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The Effect of Level and source of Poultry By-Product Meal as a Promising Protein Source on the Sustainability of Aquaculture Biomass Production of (*Oreochromis Niloticus)* in KSA

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Abstract. Fish meal (FM) is an essential product as a primary protein source in the fish feed industry. Due to the expensive price of FM and the negative impact of its high consumption on the environment, alternative protein sources for FM were necessary to be tested. Poultry by-Product meal (PBPM) is a high quality and low-cost protein source. In this study, FM was partially and completely replaced by PBPM in Nile tilapia fingerlings (Oreochromis niloticus) diet to study its effect on biomass performance and nutrient utilization. Six formulas were prepared to replace FM protein with PBPM protein: Maram feed as a commercial control (CC), feed, the experimental control (EC) 0% PBPM, (C3) 32% PBPM, (C4) 67% PBPM, (C5) 100% PBPM-Saudi Radwa Feed company (SRFC), and (C6) 100% PBPM-Con. The study period was extended for 56 days in outdoor ponds. Nile tilapia fingerlings were fed three times daily (initial average weight = 41 g). Final survival ranged between 97% and 72% in all diet treatments and final gain was (41.32g – 14.73g). However, the gain of C4 (41.32) was higher than in the controls CC (38.24) and EC (40.69) also, feed conversion ratios FCR (1.21– 4.29). The best results of growth performance and nutrient utilization were for C4 (67% PBPM). The results of this study showed that poultry by-product meal is a great alternative protein source up to 67% of the fish meal for fish meal for the feeding of Nile tilapia fingerlings.

***Keywords*:** fish meal, poultry by-product meal, chicken offal meal, nile tilapia, aquaculture.

1. Introduction

Aquaculture is an ancient phenomenon that modified the normal wetlands or water bodies to catch young fish in closed areas until harvest (Elvira A. Baluyut,1989). As human population grows rapidly, the consumption of fish will increase. As a result, aquaculture has been an important source to provide high-quality fish proteins. Fish is a vital source of animal protein, vitamins, and nutrients required for human health (Khan et al., 2018). In the Kingdom of Saudi Arabia (KSA), aquaculture development has been recently identified as a priority field after the oil and gas sector. This industry is considered an important contributor to food security, for both the creation of jobs and the general growth of the country's economy (Cardia et al., 2015).

Nile tilapia (*Oreochromis niloticus*) is cultured worldwide for many reasons. First, it resists diseases and tolerates them in different environmental conditions. In addition, it can adapt to the water of low quality. Finally, the reproduction of tilapia is rapid, and it can feed on many types of food and microorganisms (BFAR-NFFTC, 2000).

Fish meal (FM) and fish oil are the prime ingredients in fish nutrition. FM is the main source of protein that contains essential amino acids. Furthermore, fish oil offers long-chain omega-3 acids, which are important for fish's health (Olsen and Hasan, 2012). Fish feed contains a high percentage of protein, mostly of fish meals. FM is an unsustainable, expensive protein source and negatively affects the environment (Sánchez-Muros et al., 2014). Therefore, it is necessary to search for an alternative protein source for fish meal, because of this, the protein source should be high in protein content, with high palatability, and low in anti-nutritional factors (Sánchez-Muros et al., 2014).

Using food waste to feed fish, such as poultry by-product meal (PBPM), supports KSA Vision 2030 in terms of finding solutions to food waste, which reduces the problem of global pollution and supports the environment. It also provides sustainable food sources for communities. Bhaskar et al. (2014) stated, "Poultry viscera is among such animal-origin protein sources that can replace FM". The PBPM refers to chicken viscera or waste, which includes the undesirable and unusually consumed parts of the chicken's body, including the heart, lungs, intestines, feet, etc. (Aggoor et al., 2003; Ayim et al., 2018).

This research introduces PBPM as an alternative to FM and investigates its effects on fish biomass as a major source of low-cost protein. PBPM has been tested as alternative for FM with a successful result in different fish species. In the USA, PBPM was used as a FM partial substitute for up to 70% successfully in Florida PBPM pano *Trachinotus carolinus diet* (Riche, 2015). Zapata et al. (2016) noted that PBPM could successfully use up to 67% FM substitute in Totoaba. In mahseer diet, FM can be replaced by PBPM up to 100% without negative effects (Saufinas et al., 2013). Research in Mexico done by Moran Angulo et al. (2014) showed that there is an ability to replace FM by PBPM in juvenile spotted rose snapper (*Lutjanus guttatus*) up to 25%. Mamoon et al. (2018) used PBPM in the diet of African catfish (*Clarias gariepinus*) up to 50%, conserving an excellent gain and growth rate. Another experiment conducted by Keramat et al. (2014) proved that PBPM is up to 100% useful as a protein source instead of FM for the rainbow trout diet. Using 30% PBPM in African catfish (*Clarias gariepinus*) diet improves growth and gain performance (Falaye, 2011).

