. C.; Mai, K. S.; Tan, B. P., and Liu, Y. J.** (2005). Partial replacement of fishmeal by soybean meal in diets for juvenile cobia (*Rachycentron canadum*). Aquaculture Nutrition, 11(3), 175–182.

**Zhou, Q.C.; Zhao, P. Li; Wang h.L. and. Wang. L.G.** (2011). Evaluation of poultry by-product meal in commercial diets for juvenile cobia (*Rachycentron canadum).* Aquaculture, 322: 322-323.