International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.2, pp 559-565, 2017

Evaluation of untreated *Jatrophacurcas* Kernel Meal at low inclusion level on Nile tilapia (*Oreochromis niloticus*) performance, feed utilization and body composition.

Hashem H.Abd El-Rahman[1], Ali S.M. El-Nadi[1], Hesham Abozaid[1],Mamdouh I.Mohamed[1], AboEl-Fetoh M. Abdalla[2] and Hanan A. Abo-State[1*]

[1]Animal Production Department, National Research Centre, Cairo, Egypt.
[2]Technology Horticulture Crops Department, National Research Centre, Cairo, Egypt.

Abstract : Objective: The present study was undertaken in order to evaluate untreated *Jatropha curcas* kernel meal at low inclusion level on Nile tilapia (*Oreochromis niloticus*) fingerlings performance, feed utilization and body composition.**Materials and Methods** Feeding trail was conducted for eight weeks. Fish were fed diets formulated with low inclusion level of Jatropha (0%,1.5 and 2.5%). All diets were isonitrogenous(280g protein kg^{-1}) isocaloric (4561.7 kcal kg^{-1}gross energy). One hundred and thirty five fish were randomly distributed intonine aquaria(each 60×30×40 cm^3) to represents three treatments and each treatment was replicated in three aquaria. All aquaria were stocked with fifteen fish (initial weight (11.06g $fish^{-1}$).All fish fed diets two times daily at 4% feeding level of the total biomass. **Results** All inclusion levels showed decrease in growth performance parameters which reflect on feed utilization parameters. On the other hand, there was slight difference in the carcass body composition. That's may be attributed to presence of toxic compound found in *Jatropha curcas* present in Egypt and anti-nutritional factors too. **Conclusion** this study concluded that we can apply Jatropha in fish diet after applying different detoxification treatments including chemical, physical, biological and or combination of these treatments with the emphasis on Egyptian strains.
Keywords : Nile tilapia, Jatropha, growth performance, feed Utilization**,** body composition.

1. Introduction

Increasing demand for aquaculture production with increasing human population all over the world, led to increase the need of fish feed [1]. Since the price of fish feed about sixty percent of total operation cost of aquaculture production [2,3,4]. The limited source of fish feed ingredients and the competition with the human on these ingredients, could decrease greatly the contribution of those feed components, due to satisfy the increasing demand for aquaculture feed production [5]. Therefore, to use the feed ingredient with long term availability [6,7,8,9]. We need to find alternative cheap and safe sources of protein to develop low cost feed for fish farmers continuously very urgent need[10] with no confliction with human need from selected feed ingredients[11].Therefore, the study for less costly and more available aquafeed sources has become a major challenge facing aqua feed industry and fish nutritionist. The previous studies showed that a lot of plant protein (*Moringa oleifera*)leaf meal [12,13,14], Guar meal[15],DDGS[16,17,18] and Sesbania aculeate seed meal [19] could partially

replace fish meal or soya meal in the diet of tilapia,*Oreochromisniloticus*[20,21], Common carp,*Cyprinuscarpio*[22,23]; Catfish,*Clariasgariepinus*[24,25]. but high dependence on soya meal increase its price and compete with the human need, so there is an urgent need to find non-expensive plant protein sources to be used in fish feed.

Jatropha curcas is a multipurpose tree, distributed worldwide in tropical and subtropical countries [7]. This plant mainly cultivated for bio-diesel production [26,27]. The kernel meal of *Jatropha curcas*(oily extract) gave approximately 50% of its seed weight as press cake, as a source of protein with excellent source of amino acids, carbohydrates and unsaturated fatty acids [28]. Otherwise, there are two types of jatropha(toxic and nontoxic)genotypes reported in cultivation practice [29].Nontoxic Jatropha genotype found only in Mexico, while the toxic one is exist throughout the rest of world which contains toxic compounds (Phorbol esters) and antinutritional compounds (saponins,lectin,phytic acid and trypsin inhibitors) decreased greatly its use in fish and animal feeds[6].But information on fish performance fed Jatropha Kernel meal is still limited. The main aim of the present work was conducted to evaluate effect of untreated *Jatropha curcas* Kernel Meal at low inclusion level on Nile tilapia (*Oreochromis niloticus*) growth performance, feed utilization and body composition