Methodology:

2.1. Experimental station and fish preparation:

The experiment of this study was carried out in Baghanim's Farm in Bahra, Makkah. The Nile tilapia fingerlings (*Oreochromis niloticus*) were randomly collected from the farm ponds. The fingerlings were randomly divided into 4 external ponds. Each pond contains 3 cages. Each cage has 50 fish. Two cages are prepared for each treatment. For 56 days, the fish were fed to satiation within limits of 3% of body weight with one of the treatment feeds.

2.2.Diet preparation:

The PBPM was obtained from Saudi Radwa Food Co. Ltd (SRFC). It was defined as the milled dry rendered material originating from the processing of chicken waste, rendered clean parts of the carcass of the slaughtered chicken carcass. This includes heads, feet, undeveloped ova, and intestines (exclusive of feathers) as offal. The product typically consists of 10 – 18% ash and 50 – 67 % crude protein with a fat content of about 12% (Yu, 2004). All diets are isocaloric and isonitrogenous in gross nutrient terms and adjusted at appropriate levels to contain 32% crude protein and 10% lipid. A control diet based on the high-quality fish meal (LT70) served as the reference source of dietary protein used to substitute with PBPM. A ground wheat meal also included as the main carbohydrate source and bulk filler component.

Six diets were formulated with an incremental substitution of FM with PBPM up to 100% replacement. The experiment had two controls; The first one was commercial feed (Maram feed) (CC), and the experimental control (EC) made and used because of the commercial one composition is not clear regarding its having PBPM. Five feed formulations that contains different amount of PBPM, which were (EC, C3, C4, C5-SRFC, and C6-Con) for (0%, 32%, 67%, 100-SRF%, and 100-Con%, respectively) were prepared in Jeddah Fisheries Research Center (Table 1) in addition to Maram feed. Two types of PBPM from two different sources were used, one was obtained from SRFC and the other one was obtained by a contractor (Con) to make two formulas of 100% PBPM to ensure its effectiveness (C5-SRFC, and C6-Con). The components of each formulation were ground, pulverized, then mixed separately. The mixture was passed and extracted under pressure to obtain 0.3 mm pellets.

Table 1: Ingredients and Chemical Composition (%) of the Experimental Diets.

Feed stuffs/nutrient	CC, Control, commercial feed	EC, experimental control feed	C3, 32% PBPM	C4, 67% PBPM	100% PBPM - SRFC (C5)	100% PBPM - Con (C6)
Fishmeal	UN	30.7	22.7	12.7	0	0
Poultry by-product meal	UN	0	12	24	32	32
Wheat	UN	27	27	28.4	30.1	30.1
Corn gluten	UN	16.1	15.6	14.7	17.7	17.7
Soybean	UN	20.5	18.5	16.5	18.9	18.9
Premix[1]	UN	1	1	1	1	1
Fish oil	UN	2.4	1.9	1.4	0	0
Canola oil	UN	2	1	1	0	0
Vitamin C	UN	0.1	0.1	0.1	0.1	0.1
Histidine	UN	0	0	0	0	0
Methionine	UN	0	0	0	0	0
Lysine	UN	0.2	0.2	0.2	0.2	0.2
Proximate analysis as dry matter basis						
Dry matter	ND	89.7	91.0	88. 5	90.6	90.4
Crude protein	ND	32.5	32.4	31.7	32.1	32.2
Crude fat	ND	7.9	8.1	8.7	9.4	9.4
Crude ash	ND	6.28	6.51	7.30	8.22	8.27
Crude fiber	ND	2.40	2.40	2.99	2.33	2.56
Nitrogen free extract	ND	50.93	50.62	49.31	47.95	47.57
Gross energy (kcal/kg)	ND	4674	4674	4640	4673	4673

[1]Premix= vitamins and minerals that often added to fish feeds.CC: Commercial feed (Maram feed), EC, the experimental control containing 0%PBPM, C3, C4, C5, and C6 containing 0%, 32%, 67%, 100-SRFC%, and 100-Con%, respectively of PBPM. UN: Unknown composition, ND: Not determine.

2.3. Culture condition and water quality:

Before starting the experiment, 12 cages of size 1 × 1.5 × 1 were prepared. Distributed on 4 external ponds, the size of each pond is 170×1000 ×100. Any pond contains 3 cages. Every pond was provided with two oxygen pumps. The dissolved oxygen in the water was kept between 4-6 mg/L. There is also a water pump that pumps 12 L/min continuously, which leads to a complete water change daily.

