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Possibility of Using Fermented Fish Silage as Feed Ingredient in the Diets of Nile Tilapia, *Oreochromis niloticus*

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Abstract: A 12-week feeding trial was undertaken to evaluate the effect replacing of fish meal with fermented fish by-product silage (FBS) as feed ingredient for Nile tilapia, *Oreochromis niloticus* fry. Five isonitrogenous (300 g CP kg^{-1} dry matter, DM) and isocaloric (19 MJ gross energy kg^{-1} DM) diets were formulated and FM was replaced by FBS in five increased levels, 0, 25, 50, 75 and 100% g to formulate the five experimental diets, FBS0, FBS25, FBS50, FBS75 and FBS100, respectively. 375 *O. niloticus* fry (1.72±0.05g) were randomly divided into five groups (each group having three replicates) and fed for 84 dayswere randomly distributed into 15 glass aquaria (160 liter) and each aquarium holding 25 fish and randomly assigned to one of three replicates of the diets. Replacing levels of FM with FBS up to 50% did not significantly ($P<0.05$) affected growth and feed utilization parameters while the other substitution levels (75 or 100%) significantly ($P<0.05$) reduced growth and feed utilization. Fry offered the control diet exhibited the highest significant ($P<0.05$) average body weight (BW), body length (BL), weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER). Protein content in whole fish body significantly ($P<0.05$) increased while fat significantly ($P<0.05$) decreased with increasing replacing of FM by FBS while dry matter and ash content did not significantly affected.In conclusion, replacing up to 50% of FM by FBS did not affected growth and feed utilization and reduced feeding costs by 15.59% for tilapia fry. The higher replacing levels (75 or 100%) significantly reduced growth and feed utilization parameters.

Key words: Fish By-Product Silage · Fish Meal Growth · Feed Utilization · Nile Tilapia

INTRODUCTION

Finding novel sustainable protein sources has become a major drive in the aquaculture sector in order to reduce dependency on fish meal (FM) as the main protein component in aquafeeds. The current fishmeal usage in aquafeeds is becoming unsustainable as aquaculture production continues to expand. Cost is also a major constraint to production with greater requirements for more strategic use of this commodity in feeds. This exacerbates pressures on wild fisheries which cannot be sustained to meet such demands [1]. Traditionally, alternatives to protein meals have been sought from vegetable sources such as soybean meals [2] cottonseed meals [3-5] sunflower meal [6] linseed meal and canola seed meal [7,8] due to their wide spread availability, relatively favorable amino acid profiles, reduced cost and sustainable nature [9]. However, the inclusion of plant based proteins in aquafeeds provides a number of problems which include the occurrence of anti-nutritional factors (ANFs), reduced digestibility, issues of palatability and limitations of certain essential amino acids [10].

By-products or fish wastes are those non-edible parts of the fish body. They include fish head, skin, bones and cartilage, fins, scales and viscera which includes gonads, intestine and liver. After some processing, fish wastes represent a good source for animal nutrition which can be

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prepared as protein source for fish due to its high contents of fish protein containing the essential amino acids [11].

During recent years there has been increased interest in the use of enzymatic stabilization techniques for the preservation and utilization of feed materials for animal feeding. A great deal of attention has been concentrated on the utilization of fish by-products, including low grade industrial fish species, filleting waste and by-catch. It has been possible to treat terrestrial animal by-products using ensiling techniques [12]. Research effort on fishery by-products has arisen because of the high level of wastage within the industry due to its often seasonal nature and cost of storing (Freezing) and transporting these materials over long distances to the nearest fish meal plant.

Silage production is possible by lactic acid bacterial fermentation. To undergo proper fermentation the raw material must contain lactic acid bacteria, a suitable nutritional substrate for the bacteria and a temperature compatible with rapid growth. Although lactic acid bacteria are invariably present in the raw material and a starter culture is not required [13, 14] the inoculation of material with fermented starter culture is recommended. Soltan and Tharwat [15] indicated that fermented fish silage can successfully replace up to 50% of fish meal in African catfish, *Claris gariepinus* diets without adverse effect on growth performance or feed utilization.

