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THE EFFECT OF PROTEIN AND ENERGY LEVELS ON MINERAL RETENTION IN TILAPIA FISH (*O.niloticus*)

(With 9 Tables)

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مدي تاثير مستويات الطاقة والبروتين علي تخزين العناصر المعدنية في أسماك البلطي النيلي

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في هذه الدراسة تم بحث مدي تاثير مستويات مختلفة من الطاقة والبروتين في علائق الاسماك علي تخزين بعض العناصر الشائعة (الكالسيوم ,الفوسفور,البوتاسيوم,الصوديوم,الماغنسيوم) والنادرة (الحديد,النحاس,الزنك,المنجنيز)علي عدد ٢٠٠ سمكة من سمك البلطي النيلي تزن الواحدة ١٠جم خلال فترة ١٠ اسابيع. تم تغذية الاسماك علي عدد ٩ علائق ذات ثلاث مستويات مختلفة من كل من البروتين (٢٨ ,٣٢, ٣٦٪) والطاقة (١٠ ,١٢, ١٥ ميجاجول طاقة هضم لكل كجم عليقة),وتم تغذية كل عليقة لعدد ٢ حوض ,وقد وجد ان: مخزون جسم الاسماك من الرماد يزداد مع زيادة مستوي البروتين في العليقة ويقل مع زيادة مستوي الطاقة كما انه يوجد زيادة غير معنوية في مخزون المادة الجافة داخل الجسم مع زيادة الطاقة في العليقة. زيادة محتوي البروتين في العليقة ادي الي زيادة غير معنوية في مخزون كل من الكالسيوم والفوسفور والبوتاسيوم في الجسم بينما قل هذا المخزون مع زيادة محتوي الطاقة في العليقة,كما وجد ان اعلي مخزون للكالسيوم عند مستوي ٣٦٪ بروتين ,١٢ميجاجول طاقة هضم بينما الفوسفور والبوتاسيوم عند مستوي ٣٢٪ بروتين ,١٠ميجاجول طاقة هضم. زيادة مخزون الصوديوم في الجسم مع زيادة مستوي البروتين بينما قلة المخزون مع زيادة مستوي الطاقة في العليقة, كما وجد ان اعلي مخزون للصوديوم عند مستوي ٣٢٪ بروتين ,١٠ميجاجول طاقة هضم بكفاءة استخدام ٨٪ مع وجود تاثيرمعنوي لمستويات البروتين والطاقة علي هذا المخزون. اما بالنسبة للمخزون من الماغنسيوم داخل الجسم فانه يزداد مع زيادة مستويات البروتين والطاقة في العلائق بينما يقل عند المستوي الاعلي من الطاقة (١٥ ميجاجول طاقة هضم) وان اعلي مخزون له وجد عند ٣٦٪ بروتين ,١٢ميجاجول طاقة هضم بكفاءة استخدام ١٢٪ .أما بالنسبة للعناصر النادرة فقد وجد ان معدل تخزينها في الجسم يزداد مع زيادة مستوي البروتين في العليقة بينما يقل عند المستوي الاعلي من البروتين (٣٦٪), اما بالنسبة للطاقة فان زيادة مستواها ادي الي قلة المخزون من هذه العناصر داخل الجسم وبلغ المخزون من هذه العناصر في جسم السمك اعلي مستوي عند ٣٢٪ بروتين ,١٠ميجاجول طاقة هضم فيما عدا الحديد عند مستوي ٣٢٪ بروتين

١٢, ميجاجول طاقة هضم. كذلك وجد ان كل كيلوجرام من وزن السمك يحتوي علي مخزون من هذه العناصر علي اساس المادة الجافة كالاتي: ٢٠,٩٤جم كالسيوم, ١٦,٣٤جم فوسفور, ٨,٥٢جم بوتاسيوم, ٠,٩٥جم صوديوم, ١,٥١جم ماغنسيوم, ١٣,٦٠مجم حديد , ١,٩١مجم نحاس, ٢٠٠,٩مجم زنك, ١,٢٥مجم منجنيز .لذلك يجب الاهتمام بعنصري الكالسيوم والفوسفور من العناصر الشائعة والحديد والزنك من العناصر النادرة عند تكوين علائق الاسماك وذلك لارتفاع مستوي المخزون من هذه العناصر داخل جسم الاسماك.

