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Evaluation of fermented silage made from fish, tomato and potato by-products as a feed ingredient for Nile tilapia, *Oreochromis niloticus*

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ABSTRACT

Fish by-products were fermented with *Lactobacillus plantarum* at 30°C using molasses as carbohydrate source. The ensilage process was completed after 30 days and at the end, a desirable and stable pH (4.5) was attained. Dried tomato by-product meal (TBM) and potato by-product meal (PBM) were used as alternative filler and blended with the liquid silage (40:30:30 w/w) and sun-dried. The resulting dried silage meal was included in the experimental diets to replace 0, 10, 20, 30, 40 or 50% of dietary protein (by weight) in isonitrogenous (30% CP) and isocaloric (2700 kcal ME/kg) pelleted diets. No significant differences were found for apparent digestibility coefficient (ADC) of dry matter (DM), crude protein (CP), ether extract (EE) and nitrogen free extract (NFE) up to 30% inclusion level, while the highest inclusion levels (40 or 50%) significantly reduced ADC for DM, CP, EE and NFE.

In a 90-day growth trial, the replacing of dietary protein by fish silage protein up to 30% of dietary protein in tilapia diet had no significant effect on growth performance including final body weight (BW), body length (BL), condition factor (K), weight gain (WG) and specific growth rate (SGR). The highest replacing levels (40 or 50%) significantly ($P<0.001$) reduced BW, BL, K, WG and SGR. Results of growth were relatively parallel to those of feed intake, feed conversion ratio (FCR) and protein efficiency ratio (PER) indicating the possibility of replacing 30% of dietary protein by fermented silage in Nile tilapia diets to reduce feed costs.

DM and CP contents of the whole fish for the different experimental fish groups were not significantly affected, while EE in the whole fish body was significantly decreased with increasing the inclusion levels of silage in the diets and the opposite trend was observed for ash content.

From the economic view, results obtained in the present study indicated the possibility of replacing 30% of dietary protein by silage in tilapia diets without adverse effect on growth or feed utilization parameters and this replacement reduced feed costs/kg diet and feed costs/kg weight gain by 22.43 and 22.02%, respectively.

INTRODUCTION

In the last decade, the aquaculture activity in Egypt has been tremendously increased (729%) by more than 7 times. In 1997, aquaculture production was 74 thousand tons and became 539.75 thousand tons in 2005. Therefore, the total fish production in Egypt was 889.23 thousand tons as well as 188.52 thousand tons imported from the foreign countries (GAFRD, 2005).

With increasing aquaculture activities, the demand for aquatic feeds was increased tremendously, however the available feed resources in Egypt are limited. Feed constitutes the largest production cost for commercial aquaculture. Fish meal, soybean meal and yellow corn are the dominant ingredients in prepared diets for most fishes. In 2003, Egypt imported one million ton of soybean (in forms of seeds or meals) and 4.5 million tons of yellow corn (Osman and Sadek, 2004).

In Egypt, large amounts of deteriorated whole fish and fish wastes discarded daily during catching, marketing, filleting processing and canning industry causing pollution. According to the information released by "Kaha" and "Edfina" companies, the two companies produce not less than 1080 tons of tomato waste/year (Saad, 1998). The yield of potatoes crop was 1984013 tons in 1999 and the waste was determined as 12.2% (Ghazalah *et al.*, 2002). These amounts of industrial wastes are considered low quality raw materials, that if not used may cause environmental, health and economical problems and could be recycled as a potential source of high-protein feedstuff in animal feeds (livestock, poultry and fish). (Vidotti *et al.*, 2003). Fermentation of fish wastes with another agricultural by-products is more suitable and convenient for small industries and/or the farmer (Faid *et al.*, 1997).