The aim of this study was to evaluate the possibility of replacing of fish meal by silage made from fish by-product on growth performance, feed utilization and proximate composition of Nile tilapia, *O. niloticus*.

MATERIALS AND METHODS

Preparation of Fermented Fish Silage (FFS): Fish by-products (Non edible parts) were obtained from El-Obour market and minced. FBS was prepared by mixing the minced fish by-products (60%), rice bran (30%), dried molasses (5%) as a source of carbohydrate (Energy) and 5% yogurt (As a source of *Lactobacillus spp* for lactic acid anaerobic fermentation process). Potassium sorbate solution (1%) as antimicrobial agent was sprayed and the mixture was packed in black polyethylene bags. All bags were incubated in tightly hard plastic container and stored at ambient temperature that ranged from 30 to 38°C. The ensilage process completed after 30 days and at the end, a liquid FBS of pH 4.5 was obtained and sun-dried for 3 days. The resultant dried FBS had brownish color and strong fish odor and contained 38.12% crude protein (CP).

Experimental Diets: The experiment was conducted at the experimental facilities of the Fish Nutrition Lab, Department of Animal Production, Faculty of Agriculture, Benha University, Egypt. Five isonitrogenous (300 g CP kg^{-1} dry matter, DM) and isocaloric (19 MJ gross energy kg^{-1} DM) diets were formulated and fish meal was replaced by fermented fish byproducts silage at an increasing levels of 0, 25, 50, 75 and 100% representing the five diets, D1, D2, D3, D4 and D5, respectively. All dry ingredients of the fish meal, soybean meal, yellow corn and wheat bran were blended for 5 min and thoroughly mixed with soybean oil and vitamin and mineral mixture (Table 1). The ingredients were mixed well and made into dry pellets using a laboratory pellet mill (California Pellet Mill, San Francisco, CA, USA). The pellets (1-mm die) were dried for 4 h at 60°C and stored at -20°C until use.

Experimental Fish and Facilities: Nile tilapia, *Oreochromis niloticus* were obtained from Abbassa hatchery, Sharkia Governorate, Egypt. Fish were transferred in a 50-liter plastic bags filled with water and oxygen to fish Lab. Prior to the beginning of the experiment, fish were acclimatized to the experimental conditions and fed commercial diet (300 g protein kg^{-1}) twice daily to apparent satiation by hand for 15 days. After acclimatization, fish (1.71±0.05 g) were stocked into fifteen glass aquaria (160 L). Three replicate aquaria were randomly assigned to each treatment and each aquarium was stocked with 25 fish. The glass aquaria were supplied with de-chlorinated tap water and were continuously supplied with compressed air. About one-third of the water volume in each aquarium was daily replaced by new aerated fresh water after cleaning and removing of the accumulated excreta. A photoperiod of 12 h light, 12h dark (08.00 to 20.00) was used. Fluorescent ceiling lights has supplied the illumination. Fish were fed their respective diets by hand one of eight experimental diets for 84 days. Tilapia fry fed the pelleted diets (1 mm in diameter) at a daily rate of 10% (during the 1st month), then gradually decreased to 7% (2nd month) and 4% (3rd month) of total biomass 6 day/week (Twice daily at 9.00 am and 3.00 pm) and the amount of feed was bi-weekly adjusted according to the changes in body weight.

Water temperature, dissolved oxygen, pH and total ammonia were monitored during the study, to maintain water quality at optimal range for Nile tilapia. Dissolved oxygen (DO) and water temperature were measured daily at 11.00 h using YSI model 56 oxygen meter (YSI Company, Yellow Springs Instrument, Yellow Springs, Ohio, USA) and pH was recorded daily at 12.00 h using a

Table 1: Composition and chemical analysis of the experimental diets.