The temperature of the water was taken by the water thermometer twice a week during the experimental period, ranging between 26 - 31.5°C. The pH of the water was measured twice a week by the pH meter and reagent solutions. It ranged between 8-8.2 pH. Ammonia was measured twice during the experiment by reagent solutions 0,5 ppm. Nitrates 0 pp. The salinity of the water was measured by Refractometer, and it was 3000 ppm.

*2.4. **Growth and feed utilization parameters**:*

Firstly, the experiment lasted for 56 days. The fish were fed manually for 6 days a week and 3 times a day: 8 am, 12 pm, and 4 pm in three batches in each meal to apparent satiation in the ring of equal to 3% of the fish's body weight. The fish was considered satisfaction when they stop gathering of the feed in the second or third batch within 10 minutes of the first batch. Each cage had a unique labeled feed container.

Secondly, the weight and length of Nile tilapia fingerlings were measured on the first day of the experiment. The fish were collected every two weeks to determine growth and survival. The fish were collected for taking their measurements early in the morning. Oxygen pumps were turned off while fish were collected. Weight was measured with a sensitive scale. The fish were anesthetized using clove oil (25 ppm) before sampling and allowed to recover in a holding tank before fish returned to their ponds after the measurement process. Feeding was skipped until the following day. Finally, by the end of the experiment, the fish were collected to measure the final weight and length and collect samples for analysis.

Weight gain (WG), specific growth rate (SGR) survival rate, length gain, feed intake, and feed conversion ratio (FCR) were measured according to the following equations:

- Weight gain (g/fish): WG = initial mean weight - final mean weight
- Length gain (cm) = initial length – final length
- Survival (%) = (Final number of fish / initial number of fish) ×100
- Specific growth rate (%/day): SGR = $\left(\frac{\ln \text{final weight} - \ln \text{initial weight}}{\text{days of culture}}\right) \times 100$
- Feed intake = total feed consumed per tank / total fish per tank
- Feed conversion ratio (FCR) = feed intake / body weight gain

2.5. Chemical analysis:

Samples were taken from all diets and stored at -10 °C until analyzed. A sample of 10 Nile tilapia fingerlings was collected and frozen in under -10°C at the beginning of the experiment as an initial fish sample. Also, at the end of the experiment, samples of 5 fish from every cage were collected, frozen, and stored in a freezer until analyzed. Chemical analysis was done at Jeddah Fisheries Research Center. Proximate compositions of diets and fish tissue were performed according to AOAC (2000) for moisture content and ash. Crude protein (% N 6.25) was determined by the micro Kjeldahl method (1883). Total lipids were determined by a modification of the Folch method (1957).

2.6. Statistical analysis:

Statistical evaluation of the data was done by using the computer software application Sigma plot plus. one-way analysis of variance (ANOVA) was used to identify any statistical differences ($P < 0.05$) in weight resulting of tested experimental factor which was the fish diet formulation. experimental design was mono-factorial, with two replicates. Duncan's New Multiple Range Test was subsequently used to identify the significant differences between treatment mean values for selected parameters. Non-parametric test: Kruskal-Wallis One Way Analysis of Variance on Ranks was used (normality test and/or equality of variance test not met).

3. Results:

3.1. Growth performance:

As a result, the average weight gain varied from one treatment to another. The highest weight gain was in C4 (41.32). It was higher than both CC and EC (38.24 g and 40.69g, respectively). The weight gain of C3 (36.52) was less than both CC and EC. Fish fed C5-SRFC, and C6-Con had the lowest weight gain in all treatments (14.73g and 42.59 g, respectively) (Table 2). Consequently, the average values of specific growth rate SGR were 1.16%, 1.21%, 1.13%, 1.23%, 0.54% and 0.82% for CC, EC, C3, C4, C5-SRFC, and C6-Con respectively. Fish fed C4 had the highest SGR (1.23%/d) (Table 2). but fish fed C5-SRFC diet had the lowest SGR (0.54%/d), significantly lower than all other diet (Fig 1). All treatments had similar length increased with no significant (P > 0.05) differences (Table 3).

The measurements of Nile tilapia fingerling's weight with standard deviation during the experiment are shown in (Table 4). On the first day of the experiment (day 0), there were no significant differences in average fish body weight between the treatments range (41.50 – 41.90 g). By the 14th day, fish fed C4 was significantly larger (55.60) than CC and EC (51.10 g and 51.50 g, respectively). Fish fed C5-SRFC, and C6-Con were significantly smaller (44.50 g and 44.70 g, respectively). On day 28, fish fed C4 was (63.50), almost equal to fish fed CC (63.80 g) and larger than fish fed EC (62.10 g). Fish fed C5-SRFC, and C6-Con were significantly smaller (49.20 g and 54.00 g, respectively). Therefore, on day 42, fish fed C4 were (75.70) larger than fish fed EC (73.20 g) but smaller than fish fed CC (76.22 g). Fish fed C5-SRFC, and C6-Con were significantly smaller (54.90 g and 60.00 g, respectively) than fish fed both CC and EC (76.22 g and 73.20 g, respectively). At the end of the experiment (day 56), fish weight in C4 was significantly higher (82.80) than in all other treatments. Fish weight in C5-SRFC was significantly lower (56.70 g) than in all other treatments. (Fig 2) shows the average body weight for the treatments CC, EC, C3, and C4 were similar, while both C5-SRFC, and C6-Con treatments show a lower result.