Recent technological advances have made it possible for many agricultural waste products to be recycled into feed ingredients. For example, extrusion co-processing of sweet potato and poultry silage at a 60:40 ratio (wt/wt) results in a non-perishable meal that can be incorporated into the diet for a variety of animals (Ferket *et al.*, 1995). Fish wastes can be ensiled by (1) biological fermentation using lactic acid bacteria which exist naturally in the raw material or are introduced as starter cultures, or (2) chemical acidification using inorganic and/or organic acids (Raa *et al.*, 1983).

The experimental use of fish silage as an alternative protein ingredient in aquafeeds has been widely reported (Arason, 1994; Salah Al-Din, 1995; Faid *et al.*, 1997; Wassef *et al.* 2003 Soltan and Tharwat, 2006). Feeding, digestibility and growth on warm water species including Indian carp, *Cirrhinus mrigala* (Ali *et al.*, 1994) tilapia, *Oreochromis niloticus* (Fagenbro and Jauncey, 1993); *Oreochromis aureus* (Goddard and Al-Yahyai, 2001; Goddard *et al.*, 2003), Nile catfish, *Clarias lazera* (Salah Al-Din, 1995) and African catfish, *Clarias gariepinus* (Soltan and Tharwat, 2006) have shown fish silage to be highly digestible and effective replacement for fish meal in aqua-feeds.

Fish silage is liquid and to ensure an optimal use in animal feeds, its water content has to be reduced. A process for reducing water content is co-drying (Lopez, 1990 ; Dong *et al.*, 1993), whereby dry feedstuffs (fillers) are added to wet fish silage to absorb solubilized proteins and some of the moisture. Co-drying has been reported to improve the nutritional properties of the blends and to change the physical properties, which facilitates their preparation as conventional feedstuffs (Stone *et al.*, 1984).

This study was conducted to evaluate fermented fish by-products silage and co-drying with a mixture of tomato by-product meal (TBM) and potato by-product meal (PBM) as a filler in tilapia diets to reduce feed costs and the effect of incorporation of this silage on growth, feed conversion, protein utilization, nutrients digestibility and proximate analysis of whole fish.

MATERIALS AND METHODS

Preparation of tomato and potato by-products:

The practical work of the present study was carried out at Fish Nutrition Laboratory, Fac. Agric., Benha University. Tomato by-product was obtained from Kaha factory, located in Kaha, Kalubia Governorate, while potato by-product was obtained from chippsy factory, 10th of Ramadan City. Tomato and potato by-products were sun-dried and the resulting residues were ground to meal.

Preparation of fermented fish silage (FFS):

Fermented fish silage prepared from fish by-products (non edible parts) according to the method described by Fagbenro and Jauncey (1995). Fish by-products were obtained from El-Obour market and minced and distributed into 25-kg plastic container. 150 g of sugar beet molasses (as carbohydrate source) and 50 g of *Lactobacillus plantarum* starter culture (for lactic acid anaerobic fermentation) were added for 800 g of fish by-product. The substrate was swirled and incubated at 30°C for 7 days after which autolysis was halted by heating the silage at 90°C for 30 min and 1% (v/w) potassium sorbate solution (6 g in 20 ml water) was sprayed to prevent mold growth. The silage was stored for a further 21 days under anaerobic conditions to give a product of pH<4.5 (Fagbenro and Jauncey, 1993). No antioxidant was added to the silage during or after ensilation because of the low fat content of tilapias (TRS, 1989). The fermented fish silage was blended (40:30:30%, dry weight basis) with dried tomato by-product meal (TBM) and potato by-product meal (PBM) as alternative filler. The product was sun-dried for 3 days and then incorporated in the experimental diets.

Preparation of the experimental diets:

Six experimental diets were formulated (Table 1) to replace 0, 10, 20, 30, 40 and 50% (in diets D1, D2, D3, D4 and D5, respectively) of the total dietary protein by silage protein. All diets were formulated to be isonitrogenous (30% protein) and isocaloric (2700 kcal ME/kg diet). In preparing the diets, dry ingredients were first ground to a small particle size. Ingredients were mixed thoroughly with added water to obtain a 30% moisture level. Diets were passed through a mincer with diameter of 2 mm and were sun-dried for 3 days.