	Experimental diets				
Feed ingredients	Diet1	Diet2	Diet3	Diet4	Diet5
Fish meal (65%)	20	15	10	5	0
Fermented fish silage (FFS)	0	10	20	30	40
Soybean meal	47	47	47	48	48
Yellow corn	18	18	16	10	5
Wheat bran	9	4	1	1	1
Vegetable oil	3	3	3	3	3
Vit. & Min. mixture[1]	3	3	3	3	3
Sum	100	100	100	100	100
Chemical analysis (Determined on dry matter basis)					
Dry matter (DM)	94.52	95.11	94.78	95.05	93.98
Crude protein (CP)	30.33	30.18	30.22	30.80	30.49
Ether extract (EE)	6.15	6.16	6.54	5.97	6.16
Crude fiber (CF)	5.56	5.25	5.67	6.38	6.36
Ash	8.55	8.45	8.86	8.66	8.46
NFE[2]	49.41	49.96	48.71	48.19	48.53
Gross energy (MJ kg^{-1} diet)[3]	19.02	19.03	19.05	19.00	19.04

[1]Vitamin & mineral mixture/kg premix : Vitamin D_3, 0.8 million IU; A, 4.8 million IU; E, 4 g; K, 0.8 g; B1, 0.4 g; Riboflavin, 1.6 g; B6, 0.6 g, B12, 4 mg; Pantothenic acid, 4 g; Nicotinic acid, 8 g; Folic acid, 0.4 g Biotin,20 mg, Mn, 22 g; Zn, 22 g; Fe, 12 g; Cu, 4 g; I, 0.4 g, Selenium, 0.4 g and Co, 4.8 mg; [2] Nitrogen free extract (NFE) =100-(CP+EE+CF+Ash); [3]Gross energy calculated using gross calorific values of 0.2363, 0.3952 and 0.1715 MJ/g for protein, fat and carbohydrate, respectively according to Brett [20].

pH meter (Orion pH meter, Abilene, Texas, USA). Total ammonia weekly measured according to APHA [16]. During the period of the feeding trial, the water-quality parameters were averaged (±SD): Water temperature was 26.43±0.5°C: dissolved oxygen, 7.4±0.5 mg/L: pH 8.65±0.5 and total ammonia, 0.11±0.04 mg/L. All tested water quality criteria were suitable and within the acceptable limits for rearing the Nile tilapia, *O. niloticus* fingerlings [17].

Growth and Feed Utilization Indices: Also, body weight and body length were individually measured for each aquarium at the initiation and the termination of the feeding trail. Weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated using the following equations:

WG (g/fish)=*FBW–IBW*; SGR% = [*lnFBW- ln* IBW]/t×100, where FBW is final body weight (g); IBW is initial body weight (g); ln= natural logarithmic; t=time in days. FCR=*FI* /*WG*, where FI is feed intake (g); PER=*WG*/*protein intake* (g).

Proximate Analysis of Fish and Experimental Diets: At experiment termination, three fish were chosen at random from each treatment and exposed to the proximate analysis of whole fish body according to the methods of AOAC [18]. Fish and diet samples were oven-dried 105°C for 24 h, ground and stored at -20°C for subsequent analysis. Dry matter was determined after drying fish samples in an oven (105°C) for 24 h. Ash by incineration at 550°C for 12 hour. Crude protein was determined by micro-Kjeldhal method, N×6.25 (Using Kjeltech auto analyzer, Model 1030, Tecator, Höganäs, Sweden) and crude fat by Soxhlet extraction with diethyl ether (40-60°C). Crude fiber content of diets was determined using the method of Van Soest *et al.* [19]. Nitrogen-free extract was computed by taking the sum of values for crude protein, crude lipid, crude fiber and ash then subtracting this sum from 100.

Organoleptic Properties: Samples from fermented fish by-product silage (FBS treated fish were evaluated for appearance, color, texture and overall acceptability after end of experimental as described by Teeny and Miyauchi [21]. Scoring was done according to the following scheme:

Score	Description	Score	Description	Score	Description
10	Ideal	6	Fairly good	2	Poor
9	Excellent	5	Acceptable	1	Very poor
8	Very good	4	Fair	0	Repulsive
7	Good	3	Poorly fair		

Statistical Analysis: Statistical analysis of the obtained data was analyzed according to SAS [22]. Differences between means were tested for significance according to Duncan's multiple rang test as described by Duncan [23].