2. Materials and Methods

2.1. Fish and culture facilities

Monosex (all male) Nile tilapia juveniles (11.07 g) used in the present study were obtained from a commercial tilapia farm at Abbassa, Sharkia governorate, Egypt. Three treatments with triplicate groups of fish were stoked in 9 aquaria(60×30×40 cm^3) at an closed water system present in fish nutrition laboratory in the National Research Centre Dokki, Giza, Egypt at a density of 15 fish/aquarium. The experimentalfish were acclimated to the culture system for 2 weeks, during which they were fed the tested diets. At the end of the acclimation period, a random sample of 50 fish was netted from fish stock, weight collectively and the average initial weights were recorded. Water quality parameters, including water temperature (T), dissolved oxygen (DO) and pH were monitored weekly

2.2.Test diets and feeding regime

Three isonitrogenous (280 g crude proteinkg^{-1}), isocaloric(4561.7kcal kg^{-1}gross energy)tested diets were prepared. Raw jatropha (31.23% crude protein, 27.97% crude lipid, 4.28%, crude fiber, 5.20% ash and 31.32% NFE and GE 5691.8 kcalgross energykg^{-1}) was incorporated at levels of 0, 1.25 and 2.5% (Table 1). The test diets were fed to the fish twice a day (at 8 am and 13 pm) for 8 weeks. The diets were offered at 4% of the fish body weights during the experiment. The average weight of fish was recorded every 15-day intervals, their average weights were recorded and the daily rations were readjusted accordingly.

Table (1). Composition and proximate analysis (%) of the tested diets.

Ingredient (%)	0.0 %	1.25%	2.5%
Concentrate	18.0	18.1	18.2
Soybean meal	40.0	38.75	37.5
corn	28.0	28.0	28.0
Wheat Bran	9.0	8.9	8.8
Corn oil	3.0	3.0	3.0
Premix[1]	2.0	2.0	2.0
Raw Jatropha	0	1.25	2.5
Total	100	100	100
Crude protein	28.83	30.02	30.78
Crude lipid	8.3	7.6	7.9
Ash	9.16	9.03	9.22
Crude fiber	9.1	9.7	9.4
NFE[2]	44.61	43.65	42.7
GE (Kcal.)[3]	456.17	456.48	456.97

[1]Contains(Kg^{-1}): vitamin A, 3,333,333 IU; vitamin D_3, 833.333 IU; vitamin E, 3,333 mg; vitamin K, 333 mg; vitamin B_1, 333.3 mg; vitamin B_2, 1,667 mg; vitamin B_6, 500 mg; vitamin B_{12}, 3.33 mg; niacin, 10,000 mg; pantothenic acid, 3,333.3 mg; folic acid, 333.3 mg; biotin, 16.7 mg; iodine, 100 mg; iron, 10,000 mg; manganese, 20,000 mg; copper, 1,333 mg; cobalt, 33.3 mg; selenium, 33.3 mg; zinc, 16,667 mg; and calcium carbonate, 1,000 mg.
[2]Nitrogen free extract(NFE), determined by differences.
[3]Gross energy value was calculated from their chemical composition, using the factors 5.65 , 9.45, 4.00 and 4.00 (k cal/g) for protein, fat, fiber and NFE, respectively (47).

2.3. Body composition analysis

At the end of the experiment, fish in each aquarium were netted, counted, weighed and frozen at -20°C for final body composition analysis. Initial body analysis was performed on a pooled sample of 50fish, which was weighed and frozen before the experiment. A sample of each test diet was also stored -20°C for chemical analysis. Proximate analyses of the test diets and whole-body moisture, protein, lipid and ash were performed according to the standard AOAC [30] methods.