SUMMARY

The effect of different protein and energy levels in the diets on the retention of both major (Ca,P,K,Na,Mg) and trace-elements (Fe,Cu,Zn,Mn) was investigated on a total of 200 tilapia fish (*O.niloticus*), weighing 10gm each during a growth period of 10 weeks. Fish were fed on nine experimental diets having three levels of protein (28 ,32 ,36%) and energy (10,12,15 Mj/Kg digestible energy) and a control one. Experimental diets were tested, each for two replicates of aquaria. The ash retained in the fish body increased as the level of protein increased, while decreased as the level of dietary energy increased. The dry matter retained in the body increased as the energy level in the diets increased. Increasing the crude protein content of the diets, increased the retention level of calcium, phosphorus and potassium in the body of tilapia, while decreased as the energy levels increased. High retention values of Ca was found at 36% protein and 12 Mj/Kg DE, while for P and K were recorded at 32% protein level and 10 Mj/Kg DE. There was no significant (P>0.05) differences between treatments in the retention of Ca, P and K due to the effect of the protein and energy levels of the diets. The amount of sodium retained in the body of fish was decreased with increasing energy level. High retention value of Na was found at 32% protein and 10 Mj/Kg DE with utilization efficiency of 8%. Magnesium retained in the body of tilapia increased as the levels of protein and energy increased in the diets. High retention value of Mg was found at 36% protein and 12 Mj/Kg DE with utilization efficiency of 12%.Increasing protein level in the diets resulted in increased retention of all trace elements (iron, copper, zinc,and manganese), but decreased at the high level (36%). The rising energy supply reduced the retained amount of the trace elements. All trace elements gave good retention in the body of tilapia with 32% protein and 10Mj/Kg DE except Fe at 36% protein and 12Mj/Kg DE. High retention value was found for zinc and low retention value for Mn and the utilization efficiency of trace elements ranged from 1% to 39%. On average, the amount of retained

elements per Kg (on dry basis) of tilapia fish body were : 20.94g Ca, 16.34g P, 8.52g K, 0.95g Na, 1.51g Mg , 13.6mg Fe, 1.91mg Cu, 200.9mg Zn and 1.25mg Mn. It could be concluded that, the retention of minerals were not significantly ($P>0.05$) affected by the level of dietary energy, while significantly ($P<0.05$) affected by the level of the dietary protein especially with Na, Fe, Zn and Mn. Among all the major elements, calcium, phosphorus and potassium supply in the feed are of major importance, while for trace elements, iron and zinc of the diets should be taken into consideration in view of the very high retention rate.

Key words: *Tilapia Fish - Protein - Mineral retention*

INTRODUCTION

All forms of aquatic animals require inorganic elements ,or minerals for their normal life processes.Fish ,unlike most terrestrial animals can absorb some minerals ,not only from their diets but also from their external aquatic environment in both fresh water and sea water .Inspite of new developments in mineral nutrition of fish, data on inorganic elements has been confined to osmoregulation ,toxicity and related physiological functions. Although a wide range of functions has been established for the essential elements for domestic animals and humans ,information available on fish is fragmently and incomplete and a few papers are available on the metabolism of major and trace-elements in fish.Relatively little is known about the uptake, function,and biological availability of many trace elements.The most commonly used measure of nutritional status is the level of trace elements in the blood,muscle,liver and bone. For many essential elements,there is a range of tissue levels compatible with optimum growth and function. The level of mineral intake influences tissue concentration ,which causes a gradual decline in the function of an organ until deficiency occur. Metabolism in fish differs markedly from that in mammals and poultry especially because of the aqueous environment ,the metabolism adapted to it, and a differing carcass composition. The retention of minerals in the body of aquatic organisms depends on feed source,total energy and nutrients supply, interactions with the environmental water ,species ,stage of development and physiological status of the animal (Lall, 1989). Different species of fish and strains within species vary significantly in the nutritional content of the carcass (Reinitz et al., 1979; Refstie and Austreng, 1981). Although fish have the ability to

derive certain elements from the surrounding water,both practical and purified diets require mineral supplementation. Purified diets without mineral supplements result in a loss of appetite, growth depression, and high mortality (Ogino and Kamizono, 1975). The importance of mineral supplements in practical diets has also been emphasized by Arai et al. (1975) .Diet containing high level of total minerals (ash), particularly calcium,must be supplemented with trace elements.An imbalance of dietary minerals in certain diets predispose the salmon to bacterial kidney disease under specific environmental conditions (Lall, 1985) .A good knowledge of the carcass composition of fish allows the optimum feeding rations to be determined as well as an optimal nutrient conversion in connection with the quality of consumers.The distribution of many essential and toxic elements in various aquatic organisms has been reported,but the complete inorganic elements composition are known for only a few species .

In this study ,tilapia fish (*O.niloticus*) were fed on varied protein and energy diets to investigate the influences on the retention of some major (Ca,P,K,Na,Mg) and trace-elements (Fe,Cu,Zn,Mn) in the whole body of tilapia in order to assess what constitutes an adequate supply for tilapia in the diets.