RESULTS AND DISCUSSION

Growth Performance: The highest average BW (27.38) was recorded for control group which fed the basal diet

Table 2: Means and standard error for the effect of replacing levels of fish meal by fermented fish silage in the diets on growth and feed utilization of Nile tilapia.

	D1	D2	D3	D4	D5	SE
Final body weight (g)	27.38 a	25.08 ab	25.22 ab	20.77 b	13.50 c	0.78
Final body length (cm)	11.01a	10.43a	11.57a	10.38a	8.95 b	0.28
Weight gain (g/fish)	25.65 a	23.36 a	23.50 a	19.05 b	11.78 b	0.97
Specific growth rate	3.06 a	2.90 a	2.92 a	2.62 b	2.62 b	0.13
Feed intake (g/fish)	36.33 a	32.30 ab	30.00 b	30.33 bc	23.88 c	1.48
Feed conversion ratio	1.42 b	1.38 b	1.28 b	1.60ab	2.03 a	0.36
Protein efficiency ratio	2.35	2.41	2.61	2.10	1.60	0.11

Means for each row followed by different letters are significantly different (P<0.05)

(Control). Replacing of 25% or 50% of fish meal (FM) by fermented fish by-product silage (FBS) in the diets D2 and D3 reduced the final BW to 25.08 and 25.22 g but these values did not significantly different from that recorded by fed the basal diet (Table 2). Compared to fish fed the control diet (D1), the higher replacing levels of FM by FBS (75 or 100%) significantly (P<0.001) decreased BW of Nile tilapia fry to 20.77 and 13.50 g, respectively indicating the possibility of replacing 50% of FM in the basal diets of Nile tilapia fry by FFS without adverse effect on the final BW. At experiment termination the highest average BL (11.57cm) was recorded for fish group 3 which fed D3 followed in a descending order by those fed the control diet, D1 (11.01 cm), D2 (10.43), D4 (10.38)and D5 (8.95), respectively and the differences between fish groups were significant.

Increasing substituting levels of FM by FBS up to 50% did not significantly affected WG of Nile tilapia fry while the highest substituting levels (75 or 100%) significantly (P<0.05) decreased WG and the same trend was also observed for specific growth rate (SGR).

Results of Table (2) are in accordance with the results of Nwanna and Daramola [24] who found that, replacing FM by shrimp head waste meal at 0, 15, 30, 45 and 60% in 30% protein diets decreased final BW, WG, SGR and the decrease was more pronounced at the higher replacing levels. In another study, Wassef *et al.* [25] found that replacement of 25, 50, 75 or 100% of FF by FFS alone or mixed with soybean meal (1:1) did not significantly affected, BW, WG and SGR of Nile tilapia by the partial or the complete replacement of FFS alone or when mixed with soybean meal. Soltan and Tharwat [15] showed that, dried FBS can successfully replace up to 25 and 50% of FM in tilapia and catfish diets, respectively without any significant loss in final BW, WG and SGR while the higher replacing levels (50, 75 or 100% for tilapia and 75 or 100% for catfish) significantly reduced the final BW for the two fish species. In another study, Soltan and El-Laithy [26] evaluated the silage made from fish by-products and tomato and potato by-products in isonitrogenous (30%) and isocaloric (2700 Kcal ME) diets fed to Nile tilapia fry and they found that replacement of 30% of the dietary protein by silage did not significantly affected the final BW, WG and SGR while the higher replacing levels (40 or 50%) significantly reduced BW of Nile tilapia.

The present study showed that FBS possessed adequate nutritional value for Nile tilapia at suitable inclusion levels, making possible substitution level of up to 50% of expensive fish meal protein by a cheap alternative protein source (FBS) without adverse effect on growth performance of Nile tilapia fry.