3.2. Feed conversion:

The measurements of Nile tilapia fingerling's feed intake through the experiment are shown in (Table 5). As a result, feed intake showed significant differences, which ranged from 0.70 to 1.31 g/fish/d in the first 14 days of the experiment. By day 28, feed intake ranged from 0.72 to 0.81 g/fish/d. In day 42, feed intake ranged from 1.11 to 1.46 g/fish/d. By the final day of the experiment (day 56), feed intake ranged from 0.93 to 1.82 g/fish/d. (Table 5).

The total feed intake (g/fish) was 46.07, 74.39, 58.44, 83.17, 63.03, and 60.87 for CC, EC, C3, C4, C5-SRFC, and C6-Con, respectively (Fig 3). As well as that, (Fig 4) shows the feed conversion rate (FCR) for C5-SRFC (4.29) was significantly higher than fish fed other diets (1.21- 2.50). The FCR of the treatments ranged from 1.21 to 4.29, with almost significant difference among different treatment being the best of the CC. The FCR of fish fed C4 was not significantly different from fish fed EC. The survival rate varied among the treatments by the end of the experiment ranging from (72 to 97%) with significant differences (P > 0.05) among treatments. The mortality rate in the cages in the first pond as a high despite different treatments. This could result from external conditions since the experiment was conducted in open outdoor cages (Fig 5).

Table 2: Growth performance and nutrient utilization + SE of Nile tilapia fingerlings as affected by different dietary levels and source of poultry by-product meal

Parameters	(CC) Control	(EC) Control	(C3) 32% PBPM	(C4) 67%, PBPM	100% - SRFC (C5)	100% - Con (C6)	P-value
Initial body weight, g	41.89 ± 0.49[a]	41.89 ± 0.93[a]	41.50 ± 0.07[a]	41.50 ± 0.10[a]	41.90 ± 0.38[a]	41.90 ± 0.20[a]	0.043
Final body weight, g	80.13 ± 1.05[a]	81.80 ± 14.85[a]	78.00 ± 1.43[a]	82.80 ± 9.39[b]	56.70 ± 0.87[c]	66.50 ± 3.55[b]	0.156
Body weight gain, g	38.24 ± 1.55	40.69 ± 13.91	36.52 ± 1.50	41.32 ± 9.29	14.73 ± 0.49	24.59 ± 3.35	0.169
Feed intake, g fish^{-1}	46.07 ± 0.96[a]	74.39 ± 15.42[a]	58.44 ± 2.27[a]	83.17 ± 2.87[a]	63.03 ± 3.11[a]	60.87 ± 0.09[a]	0.082
Feed conversion ratio	1.21 ± 0.02[a]	2.01 ± 1.07[c]	1.60 ± 0.00[b]	2.06 ± 0.39[c]	4.29 ± 0.35[e]	2.50 ± 0.34[d]	0.122
Specific growth rate, % day^{-1}	1.16 ± 0.04	1.21 ± 0.29	1.13 ± 0.04	1.23 ± 0.20	0.54 ± 0.01	0.82 ± 0.09	0.169
Survival (%)	97.00 ± 1.41	76.00 ± 19.80	93.00 ± 7.07	72.00 ± 0.00	95.00 ± 1.41	94.00 ± 0.00	0.171

A significant difference ($p<0.05$) was observed between different treatments. Mean ± S.E.M. (n= 2), P value: Probability level, CC: Commercial feed (Maram feed), EC, the experimental control containing 0%PBPM, C3, C4, C5-SRFC, and C6-Con containing 0%, 32%, 67%, 100-SRFC%, and 100-Con%, respectively of poultry by-product meal.