MATERIALS & METHODS

A-Fish :

A total of 200 fish (*O.niloticus*) of an average 10 gm body weight were obtained from the River Nile. 180 fish were distributed randomly into 18 groups (10 fish each) stocked in 18 aquaria to be adapted for the medium two weeks before the experiment, while the rest (20 fish) represented the blank group. Each aquarium was supplied with dechlorinated tap water and provided with continuous aeration .Water temperature was checked daily ,and it was ranged from 25 to 26°C ,dissolved oxygen was kept at 3.9mg/L , pH value at 8.3 and the contents of Ca ,Mg ,Cu ,Fe & Zn were 97 ,30 ,0.1 ,0.07 & 0.6 mg/L water respectively.

B-Diets:

Fish in aquaria were given nine different feed mixtures having three graded levels of both crude protein (28%,32% and 36%) and energy (10, 12 and 15 Mj/Kg DE/Kg).The experimental diets were formulated from fish meal, corn ,soybean meal ,wheat bran and fish oil as shown in table (1). The nine diets were supplemented with the same level of mineral or vitamin

mixtures, and tested with the nine groups of fish, each consisting of two replicates. Fish were fed twice daily to satiation and the amount of feed supplied to each aquarium was recorded.The amount of the major and trace-element intakes (g/Kg body weight) were calculated (Table, 2). The experiment was durated for 10 weeks .

C-Preparation of the samples:

At the beginning of the trial, the 20 fish of the blank group were killed without losses and kept frozen to be analysed at the end of the experiment. The same was done with the nine experimental groups at the end of the trial.For preparation of the samples ,the deep frozen fish of each group were cut into pieces by the use of ribbon saw ,repeatedly forced through a mincer and homogenized in a mixer.

D-Proximate analysis:

After dry matter determination ,samples of the diet and fish were ashed in a muffle furnance at 480°C for about 48h (Kirchgessner and Schwarz , 1986). After weighing for ash determination ,the samples were taken up with 6N HCl and rinsed each in 100 ml volumetric flask.Calcium ,sodium and potassium were measured using flame photometer .Magnesium ,zinc,copper ,iron and manganese were measured using an atomic absorption spectrophotometer, in 0.6N HCl solution.

E-Statistical analysis:

Data were analysed by Analysis of Variance (ANOVA) using the SAS ANOVA procedure (Statistical analysis system, 1988). Duncan's multiple range test was used to compare differences among individual means.

RESULTS

The obtained results were summarized in Tables (2 - 9).

DISCUSSION

Tables (3 ,4&5) show the mean contents of major and trace-elements in the whole body of the nine groups of tilapia (*O.niloticus*) at the end of the experimental period.

In these results,the crude ash content of fish body decreased when the level of energy increased, while increased as the level of protein increased in the diets, a result similar to that recorded by Zeitler et al. (1984).

The data shows that calcium and phosphorus contents of whole body were increased with increasing crude protein levels and decreased as the energy levels of the diets increased. It is clear that there was a positive correlation (r=0.60) between Ca , P contents of the body and protein contents of the diets, but there was negative correlation (r=0.35) between both Ca and P in the diets and in the body of fish . This corroborates the results of the experiments on carp by Pfeffer et al. (1977) and also with that recorded by Muller and Kirchgessner (1974) on other farm animals such as piglets.Meanwhile,the rising in energy supply, reduced the content of both Ca and P in the carcass of carp (Kirchgessner and Schwarz, 1986). The retained amounts of both major and trace elements in the body of tilapia for each group and for all groups are shown in Tables (6 &7). There was no significant difference (P>0.05) between the treated groups in the Ca and P retention due to effect of protein and energy.High retention value of Ca was found at levels of 36% protein and 12 Mj/Kg DE with utilization efficiency of 18%, while for P at 32% protein and 10 Mj/Kg DE with utilization efficiency of 26% (Table, 8).

However,increasing protein content of the diets resulted in an increase in the contents of potassium (K) in the whole body of tilapia, while the reverse was recorded with the energy levels. There was no significant difference (P>0.05) between treatments in the K retention due to effect of dietary protein and energy levels. There was positive correlation (r=0.50) between K in the diets and body of fish. High retention value of K was found at levels of 32% protein and 10 Mj/Kg DE with utilization efficiency of 15%.

For sodium element, the content of the body decreased with increasing protein level in the diets, while increased as the energy level increased. Also, there was a significant (P<0.05) effect for dietary protein and energy levels on the Na retention in the body. High retention value for Na was recorded at 32% protein and 10 Mj/Kg DE with utilization efficiency of 8%. There was a negative correlation (r=0.50) between Na in the diets and fish body.