2.4.Calculations of fish performance

Growth rates and feed efficiency were calculated as follows:

weight gain (WG) = (W*f*-W*i*)
Specific growth rate (SGR) = 100)LnW*f*-LnW*i*)/*t*
Where W*i* andW*f* are initial and final weights (g) and *t*is time of experiment (days).
Feed conversion ratio (FCR) = dry feed intake (g) / fish live weight gain (g).
Protein efficiency ratio (PER) = 100 (weight gain (g) / protein intake (g)
Protein productive value (PPV) = 100(protein gain (g) /protein fed (g)).
Energy Retention (ER) = Retained energy in carcass (Kcal)/energy intake (Kcal)×100.

2.5. Statistical analysis

All data were subjected to one-way analysis of variance (ANOVA) at a 95% confidence limit, using SPSS software, version 16. Duncan's Multiple Range [31]test was used to compare means when F-values from the ANOVA were significant (P<0.05).

3. Results

Water quality parameters of the experimental set up such as temperature and pH were monitored weekly throughout the period of the experiment and they were in the tolerable ranges for Nile tilapia (*Oreochromisniloticus*) culture in all treatments [15] water temperature was around (27.5) and pH was (7.95) as mentioned by Azzaza*et al*[32].All fish grow normally and no signs of disease were observed throughout the experiment.

Table 2: Growth performance parameters of Nile tilapia fed the tested diets.

Jatropha(%)	Initial Weight (g)	Final Weight (g)	Weight gain (g)	Specific growth rate
0	11.0667	30.87 ± 0.32^{a}	19.80 ± 0.35^{a}	5.87 ± 0.02^{a}
1.25	11.0667	28.73 ± 0.63^{b}	17.68 ± 0.66^{b}	5.74 ± 0.04^{b}
2.5	11.0667	24.97 ± 0.61^{c}	13.89 ± 0.67^{c}	5.47 ± 0.05^{c}

Values in the same column with different superscripts are significantly different at P<0.05.

Growth parameters of Nile tilapia: Average values of initial weight, final body weight, weight gain and specific growth rate of Nile tilapia fed low inclusion level of *Jatropha curcas* Kernel meal are presented in Table (2). Results revealed that no significant differences (P<0.05) was found among treatments in initial weight which reflect homogeneity in fish weight at the beginning of the experiment. The results showed retardation in growth performance parameters with increasing inclusion level of Jatropha in tilapia diet. Were the final weight was the worst in the last treatment 2.5% Jatropha (24.97 g) compared with the treatment not

treated with Jatropha (30.87 g). Consequently the same trend was observed in weight gain and specific growth rate (SGR) whereas the highest weight gain was recorded in the control treatment (19.80 g $fish^{-1}$) and the lowest with 25% Jatropha (13.89 g). Also,the highest SGR value was recorded for fish fed control diet and then decreased with increasing inclusion level (5.87,5.74 and 5.47% day^{-1} $fish^{-1}$), respectively.

The data in Table (3) demonstrate the feed utilization parameters, there were significant differences among all treatments ($P<0.05$), there were decline in feed utilization parameters with increasing inclusion level of Jatropha Kernel meal, feed intake increased gradually (50.97,54.17 and 54.57g $fish^{-1}$)FCR (2.58,3.06 and3.88), PER (1.35,1.13 and 0.91),PPV (25.43,23.27 and 19.73), respectively. With respect toenergy retention (ER), there were no significant differences among treatment ($P>0.05$) ,but there were numerically differences (14.42,12.87 and 13.81).

Table 3: Feed utilization parameters of Nile tilapia fed tested diets.

Jatropha(%)	Feed intake	FCR	PER	PPV	ER
0	50.97±1.37	2.58±0.09[a]	1.35±0.05[a]	25.43±1.99[a]	14.42±1.25
1.25	54.17±2.49	3.06±0.04[b]	1.13±0.02[b]	23.27±1.19[b]	12.87±0.54
2.5	53.57±1.03	3.88±0.25[b]	0.91±0.06[c]	19.73±1.98[c]	13.81±1.59

Values in the same column with different superscripts are significantly different at $P<0.05$.

Table 4: Body composition on dry matter basis of Nile tilapia fed the tested diets.

