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Apparent Nutrient Digestibility Coefficient of Sunflower and Sesame Seed Meal in *Clarias gariepinus* (Burchell, 1822) Fingerlings

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ABSTRACT

The apparent digestibility coefficient of raw sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*) seedmeal by Clariid catfish (*Clarias gariepinus*) fingerlings was evaluated at 15,30 and 45% levels of replacement, respectively using soybean meal based diets as control diet. There was significant difference ($p < 0.05$) in Apparent Organic Matter digestibility (AOMD), Apparent Protein Digestibility (APD), Apparent Energy Digestibility (AED) Apparent Carbohydrate Digestibility (ACD) between the fish fed control diet and the fish fed test diets. However, there was no significant difference ($p > 0.05$) in apparent lipid and fibre digestibilities of fish fed control diet and test diets RSF_{15} and RSM_{15} .

Key words: Digestibility coefficient, carbohydrate, protein, organic matter, *Helianthus annuus*

INTRODUCTION

Soybean meal has high protein content and the best protein quality among plant protein feedstuffs used in fish feeds (Davies *et al.*, 1999). The meal is known to partially or totally replace fish meal in diets of many fish species (Lovell, 1988; Lim and Akinyama, 1992). However, wider use of conventional protein source fish ingredients for fish feed is limited by increasing demand for human consumption and by other animal feed industries (Siddhuraju and Becker, 2001). Hence, research focus should be directed on looking for cheaper, alternative protein source.

Sunflower (*Helianthus annuus* var. *macrocarpus*) and sesame seed (*Sesamum indicum*) are important annual crops of the world grown for oil (Salunkhe *et al.*, 1991). They have nutrient density comparable to other oilseed proteins including soybean meal and other conventional legumes (Robertson and Russel, 1972; Jackson *et al.*, 1982; Hossain and Jauncey, 1989a, b; Sanz *et al.*, 1994; Sintayehu *et al.*, 1996) and their potentials as dietary protein sources are well recognized (Olvera-Novoa *et al.*, 2002). Fagbenro *et al.* (2003) then Jauncey (1993) reported that the most important characteristics of feedstuffs is the bioavailability of nutrients, hence reliable data on the different ingredients for each species need to be well considered as a necessary prerequisite. De Silva and Anderson (1995) observed that knowing the digestibility of the main ingredients as well as of the whole diet in feed formulation and manufacture is very essential; Borghesi *et al.* (2008) reported that adequate knowledge into nutrient digestibilities of feed ingredients could result into favorable substitution of feed ingredients without reducing animal

performance. Chemical analysis and Apparent Digestibility Coefficient (ADC) results make it possible to accurately estimate not only the contribution of a particular protein source to a complete fish feed but also how much feed wastes and undigested nutrients (faeces) will potentially accumulate in fish pond (Kenan and Ozdemir, 2005). Hence, an attempt has been made to evaluate the possibility of incorporating raw sunflower and sesame seedmeal at different levels into the diets of *Clarias gariepinus* fingerlings by determining the digestibility coefficient of the nutrients in each diet with a view to bringing out the best level of incorporation of these ingredients.

MATERIALS AND METHODS

Sources and processing of ingredients: The dehulled seeds of sunflower and sesame were obtained from a farm in Kebbi State, Nigeria. They were ground in a hammer milled and the oil therein was removed using the pressure generated from locally made screw press (cassava-presser type). The cakes therefore were analysed for their proximate composition (AOAC, 1990). Fish meal, soybean meal and other feedstuffs obtained from commercial sources in Nigeria were separately milled screened to fine particles size and triplicate samples were analyzed for their proximate composition (AOAC, 1990). Based on the nutrient composition of the protein feed stuff (Table 1), a control diet and six test diets (40% crude Protein, 12% crude Lipid, 18 MJ energy) were formulated. The control diets contained soybean meal, providing 50% of the total protein. Three of the test diets contained sunflower meal protein at a replacement levels of 15, 30 and 45% for the soybean meal to serve as test diets RSF₁₅, RSF₃₀ and RSF₄₅, respectively while the other three contained sesame meal protein at the same replacement levels for the soybean meal to serve as test diets RSM₁₅, RSM₃₀ and RSM₄₅, respectively (Table 2). The feedstuffs were blended, moistened, steam pelleted and oven dried for 24 h.