Magnesium content of the body decreased with increasing the energy content of the diets. There was no significant difference (P>0.05) due to protein and energy effect on the Mg retained in the fish body as shown in Table(7). Good retention of Mg at levels of 32% protein and 12Mj/Kg DE.There was .negative correlation (r=0.36) between Mg in the diets and body of tilapia.

With increasing protein content of the diets ,the amount of iron (Fe) , manganese (Mn) ,copper (Cu) and zinc(Zn) were increased,but decreased at high level of protein (36%). Also, the dietary energy had the similar effect on Fe, Cu, and Mn contents of the body. A significant effect ($P<0.05$) for the protein, while non significant ($P>0.05$) effect for energy levels was recorded on the Fe, Cu, Zn and Mn retained in the fish body.There was a negative correlation ($r=0.71$) between trace elements (Fe, Mn, Cu, Zn) in the diets and in the body of tilapia fish. High retention of Cu, Zn and Mn was found at levels of 32% protein and 10 Mj/Kg DE, while for Fe at 32% protein and 12 Mj/Kg DE. Also,in piglets,the retention of these trace elements shows only a partial or no dependance on the amount of protein supplied (Kirchgessner and Muller, 1974).

There was no significant ($P<0.05$) difference in the ash retention of fish body due to the effect of protein and energy levels of the diets. With increasing protein and energy levels of the diets ,dry matter retained in the body non significantly ($P>0.05$) increased, but it diminished at the high level of protein (36%).

In these results, if the minerals retained are compared to the amount supplied with the diets (Table, 8), feed utilization efficiency of about 2-26% was calculated under the given conditions for the major elements (Ca ,P ,K ,Na and Mg) and 1-39% for the trace elements (Fe,Cu, Zn and Mn). These values are lower for major elements (20-50%) and higher for trace elements(1-6%) when compared with the utilization of carp as reported by Kirchgessner and Schwarz (1986).The very low utilization may be connected to the relatively high mineral contents of the feed mixtures used.

Table (9) gives an additional survey on the mean contents and retained major and trace elements in all analysed fish .Values in terms of g/Kg dry matter and g/100g crude ash are distinctly comparable to data in terms of fresh matter. The mean Ca content in tilapia (8.7g/Kg wet basis) is considered to be rather high as compared to data with carp of 3-6g/Kg (Pfeffer et al., 1977; Pfeffer, 1978; Pfeffer and Mesk, 1979; Kirchgessner and Schwarz, 1986) .Rainbow trout have clearly lower values of about 3g/Kg carcass (Pfeffer and Potthast, 1977; Pfeffer , 1978). The phosphorus content in the whole body of tilapia (5.7g/Kg wet basis) is high as compared with the phosphorus content in the carcass of carp, 4.3g/Kg (Pfeffer, 1978), 5.02g/Kg (Kirchgessner and Schwarz , 1986). Ogino and Takeda (1976) found similarly high Ca and P contents in the carcass of small carp (5-12g/Kg). The contents of magnesium (0.67g/Kg wet basis), and potassium (3.7g/Kg) in the

whole body of tilapia are higher than values in the literatures quoted for carp, 0.21g/Kg, 1.76g/Kg (Pfeffer, 1978), 0.25g/Kg, 2.05g/Kg (Kirchgessner and Schwarz , 1986) for magnesium and potassium respectively. However ,rainbow trout seem to retain less magnesium (0.26g/Kg) and potassium (2.41g/Kg) than tilapia fish in this study (0.48g/Kg for Mg ,2.82g/Kg for K) as found by Pfeffer (1978).

Among the analysed trace elements in this study, zinc had the highest concentration in the body of tilapia (95.5mg/Kg) ,while the iron ,copper and manganese contents are lower 7.0, 0.61 and 0.67 mg/Kg (wet basis) respectively. The carcasses of carp and rainbow trout had high content of these elements but the zinc concentration was the least compared to the present study as found by (Ogino and Yang, 1978, 1980; Kirchgessner and Schwarz, 1986).

From the analysed mineral contents during the growth period in this study ,it is possible to establish the major and trace elements retained per Kg weight gain (Table,9).The mean retention per Kg gain is:Ca 9.10g, P 6.16g, K 3.61, Na 0.23, Mg 0.62g, Fe 6.07mg, Cu 0.78mg, Zn 90.22mg, and Mn 0.62mg.The values in this study are higher for Ca, P, K, Mg, Zn, Mn and lower for Na, Fe, and Cu than that found in carp by Kirchgessner and Schwarz (1986) and in rainbow trout by Frenzel (1980).