Fish and experimental system:

Fingerlings of Nile tilapia were obtained from World Fish Center located at Abbassa, Sharkia Governorate, Egypt. The experimental fish were transported in plastic bags filled with water and oxygen to the fish nutrition laboratory. Fish were adapted for two weeks in 4 fiberglass tanks. Eighteen rectangular aquaria 100 × 50 × 40 cm (200 liter for each) were used (3 replicates for each treatment) and each aquarium was filled by 180 liter de-chlorinated water. The fish were weighed and randomly distributed (20 fish/aquarium) among the experimental aquaria. The average body weights (BW) were nearly similar and ranged between 5.07 and 5.15 g. All experimental aquaria were aerated by compressed air.

Fish were fed on the experimental pelleted diets (2 mm in diameter) at a daily rate of 10% (during the 1^{st} month), then reduced to 7% (2^{nd} month) and 4% (3^{rd} month) of total biomass and fish were fed 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 throughout the experimental period (90 days). About 25% of water volume in each aquarium was daily replaced by aerated fresh water after cleaning and removing the accumulated excreta. Water temperature, pH and dissolved oxygen were measured daily at 2.00 pm while total ammonia was weekly measured. Water quality parameters were found to be within acceptable limits for fish growth and health (Boyd, 1979).

Records of live BW (g) and BL (cm) of individual fish were measured at the start and the end of the experiment. Growth performance and feed utilization parameters were measured using the equations:

$$\text{Specific growth rate (SGR)} = \frac{\text{LnW2} - \text{LnW1}}{t} \times 100$$

Where:- Ln = the natural log, W1 = initial fish weight; W2 = the final fish weight in "grams" and t = period in days.

Weight gain (WG) = final weight (g) – initial weight (g)

Feed conversion ratio (FCR) = feed ingested (g)/weight gain (g)

Protein efficiency ratio (PER) = weight gain (g)/protein ingested (g)

Digestibility trial:

A chromic oxide marker was included in all experimental diets at a rate of 0.5%. During the last three weeks of the experiment, fish provided the experimental diets and feces were collected daily from each tank as described by Hajen *et al.* (1993). Feeds and collected feces were dried to a constant weight. Proximate analysis of diets and feces were conducted in triplicate for dry matter (DM) crude protein (CP), ether extract (EE), crude fiber (CF) and ash. Chromic oxide levels were determined in diets and feces (Fenton and Fenton, 1979) and apparent digestibility coefficients for DM, CP, EE and NFE were calculated (NRC, 1993) according to the equation:

Nutrient digestibility =100 -100 [(%marker in diet / % marker in feces) × (% nutrient in diet /% nutrient in feces)].

Chemical analysis:

Three fish were randomly sampled from each aquarium at termination of the experiment and subjected to chemical analysis of whole fish body. DM, EE, CP, CF and ash content of diets and fish were determined according to the methods described in AOAC (1990): DM after drying in an oven at 105°C until constant weight; ash content by incineration in a muffle furnace at 600°C for 12 hrs; CP (N × 6.25) by the kjeldhal method after acid digestion; and EE by petroleum ether (60-80°C) extraction.

Statistical analysis:

The statistical analysis of data was carried out by applying the computer program, SAS (1996) by adopting the following model :-

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

Where, Y_{ij} = the observation on the j^{th} fish eaten the i^{th} diet; μ = overall mean, α_i = the effect of i^{th} diet and e_{ij} = random error.