The superior performance of control fish group (D1) was referred to the fact that the nutritional value of FM-protein approximating almost exactly to the nutritional requirements of cultured finfish species [27]. When 25% or 50% of FM protein was replaced by FBS protein did not followed by significant effect on all growth parameters (BW, BL, WG and SGR) while the higher replacing levels (75 or 100%) significantly adversed these parameters. Soltan and Tharwat [15] showed that FM contained comparatively higher total indispensable amino acid (IAA) content (45.50%) than FFS (33.37%) and the IAA of FFS did not cover the requirements of Nile tilapia from these amino acids. Therefore, the higher replacing levels of FM by FFS (50, 75 or 100%) significantly reduced all growth performance parameters of Nile tilapia (Table 2). The higher levels (50% FM replacement by FBS) were reported in earlier reports of Lapie and Bigueras-Benitez [28] who found no differences in growth performance of Nile tilapia fed a formic acid preserved fish silage blended with FM (1:1) and growth performance was significantly reduced when the replacing levels increased up to 75%. Also, Fagbenro [29] and Fagbenro and Jauncey [30] stated that, up to 75% of FM protein could be successfully replaced with tilapia silage and soybean meal (1:1) in 30% CP diets for all male *O. niloticus*. Jeon *et al.* [31] indicated the possibility of partial substituting fish meal with tuna by-product meal up to 40% in the diet of juvenile Korean rockfish without exerting a detrimental effect on their growth (SGR). In the same trend

Table 3: Means and standard error for the effect of replacing levels of fish meal (FM) by fermented fish silage (FFS) on proximate analysis of Nile tilapia

Diets	Dry matter	Crude protein	Ether extract	Ash
D1 (control)	25.99	60.63 a	17.97 b	16.67
D2 (FBS25)	24.75	51.74 b	19.14 a	16.55
D3(FBS50)	22.18	50.74 b	22.85 a	16.63
D4(FBS75)	24.76	51.38 b	19.53 a	16.20
D5(FBS100)	24.80	50.62 b	19.81 a	17.25
Standard error (SE)	0.67	1.48	0.79	0.74

Averages within each column having different letters are significantly different (P<0.05)

Zhou *et al.* [32] replaced fish meal (FM) with fermented meal mixture of silkworm pupae, rapeseed and wheat (FMM) in the diets of mirror carp (*Cyprinus carpio* var. Specularis)and he found that, growth, feed utilization and crude lipid content were negatively correlated with FMM levels in the diet.

Feed Intake (FI): Table (2) showed that, the highest average feed intake (72.65 g) was recorded for fish fed control diet (D1) and the lowest one was recorded for fish fed D5 where the FM was completely replaced by FBS and the differences between fish groups were significant. Results of Soltan and Tharwat [15] indicated that feed intake was significantly (P<0.01) decreased with each increase in FBS content of tilapia diets as a replacement of FM. On the other hand, Wassef *et al.* [25] found that, partial or total replacement of FM by FFS alone or mixed with soybean meal did not significantly affected feed intake. One of the most common difficulties observed when using alternative sources of animal proteins is the acceptance of the feed, evidently related to its palatability. In this experiment the acceptance of the diets was very good, especially the control diet (D1). FBS included in diets fed to tilapia had positive feed utilization and digestibility [29, 31]. Plascencia-Jatomea *et al.* [33] found that the higher FI were recorded for Nile tilapia fry fed diets contained 0, 10 and 15% shrimp head silage as a replacement to fish meal and the worst FI was obtained the higher replacing levels (20, 25 and 30%).

Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER): Table (4) showed that FCR values were found to be 1.45, 1.50, 1.39, 1.80 and 1.5 for fish groups fed the different experimental diets, D1, D2, D3, D4 and D5, respectively and the differences were significant (P<0.05). Also, averages of PER ranged between 1.60 and 2.61. The best FCR and PER were recorded for fish fed the diet D3 which did not significantly different from those obtained for fish group fed the control diet (D1). The highest replacing levels of FM by FBS (75 or 100%) significantly (P<0.001) adversed FCR and PER. Similar results were obtained by Soltan and Tharwat [15] who found that, the best FCR and PER were recorded for fish fed the diet when 25% of FM protein was replaced by FBS protein which did not significantly different from those obtained for fish group fed the control diet (FFS0). The higher replacing levels of FM by FFS (50, 75 or 100%) significantly (P<0.001) adversed FCR for Nile tilapia. Plascencia-Jatomea *et al.* [33] and Fagbenro and Bello-Olusoji [34] found that, the best FCR and PER were recorded for Nile tilapia fry fed diets contained 0, 10 and 15% shrimp head silage as a replacement to fish meal and the worst FCR was obtained by the higher replacing levels (20, 25 and 30%). On the other hand, Wassef *et al.* [25] found that, partial or total replacement of FM by FFS alone or mixed with soybean meal did not significantly affected FCR and PEF. Jeon *et al.* [31] refers to the possibility of partial substituting fish meal with tuna by-product meal up to 30% in the diet of juvenile Korean rockfish without exerting a detrimental effect on feed utilization (FCR and PER).

Proximate Analysis of Whole Fish: Proximate analysis of tilapia as affected by replacing levels of FM by FFS in the diets outlined in Table (3). As shown in this table, dry mater ranged between 22.18 and 25.99%; crude protein 50.74 to 60.63%; ether extract ranged between 17.97 to 22.85 and ash from 16.20 to 17.25% and the differences among the different experimental fish groups were significant for ether extract (P<0.05) and crude protein (P<0.01) only.

As compared to control group (D1), all replacing levels of FM by FBS significantly (P<0.01) increased ash content of whole fish bodies and these results may be due to the high ash content of fish wastes used in preparation of FBS and these results were relatively similar to those obtained by Wassef *et al.* [25] who found that, replacing of FM by FFS up to 75% did not significantly affected protein content of tilapia bodies. Cavalheiro *et al.* [35] substituted fish meal by fermented shrimp industry wastes at a substituting levels of 0, 33.3, 66.6 and 100% in the diets of Nile tilapia, *O. niloticus* and they found that, the partial or complete replacement of FM by fermented shrimp industry wastes did not show any appreciable variation for the dry matter and protein content of fish. Soltan and Tharwat [15] found that, increasing FBS levels in tilapia diets up to 50% as a substitute of FM did not significantly affected protein content in whole body while the higher replacing levels (75 or 100%) significantly increased protein content of whole body. They also

Table 4: Feed costs (L.E) for producing one kg weight gain by fish fed the experimental diets.

	Nile tilapia fry						
Diets	Costs (L.E)/ton	Relative	Decrease in feed cost (%)	FCR	Feed costs* (L.E) /kg Weight gain	Relative to control %	Decrease in Feed costs (L.E)/kg weight gain
D1	5365	100	0.00	1.42	7.62	100	0
D2	4940	92.08	7.92	1.38	6.82	89.50	10.50
D3	4499	83.86	16.14	1.28	5.76	75.59	24.41
D4	4061	75.69	24.31	1.60	6.50	85.30	14.70
D5	3596	67.03	32.97	2.03	7.30	95.80	4.20

* Feed costs/kg weight gain = FCR × costs of kg feed.

Table 5: Local market price (L.E./ton) for feed ingredients used for formulating the experimental diets when the experiment was started (April 2016)

Ingredients	Price (L.E.) / ton
Fish meal	8500
Yellow corn	2800
Soybean meal	5500
Fermented fish silage (FFS)	1000
Wheat bran	2000
Vegetable oil	8200

Table 6: Organoleptic scores of Nile tilapia, *Oreochromis niloticus* treated with fermented fish by-product silage (FBS) for 12 weeks compared to control