Jatropha(%)	DM	Crude Protein	Ether Extract	Ash
Initial	17.00	54.63	16.18	11.4
0	24.20±1.06	61.50±0.26	16.22±0.48[b]	17.30±0.79
1.25	25.09±0.94	62.43±0.47	17.58±0.44[b]	18.00±0.14
2.5	25.35±0.99	61.38±0.38	18.20±0.23[a]	18.67±0.90

Values in the same column with different superscripts are significantly different at $P<0.05$.

Concerning to body composition (Table 4), the obtained results refers to the insignificant differences ($P>0.05$) in final dry matter (DM) or final crude protein in carcass (24.20,25.09 and 25.35%) and (61.50,62.43 and 61.38%), respectively. On the other hand, there are significant differences ($P<0.05$) in EE between the highest inclusion level 2.5% Jatropha (18.20%) compared with the two other treatments 0,1.25% (16.22 and 17.58). Ash content of fish carcasses significantly ($P<0.05$) increased with increasing the inclusion level of Jatropha seed meal in fish diets.

4. Discussion

The present study cleared that there were decline in allfeed utilization and growth performance parameters with increasing inclusion levels of *Jatropha curcuas* for Nile tilapia (*Oreochromis niloticus*) even in low inclusion levels compared with the previous studies of Alatise*et al.*,[25],they found that Kernel meal of Jatropha can be included up to 50% in *Clarias gariepinus* and replaced soya meal by 30% boiled Jatropha is optimum for growth performance. Workagegen *et al*[20] found that lower level up to (10%) of JCKM combined with heat treatment may consideredas good dietary protein source for juvenile Nile tilapia.This results was in a good agreement with the results of Azzaza*et al*[8]. Reddy and Pierson [33], Hajos*et al.*,[34] and Aderibigbe [35], Soltan [36,37],Hassaan*et al.*,[38] found that, feed with elevated concentration of anti-nutritional factors highly decreased the availability of nutrients which reflect the fish growth performance. The higher proportion of phytic acid reduce the digestibility of protein and the bioavailability of minerals (especially Ca^{+2} and Fe^{+2}) in fish diets especially with untreated Jatropha. which intern increase wastage of nutrients via feces. Our results in disagreement with the results of Akinleye *et al.*,[21] who found that using H-jpkm is a promising protein source(62.5%) for Nile tilapia in the diet according to feed utilization and growth performance parameters. They used another type of Jatropha (non toxic) present in Mexico and they add phytase (500FTU/kg diet) to decrease phytate –as anti-nutritive effects. These results may be due to the differences between genotypes of Jatropha in different countries, Makkar and Becker [29]found that, there are two genotypes of Jatropha (toxic and non toxic). In Mexico, the nontoxic genotype was found, while the toxic genotype spread worldwide . Which contains substance very toxic for fish called (phorbol esters) [6] and different antinutritional factors like (trypsin inhibitors,

saponins, lectin and phytic acid). They restrict using Jatropha in fish production (26) even at low inclusion levels.

Toxic or antinutritive compounds in Jatropha seed or Kernel meal may cause irritation of digestive tract which then decrease growth of fish [25]. The major antinutrients are trypsin inhibitors, phytate and lectin (9.4%) is greater three times than that found in soybean meal [39]. Force feeding of Jatropha meal which include PES represented toxic effect in miceLi *et al*[40]. These results was confirmed by Goel*et al*. [41] on rats and goats, in fish [42]. The most sensitive organs affected were kidney, intestines and liver. Many researchs have been carried out to complete detoxifiying Jatropha Kernel meals which led to deactivate the antinutrients and toxic components, such as PES, phytates, saponins and lectins by Ionizing radiation [43]; bysolid state fermentation with *Saccharomyces cerevisiae*[38];by moist heating we can inactivate antinutrients, protease inhibitors and lectins [35,44,36,37], but it is not possible to destroy PES by heat treatment because they are heat stable and can withstand roasting a temperature as high as 160C or 30 min.detoxification treatment depends on extraction of PES by organic solvents and heat treatment for detoxification of trypsin inhibitors and lectin [26]. The previous results about heat treatments may explained on the bases that heat can increase the palatability of feed leading to increasing the availability of nutrients consequently enhancing the growth performance of fish fed treated diets. The same observation was reported earlier in Nile tilapia [36,37], in common carp [22,45] in pig [46].