RESULTS AND DISCUSSION

Proximate analysis of by-products:

All experimental diets were formulated to be isocaloric and isonitrogenous (Table 1). owever, proximate analysis revealed that ingredient variability resulted in little differences in DM, CP, EE, CF and ash contents. Proximate analysis of TBM, PBM and fish by-products (FBM) are presented in Table (2). As described in this table, TBM contained 91.72 DM, 20.13% CP, 7.92% EE, 29.33% CF, 11.11% ash and 31.51% NFE. The high protein content (20.13%) in TBM show the possibility of incorporation this cheap industrial by-product in fish diets. PBM contained 94.12% DM. Based on DM, PBM contained 8.02 CP, 3.60 EE, 18.13 CF, 6.17 ash and 64.08% NFE. PBM contain reasonable amount of NFE (64.08%) which is an indicator for its potential value as a source of energy, moreover EE (3.6%) and CP (8.02%). Fish by-product contained 32.51% crude protein, 6.64 EE and 30.21% ash. The high content of protein in FBM make it possible to use this by-product as an animal protein source in preparing the fermented silage. The high content of protein in TBM and NFE in PBM refers to the possibility of using a mixture of these by-products as a filler in preparing the fermented fish by-product silage.

Digestibility trial:

The feeding value of a nutritional component of a feedstuff depends not only on the quantity of the nutrient in the feedstuff, but also on the ability of the animal to be absorb and utilize that nutrient (Middleton *et al.*, 2001).

Apparent digestibility coefficient (ADC) for the different nutrients in the experimental diets are presented in Table (3). Results of this table indicate that, apparent DM digestibilities were significantly reduced with increasing levels of inclusion of our experimental ingredient ($P<0.05$) and similar trend was also observed for the ADC of CP, EE and NFE.

The obtained results are generally in agreement with that of Middleton *et al.* (2001) who found that increasing the inclusion levels (11, 22 and 33%) of the silage made from poultry and culled sweet potatoes in hybrid tilapia (*O. niloticus* × *O. mossambicus*) diets significantly decreased ADC of DM and CP.

A good apparent digestibilities for DM, CP and EE were reported during previous FFS feeding trials with Nile tilapia (Fagbenro and Jauncey, 1993 and 1994). They indicated that apparent protein digestibility decreased from 85.5 to 80.6% with increasing FFS in the diets for the 25 and 100% FM replacement levels, respectively. Fagbenro and Bello-Olusoii (1997) showed that, ADC for DM, CP and gross energy for fermented shrimp head silage was high (>70%) for catfish fingerlings. In another study, Fagbenro and Jauncey (1998) mixed FFS (2:1, w/w) with poultry by-products meal, soybean-hydrolyzed feather meal or menhaden fish meal and each mixture was pelleted by cold extrusion method. They found that, ADC for DM, CP and gross energy of the pellets were high (>80%) and similar ($P>0.05$) among diets for *O. niloticus*.

Table (1): Composition and proximate analysis of the experimental diets.

Ingredients	Diets					
	D1	D2	D3	D4	D5	D6
Fish meal (72% CP)	18	15	12	9	7	5
Soybean meal (44% CP)	30	27	25	23	19	14
Yellow corn	32	30.5	27.5	27	23	20
Silage (36% CP)	0	10	20	30	40	50
Wheat bran	12.5	10	7	2.5	1.5	0.5
Vegetable oil	4	4	5	5	6	7
Vit. & Min. Mixture[1]	2.7	2.7	2.7	2.7	2.7	2.7
Ascorbic acid	0.3	0.3	0.3	0.3	0.3	0.3
Cr2O3	0.5	0.5	0.5	0.5	0.5	0.5
Sum	100	100	100	100	100	100
Proximate analysis (determined on dry matter basis)						
Dry matter (DM)	95.77	96.11	95.44	95.33	95.52	94.18
Crude protein (CP)	30.23	30.01	30.04	30.20	30.13	29.72
Ether extract (EE)	4.91	4.81	5.02	5.32	6.00	6.28
Crude fiber (CF)	9.16	9.24	9.13	9.30	9.52	9.24
Ash	8.11	8.43	9.21	9.73	9.8	10.35
NFE[2]	47.59	47.51	46.60	45.45	45.55	45.41
ME[3] (Kcal/kg diet)	2775	2738	2745	2740	2721	2713
P/E ratio[4]	108.9	109.6	109.4	110.2	110.7	109.5

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-Metabolizable energy was calculated from ingredients based on NRC (1993) values for tilapia.
4-Protein to energy ratio in mg protein/kcal ME.