It could be concluded that ,good retention of Ca and Mg was found at levels of 36% protein and 12 Mj/Kg DE, while P,K and Na was recorded at 32% protein and 10 Mj/Kg DE. For trace elements, highest values of retention for Cu, Zn, and Mn were found at levels of 32% protein and 10 Mj/Kg DE, while for Fe at 32% protein and 12 Mj/Kg DE.

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Table(1):Physical and chemical composition of the experimental diets fed to tilapia fish during the whole experimental period.

Ingredients	Diets								
	1	2	3	4	5	6	7	8	9
Fish meal	18.41	21.00	24.00	18.41	21.00	24.00	18.41	21.00	24.00
Soybean meal	22.00	28.00	34.00	26.59	34.00	41.00	29.59	37.00	44.00
Corn ,ground	24.02	11.43	2.47	52.00	42.00	32.00	40.00	30.00	20.00
Wheat bran	32.57	36.57	36.53	0.00	0.00	0.00	0.00	0.00	0.00
Fish oil	0.00	0.00	0.00	0.00	0.00	0.00	9.00	9.00	9.00
Mineral mix.*	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin mix.**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Protein (%)	LP (28.0)	MP (32.0)	HP (36.0)	LP (28.0)	MP (32.0)	HP (36.0)	LP (28.0)	MP (32.0)	HP(36.0)
DE (Mj/Kg diet)	Low energy level (10 MJ)			Medium energy level (12MJ)			High energy level (15MJ)		

*Min.mix.:Each Kg contains:60g manganese ;80g iron ;5g copper ;40g Zinc ;0.15g selenium ;0.35g iodine .

**Vit.mix.:Each Kg contains :2000,000 IU vit.A ;20,000 IU vit.D ;10,000 IU vit.E ;0.5g vit.K ;1.8g vit.B1 ;3.6g vit.B2 ;3g vit.B6 ; 0.09g vit.B12 ;10g pantothenic acid :27g nicotinic acid ;0.55g folic acid ;0.15g biotin ;130g choline.

#L, M, H = Low, Medium, High. P, E = Protein, Energy (digestible energy)

Table(2):Major and trace element intakes of the different tilapia groups during the experimental period

Treatments		Major elements (g/Kg body weight)					Trace-elements (mg/Kg body weight)			
DE(Mj/Kg)	Protein(%)	Calcium	Phosphorus	Potassium	Sodium	Magnesium	Iron	Copper	Zinc	Manganese
LE (10 Mj)	LP (28%)	33.05±0.03	20.82±0.17	18.89±0.11	3.00±0.15	4.10±0.06	104±39±0.11	7.85±0.10	299.51±0.11	53.21±0.05
	MP (32%)	29.13±0.04	20.26±0.07	20.43±0.15	3.14±0.03	3.67±0.14	98.47±0.11	7.59±0.10	277.73±0.17	48.67±0.13
	HP (36%)	39.10±0.05	26.66±0.07	28.19±0.06	4.55±0.08	4.34±0.08	122.90±0.16	9.70±0.11	343.70±0.21	58.14±0.03
ME (12 Mj)	LP (28%)	36.54±0.08	22.79±0.10	19.19±0.01	3.12±0.04	3.60±0.05	110.54±0.08	8.05±0.02	318.27±0.11	54.22±0.04
	MP (32%)	28.98±0.18	19.39±0.06	18.9±0.15	2.92±0.07	3.00±0.10	92.35±0.07	7.08±0.02	261.38±0.07	45.18±0.07
	HP (36%)	36.89±0.14	25.07±0.03	26.99±0.04	3.98±0.03	4.08±0.06	116.62±0.04	9.17±0.08	325.14±0.06	55.81±0.12
HE (15 Mj)	LP (28%)	37.83±0.12	24.61±0.01	20.97±0.01	3.32±0.01	3.58±0.01	118.97±0.14	8.68±0.02	343.05±0.17	59.57±0.04
	MP (32%)	30.89±0.02	20.39±0.02	20.42±0.01	3.05±0.01	3.23±0.01	98.81±0.05	7.57±0.01	279.55±0.05	48.59±0.04
	HP (36%)	39.17±0.06	26.22±0.01	28.51±0.12	4.00±0.02	4.20±0.02	122.36±0.10	9.60±0.05	342.53±0.20	59.57±0.02

Table(3):Major elements contained in the whole body of tilapia (*O.niloticus*) fed diets with different protein and energy levels (on fresh basis).