Moist heat treatment can reduce the percentage of some heat liable anti-nutritional factors (total phenols and trypsin inhibitors). Also, the level of anti-nutrients could be decreased more when the diet with combined treatment (4% NaOHand moist heat) [36,37,8]. Goel *et al*. [41]found that the level of phorbol-ester, the only toxic substance in JCKM, can decreased by heat followed by chemical treatments.

5. Conclusion

Jatropha kernel meal can be used in fish diet but after detoxification treatments individually or in combinations especially in Egyptian strains.

6. References

1. FAOThe State of World Fisheries and Aquaculture (2016)Contributing to food security and nutrition for all. Food and Agricultural Organization, Rome, Italy.
2. Fapohunda OO and Fagbenro OA(2006) Biotechnical factors affecting tilapia culture systems in the savanna region of Nigeria. Proceedings of the South International Symposium on Tilapia in Aquaculture, Veracruz, Mexico.
3. RidhaMT (2006) Comparative study of growth performance of three strains of Nile tilapia, *Oreochromis niloticus*, L. at two stocking densities. Aquac. Res., 37: 172-179.
4. FAO (2012) The State of World Fisheries and Aquaculture Part I: World Review of Fisheries and Aquaculture, Rome, Italy.
5. Siddhuraju P,Makkar HPS and Becker K (2002) The effect of ionizing radiation of antinutritional factors and the nutritional value of plant materials with reference to human and animal food. Food chem., 78:187-205.
6. Makkar HPS, Becker K, SporerF and Wink M (1997) Studies on Nutritive Potential and Toxic Constituents of Different Provenances of *Jatrophacurcas*. J. Agri. Food Chem., 45: 3152-3157.
7. Becker K and Makkar HPS(2008)*Jatrophacurcas*: A potential source for tomorrow's oil and biodiesel. Lipid Tech., 20: 104-107.
8. AzzazaNAE, El-Nisr NA, ElsharkawyEE and Elmotleb EE(2011) Chemical and Pathological Evaluation of *Jatrophacurcas* Seed Meal Toxicity With or Without Heat and Chemical Treatment. Aust .J .Basic Appl. Sci., 5: 49-59.
9. Kumar V, Khalil WK, Weiler U and Becker K(2013) Influences of incorporating detoxified *Jatropha curcas* kernel meal in common carp (*Cyprinuscarpio* L.) diet on the expression of growth hormone- and insulin-like growth factor-1- encoding genes. J.Anim. Physiol. Anim.Nutr., 97: 97-108.
10. Madalla N (2008) Novel Feed Ingredients for Nile Tilapia (*Oreochromis niloticus* L.). PhD, Dissertation, Stirling University, Scotland, UK.