Table 3: Average body lengh (cm) +SE of Nile tilapia fingerlings as affetted by fingerlings as affected by different dietary levels and source of poultry by-product meal

Parameters	(CC) Control	(EC) Control	(C3) 32%	(C4) 67%	100% - SRFC (C5)	100% - Con (C6)	P-value
Initial length, cm	12.94±0.24	12.86±0.10	12.85±0.08	12.88±0.19	12.77±0.03	12.99±0.08	0.076
Final length, cm	15.53±0.28	15.27±0.25	15.39±0.09	15.39±0.14	15.31±0.03	15.58±0.10	0.019
Gain in body length, cm	2.58±0.03	2.41±0.15	2.54±0.01	2.50±0.05	2.54±0.00	2.59±0.00	0.270

A significant difference ($p<0.05$) was observed between different treatments. Mean ± S.E.M. (n=2), P value: Probability level, CC: Commercial feed (Maram feed), EC, the experimental control containing 0%PBPM, C3, C4, C5-SRFC, and C6-Con containing 0%, 32%, 67%, 100-SRFC%, and 100-Con%, respectively of poultry by-product meal.

Table 4: Average body weight (g) +SE of Nile tilapia fingerlings fingerlings as affected by different dietary levels and source of poultry by-product meal

Age per day	(CC) Control	(EC) Control	(C3) 32%	(C4) 67%	100% - SRFC (C5)	100% - Con (C6)	P-value
0 (initial)	41.89 ± 0.49[a]	41.89 ± 0.93[a]	41.50 ± 0.07[a]	41.50 ± 0.10[a]	41.90 ± 0.38[a]	41.90 ± 0.20[a]	0.043
14	51.10 ± 0.76[a]	51.50 ± 2.31[a]	51.00 ± 0.65[a]	55.60 ± 1.51[a]	44.50 ± 0.04[a]	44.70 ± 2.01[a]	0.098
28	63.80 ± 0.23[a]	62.10 ± 3.88[a]	59.50 ± 3.85[a]	63.50 ± 4.68[a]	49.20 ± 1.40[a]	54.00 ± 5.33[a]	0.144
42	76.22 ± 1.15[a]	73.20 ± 12.80[a]	72.00 ± 0.12[a]	75.70 ± 1.57[a]	54.90 ± 0.49[a]	60.00 ± 7.04[a]	0.174
56 (final)	80.13 ± 1.05[a]	81.80 ± 14.85[a]	78.00 ± 1.43[a]	82.80 ± 9.39[a]	56.70 ± 0.87[c]	66.50 ± 3.55[b]	0.156

A significant difference was observed between different treatments. Mean ± S.E.M. (n=2), P value: Probability level, CC: Commercial feed (Maram feed), EC, the experimental control containing 0%PBPM, C3, C4, C5-SRFC, and C6-Con containing 0%, 32%, 67%, 100-SRFC%, and 100-Con%, respectively of poultry by-product meal.

Table 5: Feed intake(g/fish/day) + SE of Nile tilapia fingerlings as affected by different dietary levels and source of poultry by-product meal

Age per day	(CC) Control	(EC) Control	(C3) 32%	(C4) 67%	100% - SRFC (C5)	100% - Con (C6)	P-value
14	0.70 ± 0.01[a]	1.08 ± 0.06[a]	0.90 ± 0.12[a]	1.31 ± 0.11[a]	1.23 ± 0.17[a]	1.09 ± 0.05[a]	0.092
28	0.75 ± 0.04[a]	0.75 ± 0.07[a]	0.72 ± 0.03[a]	0.81 ± 0.06[a]	0.75 ± 0.03[a]	0.69 ± 0.01[a]	0.257
42	1.11 ± 0.01[a]	1.32 ± 0.12[a]	1.38 ± 0.12[a]	1.43 ± 0.17[a]	1.41 ± 0.04[a]	1.46 ± 0.02[a]	0.238
56	0.93 ± 0.02[a]	1.67 ± 0.35[a]	1.37 ± 0.11[a]	1.82 ± 0.03[a]	1.37 ± 0.00[a]	1.37 ± 0.02[a]	0.129
Total feed intake	46.07 ± 0.96[a]	74.39 ± 15.42[d]	58.44 ± 2.27[b]	83.17 ± 2.87[c]	63.03 ± 3.11[b]	60.87 ± 0.09[b]	0.082

A significant difference was observed between different treatments. Mean ± S.E.M. (n), P value: Probability level, CC: Commercial feed (Maram feed), EC, the experimental control containing 0%PBPM, C3, C4, C5-SRFC, and C6-Con containing 0%, 32%, 67%, 100-SRFC%, and 100-Con%, respectively of poultry by-product meal.