Table (2): Proximate analysis of tomato by-product meal (TBM), potato by-product meal (PBM), fish by-product meal (FBM) and fermented fish fermented fish silage (FFS).

Item	TBM	PBM	FBM	FFS
Dry matter (DM)	91.72	94.12	70.25	95.16
Crude protein (CP)	20.13	8.02	32.51	35.92
Ether extract (EE)	7.92	3.60	6.64	8.17
Crude fiber (CF)	29.33	18.13	0	3.26
Ash	11.11	6.17	30.21	14.16
NFE*	31.51	64.08	30.64	38.49

* Nitrogen free extract (NFE) =100-(CP+EE+CF+Ash)

Table (3): Apparent digestibility coefficients (ADC) for different nutrients in experimental diets.

Diets	DM	CP	EE	NFE
D1	80.20±2.05 a	75.44±1.10 a	85.16±0.67 a	80.70±1.32 a
D2	80.24±2.05 a	75.35±1.10 a	84.35±0.67 a	82.90±1.32 a
D3	80.71±2.05 a	74.66±1.10 a	85.11±0.67 a	79.21±1.32 a
D4	78.97±2.05 a	75.11±1.10 a	84.65±0.67 a	80.18±1.32 a
D5	76.71±2.05 b	69.36±1.10 b	84.31±0.67 b	80.12±1.32 a
D6	74.33±2.05 b	70.46±1.10 b	80.31±0.67 b	75.32±1.32 b
Prob.	0.04130	0.04110	0.04271	0.04910

Means followed by the different letters in each row for each trait are significantly different (P<0.05).

Growth trial:

The effects of the experimental diets on fish growth performance after 90 days of experimental feeding are included in table (4). As described in this table, replacing of dietary protein by FFS protein up to 30% in tilapia diet had no significant effect on growth performance including BW, BL, K,WG and SGR.

The finding that the incorporation of more 30% dietary protein significantly decreased fish growth agree with the poor growth reported by Middleton *et al.* (2001) who found that the inclusion of silage made from poultry and culled sweet potatoes in the diets up to 33% did not significantly affect BW, WG and SGR of hybrid tilapia (*Oreochromis niloticus* × *O. mossambicus*) while the highest replacing levels significantly reduced these growth parameters. Also, Saber (2007) found that substitution of FM by FFS (made from fish-by-products and rice bran as a filler) in Nile tilapia diets up to 25% did not significantly affect the final BW, BL, WG and SGR, while the highest replacing levels (50, 75 or 100%) significantly reduced these growth parameters.

Ferket *et al.* (1995) co-extruded poultry silage and dried cull sweet potatoes to produce a feed ingredient and they demonstrated that this co-extruded product was a high feed ingredient for turkeys and chickens, however provided the dietary inclusion level did not exceed 30%. Soltan and Tharwat (2006) prepared fermented fish silage from fish by-products and rice bran (as a filler) and incorporated the silage in the diets of Nile tilapia, *O. niloticus* and African catfish, *Clarias gariepinus* to replace 25, 50, 75 or 100% of fish meal. The authors found that, when 25% of fish meal (FM) was replaced by fermented fish silage (FFS), no significant effect was detected on all growth parameters (BW, BL, WG and SGR), while the highest replacing levels (50, 75 or 100%) significantly adversed these parameters. Also, Jatomea *et al.* (2002) found that, replacing FM by shrimp head silage in Nile tilapia diets up to 15% showed the best response in growth performance while the highest replacing levels (20, 25 or 30%) resulted in the worst growth response. Nwanna and Daramola (2001) found that, replacing FM by shrimp head waste meal at 0, 15, 30, 45 and 60% in 30% protein diets decreased final BW, WG and SGR and the decrease was more pronounced at the highest replacing levels.