11. Tacon AGJ and Foster IP (2000) Global trends and challenges to aquaculture and aqua-feed development in the new millennium. International Aqua-feed Directory and buyers Guide 2001, Trust RAL, Uxbridge, Middlesex, UK.
12. Dongmeza E, Siddhuraju P, Francis G and Becker K (2006) Effects of dehydrated methanol extracts of moringa (*Moringa oleifera* Lam.) leaves and three of its fractions on growth performance and feed nutrient assimilation in Nile tilapia (*Oreochromis niloticus* L.). Aquaculture 261, 133-148.
13. Richter N, Siddhuraju P and Becker K(2003) Evaluation of the quality of (*Moringa oleifera* Lam.) leaves as an alternative protein source for Nile tilapia (*Oreochromis niloliticus*L.). Aquaculture, 217: 599–611.
14. Abo-State HA, Hammouda YA, El-Nadi A and Abozaid H (2014) Evaluation of feeding raw Moringa (*Moringaoleifera* Lam.) leaves meal in Nile tilapia fingerlings(*Oreochromis niloticus*)diets. Glob. Vet., 13(1):105-111.
15. El-Sayed AM, Abo-State HA and Tahoun A (2016) Evaluation of Guar meal as a dietary protein source in Nile tilapia (*Oreochromis niloticus*) reared in Hapa-pond system. J. Fish. Aquat. Sci., 11:317-322.
16. Abo-State HA, Tahoun AM and Hammouda YA (2009) Effect of Replacement of soy bean meal by DDGS Combined with Commercial phytase on Nile tilapia *(Oreochomis niloticus)* Fingerlings Growth performance and Feed utilization. Am. Eurasian J.Agric. Environ. Sci., 5(4): 473-479.
17. Tahoun AM, Abo-State HA and Hammouda YA (2009) Effect of adding Commercial phytase to DDGS based on the performance and feed utilization of Nile tilapia (*Oreochromius niloticus*) fingerlings. Am. Eurasian J.Agric. Environ. Sci., 5(4): 550-555.
18. Soltan MA,Radwan AA, Gomaa AH and Farag AM (2015) Using distillers dried grains as an alternative protein source in Nile tilapia (*Oreochromis niloticus*) feeds. Egypt. J. Aquat. Biol. & Fish., Vol. 19(3):23-33.
19. Hossain MA, FockenU and Becker K (2001) Evaluation of an unconventional legume seed, *Sesbania acuelata*, as a dietary protein source for common carp,*Cyprinus carpio*. Aquaculture 198, 129–140.
20. Workagegen KB, Ababbo ED, Tossa BT(2013) The Effect of Dietary Inclusion of *Jatrophacurcas* Kernel Meal on Growth Performance, Feed Utilization Efficiency and Survival Rate of Juvenile Nile tilapia. J. Aquac. Res. Development 4: 193 doi:10.4172/2155-9546.1000193.
21. Akinleye O, Kumar V, Makkar HPS, Angulo-Escalante MA and Becker K(2012) *Jatropha platyphylla* kernel meal as feed ingredient for Nile tilapia (*Oreochromis niloticus*L.):growth, nutrient utilization and blood parameters. J. Anim. Physiol. An. N., 96:119-129.
22. Kumar V, Makkar HPS and Becker K(2008) Detoxification of *Jatrophacurcas* seed meal and its utilization as a protein source in fish diet. Comp Biochem Phys A 151: 13-19.
23. Makkar HPS and Becker K (1999) Nutritional studies on rats and fish Carp (*Cyprinus carpio*) fed diets containing unheated and *Jatropha curcas* meal of a non-toxic provenance. Plant Food Hum.Nutr., 53:183-192.
24. Akintayo IA, Obasa SO, Alegbeleye WO and Bangbose AM (2008) Evaluation of toasted sunflower(*Helianthus annus*) seed meal in the diets of African catfish (*Clariusgariepinus*) fingerlings.*V. 20, Article #157.* Retrieved November 7, 2016,
25. Alatise SP, AdedodunMA and Ajiboye GE (2014) Effects of Boiled Jatropha Kernel Meal as a Substitute for Soybeans Meal in Diet of African Mud Catfish *(Clarias gariepinus*) Fingerlings.J. Fish. Aquat. Sci., 9(6):446-454.
26. Makkar HPS, Francis G and Becker K(2008) Protein concentration from *Jatropha curcas* screw-pressed seed cake and toxic and antinutrimental factors in protein concentrate. J. Sci. Food Agr., 88: 1542-1548.
27. Parawira W (2010) Biodiesel production from *Jatropha curcas*: A Review. Scientific Research and Essays, 5(14): 1796-1808.
28. Kumar V, Makkar HPS and Becker K (2010) Detoxified *Jatrophacurcas* kernel meal as a dietary protein source: growth performance, nutrient utilization and digestive enzymes in common carp (*Cyprinus carpio* L.) fingerlings. Aquacult.Nutr., 17(3): 313-326.
29. Makkar HPS and Becker K (2009)*Jatropha curcas*, a promising crop for the generation of biodiesel and value- added coproducts . Eur. J. lipid Sci. Technol., 111:773-787.
30. Association of Official Analytical Chemists Official Methods of Analysis, 16thedn, AOAC (1995), Arlington, VA, USA.
31. Duncan D (1955) Multiple range tests and multiple F tests. Biometrics, 11: 1-42.