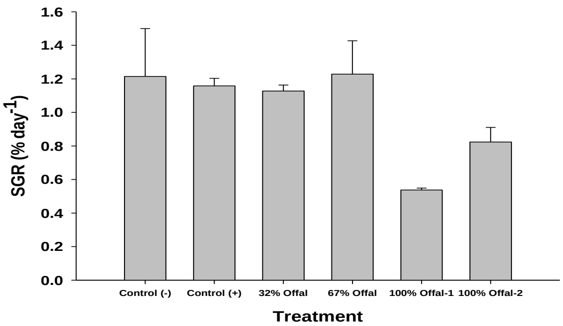

Figure 1: Specific growth rate of Nile tilapia fingerlings

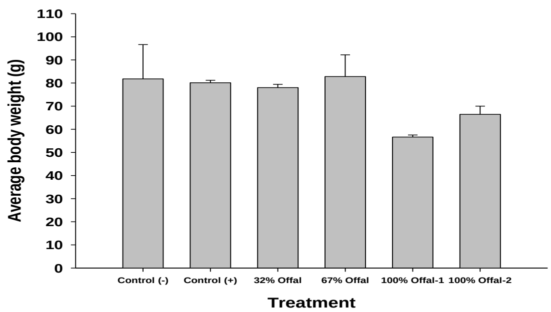

Figure 2: Average body weight (g) of Nile tilapia fingerlings.

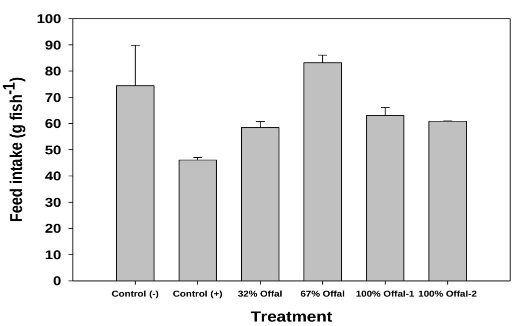

Figure 3: Nile tilapia fingerlings total feed Intake.

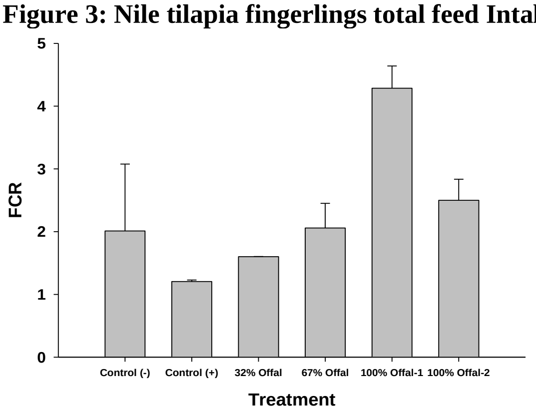

Figure 4: Feed conversion ratio of Nile tilapia fingerlings.

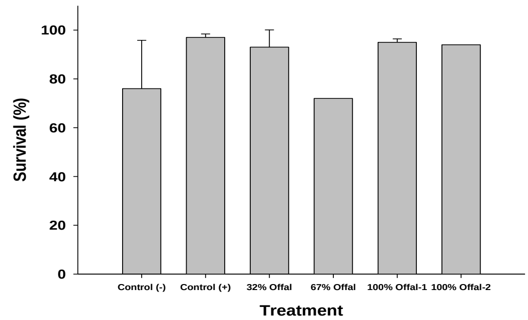

Figure 5: Survival rate of Nile tilapia fingerlings.

3.3. Proximate Composition:

The proximate composition results of the fish fed different diets are shown in (Table 6). The body moisture content ranged from 69.6% to 72.52% among treatments (Table 6). Moreover, it was 69.78%, 70.02%, 70.10%, 72.20%, 70.8%, and 69.6% for CC, EC, C3, C4, C5-SRFC, and C6-Con, respectively. Moisture content in fish fed C4 was higher than all other treatments. Generally, the crude protein content of fish ranged between (31.23% to 34.98%) which was the highest in fish fed CC and the lowest in fish fed C5-SRFC. Groups fed C4, C5-SRFC, and C6-Con showed high lipid than those fed CC, EC, and C3. The highest lipid was recorded by C6 (10.13%), and the lowest was from C3. There were no significant differences in crude lipid content among the treatment diets C4, C5-SRFC, and C6-Con or between CC and EC (7.40% and 8.10% respectively) (Table 6). The crude fiber content of fish of all treatments ranged between (2.83% to 4.41%). The fish fed C3 showed the lowest crude fiber and those fed C5-SRFC was the highest. There were no significant different in crude fiber among groups fed C4, C5-SRFC, and C6-Con. Ash content ranged from 1.01 % to 4.18 % among treatments. The ash content of C6 was higher than in the other groups, but differences were not significant. Differences in NFE was significant, the groups fed EC and C6 showed significantly lower values than those on the other feeds

Table 2: Proximate Composition+ SE of Nile tilapia fingerlings as affected by different dietary levels and source of poultry by-product meal