The highest levels (50% FM replacement by FFS) were reported in earlier reports of Lapie and Bigueras-Benitez (1992) who found no differences in growth performance of Nile tilapia fed 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 (1994) and Fagbenro *et al.* (1994) 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*.

In the present study, increased dietary FFS resulted in decreased growth performance, opposite to results of Cavalheiro *et al.* (2007) who substituted FM by fermented shrimp industry wastes at substituting levels of 0, 33.3, 66.6 and 100% in the diets of Nile tilapia and found that, the partial or complete replacement of fish meal by fermented shrimp industry wastes did not significantly affect the condition factor and the daily gain in weight or length.

Feed utilization:

Averages of mean feed consumption (expressed in g/fish) for the six experimental diets are given in Table (4). Compared to control, inclusion level of silage up to 30% did not significantly affect feed intake, while the higher inclusion levels (40 or 50%) significantly reduced the feed intake. Generally, the diets were accepted especially D2(10% of dietary protein replaced by silage) which was avidly consumed by fish during the entire experiment. Soltan and Tharwat (2006) indicated that, feed intake was significantly ($P<0.01$) decreased with increasing FFS content of Nile tilapia diets as a replacement of FM.

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 diet D2. FFS included in diets fed to tilapia had positive feed utilization and digestibility

Table (4): Growth performance, feed utilization and proximate analysis of Nile tilapia as affected by incorporation of some untraditional feedstuffs in the diets.

Item	No.	Experimental diets							
		D1	D2	D3	D4	D5	D6	±*SE*	*Prob.*
Growth performance									
Body weight (g)									
Initial	60	5.10	5.15	5.10	5.07	5.13	5.13	0.11	0.9761
Final	60	42.97 a	44.46 a	42.04 a	41.32 a	32.04 b	28.04 c	1.27	0.0001
Body length (cm)									
Initial	60	6.61	6.60	6.63	6.62	6.63	6.67	0.23	0.5613
Final	60	13.30 a	13.25 a	13.27 a	13.20 a	11.96 b	11.96 b	0.15	0.0001
Condition factor									
Initial	60	1.77	1.80	1.75	1.75	1.76	1.74	0.06	0.2521
Final	60	1.83 a	1.83 a	1.80 a	1.80 a	1.87 b	1.64 c	0.05	0.0460
WG (g/fish)	3*	37.87 b	39.31 a	36.94 b	36.25 b	26.91 c	22.91 d	0.20	0.0001
SGR	3*	2.37 ab	2.40 a	2.34 b	2.33 b	2.04 c	1.89 d	0.01	0.0001
Feed utilization									
FI (g/fish)	3*	70.67ab	73.67 a	69.67 ab	68.12 ab	62.15 c	57.00 d	1.05	0.0001
FCR	3*	1.87 c	1.87 c	1.89 c	1.88 c	2.31 b	2.49 a	0.03	0.0001
PER	3*	1.77 a	1.78 a	1.77 a	1.76 a	1.46 b	1.46 b	0.02	0.0001
Proximate analysis (%) of fish *(determined on dry matter basis)*									
Dry mater	9	24.55	24.13	25.54	25.76	24.01	25.86	0.42	0.0616
Protein	9	68.42	68.24	67.38	66.97	68.66	67.15	2.25	0.1522
Fat	9	14.88 a	14.95 a	14.44 a	14.02 a	12.54 b	12.40 b	0.46	0.0254
Ash	9	15.42 b	15.46 b	16.46 ab	16.70 ab	17.68 a	17.65 a	0.39	0.0421

Means followed by the different letters in each row for each trait are significantly different (P<0.05).