Table 1: Proximate composition of carcass of protein feed ingredients

Composition	Ingredients				
	Fish meal	Soybean meal	Sunflower meal	Sesame meal	Corn meal
Moisture	7.59	8.92	9.48	8.39	9.21
Crude protein	69.76	42.81	40.01	42.21	8.89
Crude lipid	8.82	18.56	20.28	15.92	1.49
Crude fibre	-	5.63	12.80	5.48	29.78
Ash	13.83	6.01	5.89	7.27	3.81
NFE	-	18.07	11.54	20.73	46.82

NFE: Nitrogen free extract

Table 2: Gross composition of experimental diets fed to *Clarias gariepinus* at varying replacement levels of diets

Composition (g/100 g dry matter)	Replacement level						
	CTR	RSF ₁₅	RSF ₃₀	RSF ₄₅	RSM ₁₅	RSM ₃₀	RSM ₄₅
Fish meal	27.24	27.24	27.24	27.24	27.24	27.24	27.24
Soybean meal	46.71	39.71	32.70	25.70	39.71	32.70	25.70
Raw samples	-	7.48	14.96	22.44	7.08	14.16	21.25
Corn meal	11.25	11.25	11.25	11.25	11.25	11.25	11.25
Fish oil	5.09	5.09	5.09	5.09	5.09	5.09	5.09
Vitamin premixes	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Starch	4.76	4.22	3.76	3.28	4.63	4.26	4.17
Total	100	100	100	100	100	100	100

Vitamin premixes

Culture condition: *Clarias gariepinus* fingerlings were acclimated to experimental condition for seven days prior to the feeding trial. Groups of 15 *Clarias* fingerlings (3.28 ± 0.15 g) were stocked into aquaria comprising 60 L capacity rectangular tanks. Each diet was fed to catfish in triplicate tanks twice daily (9-10, 16-17 h) at 5% body weight for 28 days. Faecal collection began 7 days after the feeding of experimental diets commenced. Collection of faecal samples was carried out for 21 days using a 2 cm-pipe six hours after feeding. Uneaten diets were siphoned 90 min after feeding. Droppings from the same tanks were pooled together in a bowl and stored in a freezer. Water temperature and dissolved oxygen were measured using combined digital YSI dissolved oxygen meter (YSI model 57, Yellow Spring, Ohio) pH was monitored weekly using pH meter (Mettler Teledo-320, Jenway UK).

Proximate analyses: The proximate analyses of feed ingredients, diets and faeces for crude protein, crude fibre, crude lipid, fat and ash were carried out in triplicate using the methods described by the AOAC (1990). A factor of 6.25 was used to convert nitrogen to protein. The nitrogen free extract was estimated by difference. Energy content of faeces and diets were determined using the physiological value of 5.6 kcal g⁻¹ protein, 4.1 kcal g⁻¹ carbohydrate and 9.5 kcal g⁻¹ lipid.

AIA analyses: AIA analyses were carried out on test diets and faeces using the methods described in Halver *et al.* (1993), Adeparusi and Jimoh (2002).

Determination of digestibility coefficient: This was calculated on the percentage of AIA in feed and in faeces and the percentage of nutrient on diets and faeces:

$$\text{Digestibility (\%)} = 100 - \left(100 \left(\frac{\% \text{AIA in feed}}{\% \text{AIA in faeces}} \times \frac{\% \text{Nutrients in faeces}}{\% \text{Nutrients in feed}} \right) \right)$$

Apparent Organic Matter Digestibility (AOMD) was calculated as follow:

$$\text{AOMD} = 100 - \left(100 \left(\frac{\% \text{AIA in feed}}{\% \text{AIA in faeces}} \right) \right)$$

Statistical analyses: Results are expressed as Mean $\pm$ SD. All data were subjected to one way ANOVA using SPSS 13.0 for window software. Where significant differences occurred, the group means were further compared with Duncan's multiple range test using SPSS 13.0 (SPSS, IL, USA).