Treatments		Whole body analysis		Major elements (g/Kg body weight)					body
DE(Mj/Kg)	Protein(%)	Dry matter (%)	Ash (%)	Calcium	Phosphorus	Potassium	Sodium	Magnesium	weight (g/fish)
Blank group		25.6±0.12	3.79±0.02	6.82±0.01	3.95±0.06	4.41±0.15	0.67±0.02	0.83±0.01	10.00±0.02
LE (10 Mj)	LP (28%)	30.4±0.15	5.05±0.03	8.30±0.12	5.40±0.12	3.62±0.10	0.24±0.02	0.65±0.01	51.42±0.10
	MP (32%)	29.7±0.03	5.17±0.12	9.10±0.10	6.00±0.15	3.77±0.01	0.37±0.02	0.73±0.01	54.33±0.15
	HP (36%)	28.0±0.23	4.82±0.05	8.50±0.12	5.60±0.12	3.58±0.03	0.15±0.02	0.64±0.02	39.42±0.05
ME (12 Mj)	LP (28%)	32.4±0.15	5.42±0.01	9.30±0.12	6.20±0.10	3.70±0.03	0.36±0.01	0.71±0.01	44.34±0.05
	MP (32%)	30.8±0.10	4.81±0.03	8.50±0.15	5.70±0.15	3.57±0.01	0.22±0.01	0.71±0.01	66.63±0.12
	HP (36%)	28.7±0.12	4.74±0.01	8.40±0.15	5.50±0.21	3.52±0.01	0.18±0.01	0.62±0.01	41.52±0.01
HE (15 Mj)	LP (28%)	34.1±0.10	5.19±0.07	9.00±0.40	5.90±0.15	3.87±0.12	0.47±0.02	0.70±0.02	36.21±0.01
	MP (32%)	31.9±0.17	4.86±0.08	8.60±0.15	5.70±0.15	3.83±0.10	0.38±0.02	0.70±0.06	58.34±0.12
	HP (36%)	29.6±0.21	4.53±0.10	8.30±0.12	5.40±0.12	3.80±0.21	0.33±0.02	0.60±0.12	35.53±0.01

Table(4):Trace elements contained in the whole body of tilapia (*O.niloticus*) fed diets with different protein and energy levels (on fresh basis).

Treatments		Whole body analysis		Trace elements (mg/Kg body weight)			
DE(Mj/Kg)	Protein(%)	Dry matter (%)	Ash (%)	Iron	Copper	Zinc	Manganese
Blank group		25.6±0.12	3.79±0.02	11.2±0.12	0.30±0.01	130.0±0.15	0.93±0.01
LE (10 Mj)	LP (28%)	30.4±0.15	5.05±0.03	6.4±0.15	0.60±0.01	74.4±0.12	0.69±0.02
	MP (32%)	29.7±0.03	5.17±0.12	7.2±0.12	0.48±0.02	126.3±0.12	0.68±0.02
	HP (36%)	28.0±0.23	4.82±0.05	6.5±0.12	0.71±0.01	96.3±0.12	0.50±0.01
ME (12 Mj)	LP (28%)	32.4±0.15	5.42±0.01	7.0±0.12	0.46±0.01	73.6±0.09	0.76±0.01
	MP (32%)	30.8±0.10	4.81±0.03	7.8±0.06	1.06±0.03	120.6±0.12	0.82±0.01
	HP (36%)	28.7±0.12	4.74±0.01	6.5±0.17	0.40±0.02	61.2±0.12	0.45±0.01
HE (15 Mj)	LP (28%)	34.1±0.10	5.19±0.07	7.1±0.15	0.36±0.02	89.1±0.06	0.63±0.01
	MP (32%)	31.9±0.17	4.86±0.08	7.8±0.17	0.97±0.01	126.1±0.06	0.92±0.01
	HP (36%)	29.6±0.21	4.53±0.10	7.1±0.12	0.48±0.01	92.1±0.06	0.60±0.01

Table(5):Mean values of dry matter,ash, major and trace elements contained in the body of tilapia groups (on DM basis).