* Average of three aquaria (3 replicates)

For any particular diet, the mean feed consumption increased slightly with growth. It has been hypothesized that feed consumption is regulated by the metabolizable energy (De Silva *et al.* 1991). Other factors are also known to influence feed intake. De Silva and Gunasekera (1989) indicated that, the net intake of protein and energy in *O. niloticus* fry is affected by dietary protein content. Results of the present study indicated that consumption and or appetite is related to the energy and protein source of the diet because the experimental diets were formulated to be isocaloric and isonitrogenous. It is evident therefore that, increasing silage content (40 or 50%) in the experimental diets has a significant (P<0.001) negative effect on feed intake of *O. niloticus*.

Feed conversion (expressed as g feed/g weight gain) is presented in Table (4). As shown in this table, FCR values are approximately similar and ranged from 1.87 to 1.89 for the low inclusion levels of silage (10, 20 and 30%) with insignificant differences in FCR values while the highest inclusion levels (40 or 50%) significantly adversed FCR and the same trend was also observed for protein efficiency ratio (PER). The results of FCR obtained are relatively similar to those obtained by Soltan and Tharwat (2006) who found that, FCR increased when the substitution of FM by FFS increased and FCR and the best FCR and PER were recorded for fish fed the diet FFS25 where 25% of FM protein was replaced by FFS protein and did not significantly different from those obtained for fish group fed the control diet (FFS0). They added that, the highest replacing levels of FM by FFS (50, 75 or 100%) significantly (P<0.001) adversed FCR and PER. Saber (2007) found that substitution of FM by FFS (made from fish-by-products and rice bran as a filler) in Nile tilapia diets up to 25% did not significantly affect feed intake, FCR and PER while the highest replacing levels (50, 75 or 100%) significantly reduced these growth parameters.

On the other hand, Lapie and Bigueras-Benitez (1992) found no difference in feed efficiency between *O. niloticus* fed a formic acid preserved fish silage blended with FM (1:1) or a FM-based diet. In another study, Wassef *et al.* (2003) found that, partial or total replacement of FM by FFS alone or mixed with soybean meal did not significantly affect FI, FCR and PER.

The highest replacing levels of silage in the experimental diets (40 or 50%) significantly (P<0.001) reduced growth parameter and feed utilization and this may be due to, sub-optimal amino acid balance, inadequate levels of energy of fish by-product compared to fish meal. TBM contains considerable amounts (29.33%) of crude fiber (Table 2) as well as methionine and lysine are limiting essential amino acids in this by-product as reported by Hassanen *et al.* (1995). A poor palatability of PBM decrease the feed intake and the content of anti-nutritional factors, such as the heat-stable glucoalkaloid solanine (Tacon and Jackson 1985) or pronteinas inhibitors (Ryan and Hass, 1981) that can reduce protein digestibility. As due to one or more of these reasons, the highest replacing levels (40 or 50%) of FFS (prepared from these by-products) as a substitute of dietary protein decreased all growth parameters and feed utilization of Nile tilapia.

Generally, results of the present study indicated that the lower inclusion of FFS (up to 30%) as a substitute of dietary protein in tilapia diets did not significantly affected all growth and feed utilization while the highest substituting levels (40 or 50%) significantly reduced these parameters indicating the possibility of replacing 30% of dietary protein in the balanced diet for Nile tilapia by silage to reduce feed costs.