Feeding Regime	Initial	(CC) Control	(EC) Control	(C3) 32%	(C4) 67%	100% - SRFC (C5)	100% - Con (C6)
Moisture	72.52±0.10	69.78±0.14	70.02±0.26	70.10±0.10	72.20±0.20	70.8±0.31	69.60±0.21
Crude protein	28.37±0.80	36.53±1.02^{a}	35.23±0.87^{b}	34.98±1.04^{ab}	34.20±0.10^{a}	31.23±0.87^{b}	33.15±0.87^{b}
Crude lipid	2.78±1.78	7.40±0.16^{b}	8.10±0.62^{b}	6.82±0.24^{c}	8.10±0.10^{a}	8.10±0.62^{a}	10.13±0.62^{a}
Crude fiber	3.10±0.80	3.34±0.26^{b}	4.41±0.23^{a}	2.83±0.71^{c}	4.24±0.60^{a}	4.41±0.23^{a}	3.52±0.23^{a}
Ash	4.01±0.14	1.29±0.61	3.18±0.20	1.01±0.31	2.49±0.31	3.18±0.20	4.18±0.20
NFE	61.74±0.52	51.44±2.71^{a}	49.08±1.00^{b}	54.36±2.59^{a}	50.97±1.47^{a}	53.08±3.12^{a}	49.02±1.18^{b}

Mean having different superscripts within row are significantly different($p<0.05$). CC: Commercial feed (Maram feed), EC, the experimental control containing 0%PBPM, C3, C4, C5-SRFC, and C6-Con containing 0%, 32%, 67%, 100-SRFC%, and 100-Con%, respectively of poultry by-product meal.

4. Discussion:

4.1. Growth performance and survival rate:

The results for 56 days of fish growing on different combinations of protein sources fish meal and poultry by-product meal (PBPM) were satisfactory for some diet treatments. In this study, Nile tilapia fingerlings (*Oreochromis niloticus*) of C4 showed equivalent or even better growth to fish fed CC and EC over a 56-days study period. However, growth was significantly lower in fish fed the C5-SRFC, and C3 diet than those fed CC and EC. Compared with the African Catfish, fingerlings, the growth performance was unaffected when fish fed 50% poultry offal meal diet. Nevertheless, they found reduced growth in fingerlings fed a 100% PBPM (Mamoon et al., 2018). Zapata et al. (2016) illustrated that the Totoaba *Totoaba macdonaldi* juveniles, fed PBPM at 67% had higher growth, while fish fed a 100% PBPM diet showed decreased growth.

This study observed that the fish-fed diets with C4 had better SGR values to fish fed with both CC and EC. Different of Moran Angulo et al. (2014) noted the best results specific growth rate (SGR) for juvenile spotted rose snapper fed 0% and 25% poultry by-product meal. There were significant differences in feed intake among the treatments due to the fish appetite for the feed. In addition, by observing, tilapia didn't prefer CC diet since it has a different texture which allows it to float for a long time, while the feed intake was higher for all other treatments which were low sinking diets.

The FCR values of 1.21 to 5.79 have been recorded in this study. The range of FCR for Tilapia in well-prepared fish diets is usually between 0.9 and 1.3 (Craig et al., 2017). The lower FCR, the better the value (Omasaki, 2017). Nevertheless, the Detection of FCR in this study was similar to other research, such as Saufinas et al. (2013), which observed higher FCR values of 3.27 to 5.79 for Malaysian mahseer *Tor tambroides*. On the other hand, Moran Angulo et al. (2014) discovered better FCR values of 2.06-2.16 for the African catfish, *Clarias gariepinus*. Additionally, Keramat et al. (2014) examine the FCR values of 1.26 to 2.42 for rainbow trout. Compared with Falaye et al. (2011), reported FCR values of 1.48-1.62 for African catfish. The survival rate of fingerlings Nile tilapia in most treatment cages was excellent throughout the experiment, except for the cages in the first pond, even though they had different treatments. The C4 fish had a had lower survival than the other groups but this can't be attributed to treatment effect. Similar results were reported by Zapata et al. (2016).

The present results indicate that PBPM could be included in the Nile tilapia fingerlings up to 56 days of age between 32-67% of fish meal without negative effect on growth performance. This show that PBPM is a good quality protein that may be used in animal nutrition (Attia et al., 2003), but could not stand as a sole protein source due to deficient of several amino acids and /or low-quality protein (Bhaskar et al., 2014). The positive effect of using a fish meal and PBPM in fish meal nutrition could be attributed to the complementary effect between amino acids of both sources, decreasing the anti-nutritional factors and better digestibility (Attia et al., 2003).