RESULTS AND DISCUSSION

Table 2 showed the proximate composition of soybean meal, sunflower meal, sesame meal, corn and fish meal. Table 3 showed the proximate composition of the experimental diet; it revealed the diets to be isonitrogenous as there was no significant difference ($p > 0.05$) in the protein content of the diets. Fish in different dietary groups fed actively on the experimental diets throughout the experiments. The AIA in diet CTR was significantly lower ($p < 0.05$) than the test diets. There was no significant difference ($p > 0.05$) in the AIA of the test diets. The highest AIA in faeces was recorded in the faecal samples of fish fed diet RSM₁₅ while the lowest was recorded in the faecal

Table 3: Proximate composition of experimental diets fed to *Clarias gariepinus* at varying replacement levels

Composition (g/100 g dry matter)	Replacement level						
	CTR	RSF ₁₅	RSF ₃₀	RSF ₄₅	RSM ₁₅	RSM ₃₀	RSM ₄₅
Moisture	9.17±0.15 ^b	9.67±0.72 ^a	9.36±0.46 ^{ab}	9.57± 0.09 ^{ab}	9.39±0.19 ^{ab}	9.43±0.26 ^{ab}	9.37±0.15 ^{ab}
Crude protein	40.60±0.72	40.47±0.46	40.28±0.87	40.18± 0.28	40.48±0.61	40.42±0.36	40.24±0.38
Crude lipid	11.74±0.04 ^c	12.18±0.12 ^{ab}	12.28±0.05 ^a	12.32±0.05 ^a	11.93±0.12 ^{bc}	12.33±0.06 ^a	12.46±0.35 ^a
Crude fibre	5.84±0.10 ^b	5.84±0.08 ^b	6.44±0.29 ^a	6.44±0.28 ^a	5.53±0.28 ^b	5.90±0.04 ^b	5.87±0.22 ^b
Ash	9.35±0.10 ^a	8.71±0.24 ^{bc}	8.80±0.11 ^{bc}	9.04±0.47 ^{ab}	8.91±0.13 ^{abc}	8.81±0.11 ^{bc}	8.51±0.27 ^c
NFE	23.13±0.74	23.42±0.39	23.05±0.75	22.46±0.13	23.76±0.93	22.92±0.26	23.55±0.94
Energy (MJ)	4.31±0.02 ^d	4.34±0.01 ^{bc}	4.34±0.02	4.32±0.01 ^{cd}	4.35±0.01 ^{ab}	4.35±0.02 ^b	4.37±0.01 ^a
AIA	0.62±0.02	0.74±0.02 ^b	0.74±0.01 ^b	0.75±0.03 ^b	0.74±0.03 ^b	0.75±0.03 ^b	0.74 ±0.02 ^b

Figures in each row with different superscript are significantly different at $p < 0.05$ from each other, AIA: Acid insoluble ash, NFE: Nitrogen free extract

Table 4: Proximate composition of faecal samples fed to *Clarias gariepinus* at varying replacement levels

Composition (g/100 g dry matter)	Replacement level						
	CTR	RSF ₁₅	RSF ₃₀	RSF ₄₅	RSM ₁₅	RSM ₃₀	RSM ₄₅
Moisture	9.54±0.25	9.77±0.58	9.83±0.22	9.45±0.41	9.99±0.29	9.61±0.61	9.40±0.07
Crude protein	15.80±0.18 ^d	15.39±0.18 ^{de}	15.46±0.08 ^{de}	18.14±0.31 ^b	15.22±0.15 ^e	16.69±0.39 ^f	19.43±0.50 ^a
Crude lipid	6.46±0.12 ^a	6.12±0.23 ^{ab}	6.24±0.28 ^a	6.09±0.16 ^{ab}	5.84±0.10 ^b	6.09±0.20 ^{ab}	6.11±0.22 ^{ab}
Crude fibre	12.6±0.47 ^a	11.09±0.24 ^b	10.57±0.26 ^b	10.78±0.29 ^b	10.61±0.32 ^b	10.61±0.32 ^b	10.71±0.17 ^b
Ash	5.39±0.21 ^a	5.44±0.25 ^a	4.91 ±0.10 ^b	4.58±0.26 ^{bc}	5.33±0.14 ^a	4.48±0.27 ^c	4.64±0.27 ^{bc}
NFE	50.23±0.45 ^c	52.18±0.63 ^a	52.99±0.23 ^a	50.92±0.69 ^{bc}	51.80±1.38 ^{ab}	52.76±0.22 ^a	49.88±0.23 ^c
Energy (MJ)	3.53±0.12 ^d	3.57± 0.05 ^{cd}	3.62±0.03 ^{bc}	3.67±0.03 ^{ab}	3.56±0.01 ^{cd}	3.66±0.03 ^{ab}	3.71±0.06 ^a
AIA	2.78±0.06 ^b	2.79±0.05 ^{ab}	2.49±0.02 ^d	2.38±0.04 ^e	2.86±0.06 ^a	2.67±0.06 ^c	2.46±0.01 ^d