Proximate analysis of whole fish:

Concerning the proximate analysis of whole fish body, results of Table (4) showed that, dry matter and protein contents for the different experimental fish groups were approximately similar (24.01-25.86 and 66.97-68.66%%, P>0.05). Fat content in whole fish body was significantly decreased with increasing inclusion levels of silage in tilapia diets and the opposite trend was observed for ash content where the increasing inclusion levels of silage in tilapia diets significantly increased ash content of whole fish body. Wassef *et al.* (2003)

found that, replacing FM by FFS up to 75% did not significantly affected protein content of tilapia bodies. In this respect, Soltan and Tharwat (2006) found that partial or total replacement of FFS by FM did not significantly affected DM or EE content of Nile tilapia fish and increasing FFS levels in tilapia diets up to 50% as a substitute of FM did not significantly affected protein content while the higher replacing levels (75 or 100%) significantly increased protein content of whole body. They added that, as compared to control group, all replacing levels of FM by FFS significantly ($P<0.01$) increased ash content of whole fish bodies

In a recent study, Cavalheiro *et al.* (2007) substituted fish meal by fermented shrimp industry wastes at 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 fish meal by fermented shrimp industry wastes did not show any appreciable variation for the dry matter and protein content of fish. Saber (2007) indicated that, DM, CP and EE were significantly ($P<0.01$) affected by the increased levels of FFS in Nile tilapia diets as a substitute of FM.

Economical evaluation:

Results of economic evaluation including feed costs, costs of one kg gain in weight and its ratio to that of control group fed the diet control diet (D1) are presented in Table (5). As presented in this table, costs of one ton of the diets D1, D2, D3, D4, D5 and D6 were 2697.0, 2485.5, 2302.5, 2092.0, 1958.0 and 1805.0 L.E., respectively. These results indicated that, compared to the control diet, incorporation of silage in tilapia diets as a substitute of dietary protein decreased feed costs by 7.84, 14.63, 22.43, 27.40 and 33.07% and costs of one kg gain in weight were decreased by 7.74, 24.21, 22.02, 10.32 and 10.91% for the diets D1, D2, D3, D4, D5 and D6, respectively.

Results of the present study indicated that, replacement of 30% of dietary protein by silage in tilapia diets did not significantly affected all growth and feed utilization parameters and reduced feed costs/kg diet and feed costs/kg weight gain by 22.43 and 22.02%, respectively. The higher replacing levels of dietary protein by silage protein (40 or 50%) in tilapia diets significantly reduced all growth and feed utilization parameters and also reduced feed costs/kg diet and feed costs/kg weight gain. Soltan and Tharwat (2006) found that, replacing 25% or 50% of FM by FFS in Nile tilapia and catfish diets did not significantly adverse growth or feed utilization parameters of Nile tilapia and catfish, respectively and this replacement reduced feed costs/kg diet and feed costs/kg weight gain by 7.35 and 11.30%, for tilapia and by 15.59 and 19.39% for catfish, respectively. Also, Saber (2007) concluded that, replacing 25% of FM by FFS reduced feed costs by 7.93% for tilapia fingerlings.

Table (5): Feed costs (L.E) for producing one kg weight gain by fish fed the experimental diets.

Diets	Costs (L.E)/ton	Relative to control %	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	2697.0	100	0	1.87	5.04	100	0
D2	2485.5	92.16	7.84	1.87	4.65	92.26	7.74
D3	2302.5	85.37	14.63	1.89	3.82	75.79	24.21
D4	2092.0	77.57	22.43	1.88	3.93	77.98	22.02
D5	1958.0	72.60	27.40	2.31	4.52	89.68	10.32
D6	1805.0	66.93	33.07	2.49	4.49	89.09	10.91

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

Local market price (L.E./ton) for feed ingredients used for formulating the experimental diets when the experiment was started; fish meal 7000 LE/ton, yellow corn 1100; soybean meal 2000; Silage 1000; wheat bran 1000; corn oil 3000 LE/ton and vit.& Min. Mixture 10 LE/kg.

CONCLUSION

From the present results, it could be concluded that replacing 30% of dietary protein by fish waste silage in tilapia diets without adverse effect on growth or feed utilization parameters of tilapia, and this replacement reduced feed costs/kg diet and feed costs/kg weight gain by 22.43 and 22.02%, respectively.

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