Treatment	g/Kg body weight		Major elements (g/Kg body weight)					Trace elements (mg/Kg body weight)			
Prot.&DE	DM	Ash	Ca	P	K	Na	Mg	Fe	Cu	Zn	Mn
28%	323±4.6^{a}	161.6±1.2^{a}	27.46±0.3^{a}	18.05±0.2^{a}	11.55±0.1^{a}	1.12±0.2^{a}	2.14±0.1^{a}	21.15±0.2^{b}	1.46±0.1^{a}	244.7±5.4^{b}	2.14±0.1^{ab}
32%	308±5.5^{a}	160.7±3.3^{a}	28.34±0.1^{a}	18.83±0.1^{a}	12.08±0.2^{a}	1.04±0.1^{b}	2.31±0.1^{a}	24.68±0.1^{a}	2.73±0.2^{a}	403.7±1.7^{a}	2.63±0.1^{a}
36%	288±3.4^{b}	163.2±1.2^{a}	29.17±0.1^{a}	19.10±0.1^{a}	12.60±0.2^{a}	0.76±0.1^{b}	2.15±0.1^{a}	23.26±0.2^{b}	1.84±0.1^{a}	288.9±6.1^{b}	1.81±0.1^{b}
10 Mj	294±2.5^{1}	170.4±1.5^{1}	29.35±0.2^{1}	19.29±0.1^{1}	12.45±0.1^{1}	0.85±0.2^{2}	2.28±0.1^{1}	22.79±0.2^{1}	2.04±0.1^{1}	336.7±7.0^{1}	2.11±0.1^{1}
12 Mj	306±4.0^{1}	163.1±1.1^{1}	28.53±0.2^{1}	18.95±0.2^{1}	11.76±0.1^{1}	0.82±0.1^{2}	2.22±0.1^{1}	23.20±0.3^{1}	2.09±0.2^{1}	278.2±9.0^{1}	2.22±0.1^{1}
15Mj	319±6.1^{1}	152.4±1.1^{2}	27.05±0.2^{1}	17.77±0.1^{1}	12.01±0.2^{1}	1.22±0.1^{1}	2.10±0.1^{1}	22.98±0.2^{1}	1.88±0.2^{1}	321.1±8.8^{1}	2.26±0.1^{1}

*Mean in the same column with the same numbers and letters are not significantly different (P<0.05)

Table (6):Major and trace elements retained in the whole body of tilapia (on fresh basis).

Treatments		Major elements (g/Kg body weight)					Trace elements (mg/Kg body weight)			
DE(Mj/Kg)	Protein (%)	Calcium	Phosphorus	Potassium	Sodium	Magnesium	Iron	Copper	Zinc	Manganese
LE (10 Mj)	LP (28%)	7.00±0.20	4.67±0.03	2.92±0.01	0.06±0.01	0.39±0.02	4.28±0.03	0.53±0.01	49.03±0.01	0.38±0.01
	MP (32%)	7.37±0.03	5.34±0.08	3.13±0.08	0.24±0.01	0.55±0.01	5.16±0.04	0.50±0.01	100.40±0.10	0.55±0.02
	HP (36%)	6.60±0.10	4.57±0.02	2.54±0.03	0.08±0.01	0.51±0.01	3.81±0.03	0.69±0.02	63.20±0.10	0.25±0.01
ME (12 Mj)	LP (28%)	7.67±0.13	5.19±0.03	2.71±0.04	0.29±0.02	0.45±0.01	4.51±0.03	0.38±0.01	44.24±0.05	0.45±0.01
	MP (32%)	7.51±0.05	5.11±0.03	3.00±0.02	0.20±0.01	0.60±0.02	6.16±0.04	1.01±0.01	102.05±0.05	0.75±0.02
	HP (36%)	6.75±0.05	4.58±0.03	2.65±0.05	0.07±0.01	0.48±0.01	3.86±0.03	0.41±0.01	29.88±0.03	0.24±0.01
HE (15 Mj)	LP (28%)	7.18±0.03	4.70±0.10	2.76±0.05	0.36±0.01	0.55±0.02	4.19±0.02	0.19±0.01	53.31±0.06	0.28±0.01
	MP (32%)	7.38±0.03	4.97±0.05	3.09±0.04	0.22±0.01	0.51±0.01	5.83±0.04	0.98±0.01	101.77±0.03	0.69±0.02
	HP (36%)	6.20±0.10	4.23±0.08	2.54±0.07	0.08±0.01	0.28±0.01	3.94±0.03	0.48±0.01	55.49±0.02	0.28±0.01

Table(7):Mean values of dry matter,ash, major and trace elements retained by all tilapia groups (on DM basis).