32. Azzaza MS,Dhrajef MN and KrajemMM (2008) Effects of water temperature on growth and sex ratio of juvenile Nile tilapia *Oreochromis niloticus* (Linnaeus) reared in geothermal water in southern Tunisia. J. Therm. Biol., 33: 98-105.
33. Reddy NR and Pierson MD (1994) Reduction in antinutritional and toxic components in plant foods by fermentation. Food Res. Int., 27: 281-290.
34. Hajos G, Gelenser E, Pusztai A , Grant G , Sakhri M , Bardocz S(1995) Biological Effects and Survival of Trypsin Inhibitors and Agglutinin from Soybean in Small Intestine of the Rat. J. Agric. Food Chem., 43: 165-170.
35. Aderibigbe AO, Jonson CO, Makkar HPS, Becker K and Foidl N (1997) Chemical composition and effects of heat on organic matter- and nitrogen-degradability and some anti nutritional components of Jatropha meal. Anim. Feed Sci. Tech., 65: 223-243.
36. Soltan MA(2005a) Partial and total replacement of soybean meal by raw and heat treated linseed meal in tilapia diets. Egyptian J. Nutrition and Feeds, 8(1) *Special Issue*:1091-1109.
37. Soltan MA (2005b) Potential of using raw and processed canola seed meal as an alternative fish meal protein source in diets for Nile tilapia, *(Oreochromis niloticus)*. Egyptian J. Nutrition and Feeds, 8(1) *Special Issue*:1111-1128.
38. Hassaan MS,Soltan MA and Abdel-Moez AM (2015) Nutritive value of soybean meal after solid state fermentation with *Saccharomyces cerevisiae* for Nile tilapia, *Oreochromis niloticus.*, Anim. Feed Sci. Tech., 201:89-98.
39. Kumar V, Gavryliuk O, Sinha SA, Barman D, DeClercq E, Das A and Mandal SC(2012)Jatropha meal, apromising plant protein source in aquafeed development. Aquaculture Asia, 38-45.
40. Li CY, Devappa RK, Liu JX, Makkar HPS and Becker K(2010) Toxicity of *Jatropha curcas* phorbol esters in mice. Food Chem. Toxicol., 48:620-625.
41. Goel G, Makkar HPS, Francis G and Becker K(2007) Phorbol esters: structure, biological activity, and toxicity in animals. Int. J. Toxicol., 26: 279-288.
42. Becker K and MakkarHPS (1998) Effects of phorbol esters in carp (*Cyprinuscarpio* L). Vet. Hum. Toxicol., 40: 82-86.
43. Siddhuraju P and Becker K(2001) Preliminary nutritional evaluation of Mucuna seed meal (*Mucuna pruriens* var.utilis) in Common carp (*Cyprinus carpio* L.): An assessment by growth performance and feed utilization. Aquaculture,196: 105-123.
44. Aregheore EM, Becker K and Makkar HPS (2003) Detoxification of a toxic variety of *Jatropha curcas* using heat and chemical treatments and preliminary nutritional evaluation with rats. S. Pac. J. Nat. Sci., 21: 51-56.
45. Mazurkiewicz J (2009) Utilization of domestic plant components in diets for common carp *Cyprinus carpio* L. Arch. Pol Fish, 17: 5-39.
46. Wang H, Yi C , Zhao Y , Liu H , Liu J , MakkarHPS and Becker K (2011) Effect of replacing soybean meal by detoxified *Jatropha curcas* kernel meal in the diet of growing pigs on their growth, serum biochemical parameters and visceral organs. Anim. Feed Sci. Tech., 170: 141-146.
47. Jobling M(1983) A short review and critique of methodology used in fish growth and nutrition studies. J. Fish Biol., 23: 685 – 703.

*****