4.2. Proximate composition:

In this study, the moisture content was higher in Nile tilapia fed 67% PBPM diet. Unlike Moran Angulo et al. (2014), which detected there are no significant differences (P > 0.05) in moisture content in juvenile spotted rose snapper results. Hence, the protein content of Nile tilapia differs from one treatment to the other. The higher protein content was in both CC and EC. Followed by C3 and C4. In contrast to Mamoon et al. (2018) observed that African mudfish fingerlings fed 50% PBPM diet had the highest protein content (69.88%). On the other hand, Zapata et al. (2016) did not observe significant differences in the protein content of totoaba *Totoaba macdonaldi* between the treatments. Likewise, Riche (2015), Moran Angulo et al. (2014) and Keramat Amirkolaie et al. (2014) obtained similar protein content.

The similarity of lipid content among treatments showed that fish lipid was different among in various diets. Other studies found comparable results. Zapata et al. (2016) showed similar lipid levels for all treatments in the grass carp fry Diet. Also, matching results were observed by Moran Angulo et al. (2014) in juvenile spotted rose snapper.

The crude fiber content varies significantly (P>0.05) among treatments groups. Likewise, the results observed in the crude fiber content for African mudfish was similar to the control (Mamoon et al., 2018).

It should be noted that the ash content was not varied among the treatment groups. Likewise, Keramat et al. (2014) resulted that the ash content did not change in rainbow trout, *Oncorhynchus mykiss* between the different diets. Similar results were detected by Moran Angulo et al. (2014) in ash content of spotted rose snapper treatments result. However, Falaye et al. (2011) observed an increase in the fish ash in African catfish fed PBPM.

Conclusion:

The results proved that FM protein could be replaced by PBPM protein in Nile tilapia fingerlings diets between 32- 67% with better growth rate, feed utilization, and fish biomass. Additionally, poultry by-product meal is a high-quality protein source with good palatability, low-cost, availability, and it supports environmental sustainability. The researched recommend increasing research on poultry by-product and focusing on 67% and 100%. It is also necessary to ensure the quality of the poultry by-product meal because it directly impacts the performance of fish.

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تأثير مستوي ومصدر مخلفات مجازر الدواجن كمصدر للبروتين واعد في علائق أسماك البلطي النيلي على استدامة الاداء الإنتاجي في مزارع الاسماك بالمملكة العربية السعودية

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المستخلص. يعتبر مسحوق السمك (FM) مصدر أساسي للبروتين في صناعة أعلاف الأسماك. نظرًا لارتفاع سعر مسحوق السمك والتأثير السلبي لاستهلاكه المرتفع على البيئة، كان من الضروري اختبار مصادر بروتين بديلة لمسحوق السمك. تعتبر مخلفات مجازر الدواجن مصدر بروتين عالي الجودة ومنخفض التكلفة. في هذه الدراسة، تم استبدال مسحوق السمك جزئيًا وكليًا بمخلفات مجازر الدواجن في تغذية إصبعيات البلطي النيلي (Oreochromis niloticus) لدراسة تأثيره على أداء الكتلة الحيوية والاستفادة من العناصر الغذائية. تم تحضير ستة اعلاف من مخلفات مجازر الدواجن لتحل محل مسحوق السمك (اعلاف مرام التجارية) ;كمجموعة مراقبة، (EC) ومجموعة المراقبة التجريبية الثانية تحتوي ٠ %من مخلفات مجازر الدواجن، (C3) 32٪ مخلفات مجازر الدواجن، 67٪ (C4) مخلفات مجازر الدواجن رضوي، (C5) 100٪ مخلفات مجازر الدواجن من انتاج شركة رضوى السعودية المحدودة، 100٪ (C6)مخلفات مجازر الدواجن من متعاقد. امتدت فترة الدراسة لمدة ٥٦ يومًا في الأحواض الخارجية. تم تغذية إصبعيات البلطي النيلي ثلاث مرات يومياً (متوسط الوزن الأولي = 41 جرام). تراوحت نسبة البقاء على قيد الحياة النهائية بين ٩٧٪ و٧٢٪ في جميع الانظمة الغذائية. كانت الزيادة الوزن النهائية (41.32 جرام – 14.73 جرام). ومع ذلك، كانت زيادة وزن C4 (41.32) أعلى مما كان عليه في عناصر المراقبة CC (38.24) وEC (40.69). نسب تحويل العلف FCR (1.21 – 4.29). كانت أفضل النتائج لأداء النمو واستخدام المغذيات عند تركيبة لـ 67) C4٪ (PBPM. أظهرت نتائج هذه الدراسة أن مخلفات مجازر الدواجن تعتبر مصدر بروتين بديل لمسحوق السمك في تغذية إصبعيات البلطي النيلي.

الكلمات المفتاحية. البلطي النيلي، مسحوق السمك، مخلفات مجازر الدواجن، البلطي النيلي، الاسترراع السمكي.