	Time of sampling				
		12-weeks			
Variable	D1	D2	D3	D4	D5
Appearance	9.1±0.06^{a} (E)	8.0±0.05^{b} (VG)	9.0±0.06^{a} (E.)	8.0±0.05^{b} (VG)	7.5±0.07^{c} (G.)
Color	9.1±0.05^{a} (E)	9.0±0.07^{a} (E.)	9.o±0.05^{a} (E.)	7.8±0.06^{b} (G.)	7.7±0.06^{b} (G.)
Odor	8.8±0.04^{a} (VG)	8.5±0.05^{a} (VG)	8.7±0.04^{a} (VG)	7.5±0.07^{b} (G.)	7.0±0.07^{b} (G.)
Texture	8.5±0.05^{a} (VG)	8.0±0.06^{ab} (VG)	8.4±0.04^{a}(VG)	7.7±0.05^{b} (G.)	7.0±0.07^{b} (G.)
Overall acceptability	89.3±0.8^{a} (VG)	83.8±0.7^{ab} (VG)	88.3±0.7^{a}(VG)	76.0±0.4^{b} (G.)	73.0±0.5^{b} (G.)

$^{a-c}$Means within a raw with the different superscript are significantly different ($p<0.05$).
Values are expressed as Mean±SD; G. = Good. V.G.= Very good. E = Excellent

added that partial or total replacement of FFS by FM did not significantly affected EE content of tilapia fish. Soltan *et al.* [36] found that DM of catfish did not significantly affected by all replacing levels of FM by FBS (25, 50, 74 and 100%) and the same trend was also observed for ash content of whole fish bodies and they added that compared to control fish group, all replacing levels of FM by FFS significantly ($P<0.001$) decreased protein and EE content whereas fish group fed the control diet (FFS0) gained the highest protein and EE contents. Mach and Nortvedt [37] fed two moist diets based on raw fish with or without added fish silage to Cobia, *Rachycentron canadum*. They found no significant differences in nutritional composition between the fillet groups, which were of high quality with a balance of essential and non-essential amino acids and medium levels of omega-3 fatty acid composition. Hernández *et al.* [38] indicated that replacement of fish meal (FM) with tuna by-product meal (TBM), in diets for spotted rose snapper, *Lutjanus guttatus* did not significantly affected whole-body proximate composition.

Economical Efficiency: The current investigation highlights the potential of using fermented fish silage as a replacement for fish meal in the diets of Nile tilapia. Generally, results of the present study showed the possibility of replacing of FM by FBS up to 50% in tilapia diets without adverse effect on growth performance and feed utilization parameters. Feed cost is considered to be the highest recurrent cost in aquaculture, often ranging from 30 to 60%, depending on the intensity of the operation [39-42]. Any reduction in feed costs either through diet development, improved husbandry or other direct or indirect means is therefore decreased the total production investment and increased the net return [43-45]. All other costs are almost constant, therefore, the feeding costs required to produce one kg gain in weight could be used to compare the economical efficiency of different experimental treatments.

As shown in Tables (4, 5), feed costs (LE/ton) decreased gradually with increasing substitution level of FM by FBS. Data presented in the same tables showed that, increasing substitution level of FM by FFS at 25, 50, 75 and 100% decreased feed costs by 7.92, 16.14, 24.31 and 32.97%, respectively.

Compared to the control diet, feed costs (LE/kg WG) decreased for all substitution levels of FM by FBS in the experimental diets. In conclusion, replacing 50% of fish meal by fermented fish by-product silage reduced feedcosts by 16.14% and reduced feed costs (L.E)/kg weight gain by 24.41%.

Organoleptic Properties: The sensory scores of appearance, color, odor, texture and overall acceptability of Nile tilapia, *Oreochromis niloticus* treated with fermented fish by-product silage (FBS) were illustrated in Table (6). Fish control scores after end experimental were 9.1, 9.1, 8.8, 8.5 and 89.3% received higher scores compared with Nile tilapia, *Oreochromis niloticus* treated with fermented fish by-product silage (FBS) had the lowest scores after 12 weeks, while the Nile tilapia, *O. niloticus* treated with fermented fish by-product silage (FBS50) had the nearest scores from control.

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