Treatment	g/Kg body weight		Major elements (g/Kg body weight)					Trace elements (mg/Kg body weight)			
Prot.&DE	Dry matter	Ash	Ca	P	K	Na	Mg	Fe	Cu	Zn	Mn
28%	263.5±4.6^{a}	127.6±1.2^{a}	21.36±0.2^{a}	14.57±0.1^{a}	6.91±0.1^{a}	0.76±0.1^{b}	1.46±0.1^{a}	11.31±0.1^{b}	1.44±0.1^{a}	126.5±2.6^{b}	1.44±0.1^{ab}
32%	264.9±7.5^{a}	135.9±3.3^{a}	19.45±0.1^{a}	19.48±0.1^{a}	11.29±0.1^{a}	1.79±0.1^{a}	1.47±0.2^{a}	17.31±0.2^{a}	2.68±0.2^{a}	318.4±0.1^{a}	1.84±0.2^{a}
36%	221.4±3.2^{b}	125.3±1.2^{a}	22.00±0.1^{a}	14.98±0.1^{a}	7.36±0.1^{a}	0.25±0.1^{b}	1.62±0.1^{a}	12.81±0.2^{b}	1.89±0.1^{a}	157.9±2.1^{b}	0.78±0.1^{b}
10 Mj	239.7±2.4^{1}	139.8±1.8^{1}	19.20±0.3^{1}	19.41±0.2^{1}	10.91±0.2^{1}	1.54±0.1^{1}	1.38±0.1^{1}	13.91±0.3^{1}	1.98±0.1^{1}	230.8±5.6^{1}	1.39±0.1^{1}
12 Mj	253.7±4.2^{1}	132.4±1.1^{1}	23.05±0.2^{1}	15.54±0.1^{1}	7.66±0.1^{1}	0.68±0.1^{2}	1.66±0.1^{1}	14.39±0.3^{1}	1.96±0.2^{1}	172.8±2.0^{1}	1.22±0.1^{1}
15Mj	256.4±6.2^{1}	116.5±1.0^{2}	20.55±0.1^{1}	14.08±0.1^{1}	6.99±0.2^{1}	0.67±0.1^{2}	1.50±0.1^{1}	12.49±0.2^{1}	1.78±0.1^{1}	199.2±5.8^{1}	1.15±0.1^{1}

*Mean in the same column with the same numbers and letters are not significantly different (P<0.05)

Table(8):Utilization efficiency (mean %) of major and trace elements by different groups of tilapia.

Treatments		Major-elements (%)					Trace-elements (%)			
DE(Mj/Kg)	Protein(%)	Calcium	Phosphorus	Potassium	Sodium	Magnesium	Iron	Copper	Zinc	Manganese
LE (10 Mj)	LP (28%)	21.18	22.43	15.46	2.00	9.52	4.10	6.75	16.37	1.09
	MP (32%)	25.30	26.36	15.32	7.65	15.00	5.24	6.59	36.15	1.13
	HP (36%)	16.88	17.14	9.01	1.76	11.76	3.10	7.11	18.39	0.43
ME (12 Mj)	LP (28%)	20.99	22.77	14.12	9.29	12.50	4.08	4.72	13.90	0.83
	MP (32%)	25.91	26.36	15.87	6.84	20.00	6.67	14.26	39.04	1.66
	HP (36%)	18.30	18.27	9.82	1.76	11.76	3.31	4.47	9.19	0.43
HE (15 Mj)	LP (28%)	18.98	19.10	13.16	10.83	15.38	3.48	2.19	15.54	0.47
	MP (32%)	23.89	24.37	15.13	7.22	15.79	5.90	12.95	36.40	1.42
	HP (36%)	15.83	16.13	8.91	2.00	6.67	3.22	5.00	16.20	0.47

Table(9): The mean major and trace elements retained in tilapia (*O.niloticus*) bodies.

Parameters	Major elements (g)					Trace elements (mg)			
(Mean of all groups)	Calcium	Phosphorus	Potassium	Sodium	Magnesium	Iron	Copper	Zinc	Manganese
Per Kg fish (wet basis)	8.7±0.12	5.7±0.06	3.7±0.15	0.30±0.03	0.67±0.01	7.0±0.25	0.61±0.03	95.5±0.15	0.67±0.01
Per Kg fish (dry basis)	28.4±0.15	18.6±0.06	12.1±0.06	0.98±0.02	2.20±0.12	22.9±0.15	1.99±0.11	312.1±0.26	2.19±0.06
Per 100 g ash	17.6±0.12	11.5±0.12	7.5±0.21	0.60±0.02	1.35±0.02	14.1±0.06	1.23±0.04	193.0±0.26	1.35±0.10
Retained per Kg B.Wt(wet basis)	7.11±0.17	4.82±0.11	2.82±0.07	0.18±0.03	0.48±0.02	4.63±0.20	0.57±0.03	66.93±3.20	0.45±0.01
Retained per Kg B.Wt(dry basis)	20.94±1.18	16.34±1.41	8.52±1.08	0.95±0.13	1.51±0.10	13.6±1.02	1.91±0.30	200.9±3.40	1.25±0.04
Retained per Kg gain	9.10±0.15	6.16±0.13	3.61±0.08	0.23±0.01	0.62±0.01	6.07±0.30	0.78±0.01	90.22±4.10	0.62±0.02