Figures in each row with different superscript are significantly different at $p < 0.05$ from each other, AIA: Acid insoluble ash, NFE: Nitrogen free extract

samples of fish fed diet RSM₁₅. Significant variation ($p < 0.05$) was recorded among the AIA of fish fed control diets and test diets but the variation lack definite pattern that is, it is not related to the level of inclusion of the seed meal. Table 4 showed the proximate composition of faecal samples of fish fed control and test diets. There was no significant difference ($p > 0.05$) in the protein content of the faecal samples of fish fed diet CTR, RSF₁₅ and RSF₃₀. Similarly there was no significant difference ($p > 0.05$) in the protein content of the faecal samples of fish fed RSM₁₅ and RSM₁₅, RSM₃₀. The crude lipid content of the faecal samples of fish fed diet CTR was not significantly different ($p > 0.05$) from that of fish fed diet RSF₁₅, RSF₃₀, RSF₄₅, RSF₄₅, RSM₃₀, RSM₄₅. There was significant difference ($p < 0.05$) in the crude fibre content of fish fed diet CTR and fish fed other test diets. However there was no significant difference ($p > 0.05$) in the crude fibre content of fish fed diet CTR and fish fed other test diets. However, there was no significant difference ($p > 0.05$) in the crude fibre content of the faecal samples of fish fed test diets. Table 5 presents apparent digestibility coefficient of nutrients in raw sunflower and sesame meal based diets fed to *Clarias gariepinus* fingerlings. A significant variation ($p < 0.05$) exists among the fish fed control diet and test diets with respect to AOMD, APD, AED, ACD. There was no significant difference ($p > 0.05$) in Apparent Fiber Digestibility (AFD) and Apparent Lipid Digestibility (ALD) of the fish fed diet CTR and diets RSF₁₅ and RSM₁₅.

The apparent digestibility coefficient for organic matter, protein, energy, lipid, fibre, carbohydrate of control diets were highest in comparison to those found raw sunflower and sesame seed meal incorporated diets. The value is in agreement with the values reported for carp

Table 5: Apparent digestibility coefficient of nutrients of raw sunflower and sesame meal based diets fed to *Clarias gariepinus*

Coefficient	Diets						
	CTR	RSF ₁₅	RSF ₃₀	RSF ₄₅	RSM ₁₅	RSM ₃₀	RSM ₄₅
AOMD	77.55±0.52 ^a	73.37±0.69 ^{bc}	70.27±0.17 ^c	68.36±1.39 ^e	74.17±1.24 ^b	71.90±0.74 ^c	69.79±0.72 ^{de}
APD	91.26±0.41 ^a	89.8±0.37 ^{bc}	88.59±0.26 ^d	85.71±0.49 ^e	90.27±0.58 ^b	88.99±0.65 ^{cd}	89.40±0.53 ^e
AED	81.63±0.52 ^a	78.12±0.82 ^b	75.26±0.13 ^{cd}	73.10±0.99 ^e	78.75±0.93 ^b	76.32±0.69 ^c	74.50±0.77 ^d
ALD	87.65±0.23 ^a	86.64±0.37 ^{ab}	84.88±0.56 ^d	84.33±1.03 ^d	87.32±0.93 ^{ab}	86.11±0.76 ^{bc}	85.19±0.43 ^{cd}
AFD	52.15±0.88 ^a	50.20±1.75 ^{ab}	49.69±1.90 ^{bc}	46.80±5.51 ^{bc}	50.39±1.36 ^{ab}	49.40±2.37 ^{bc}	44.83±2.23 ^c
ACD	51.86±1.19 ^a	40.67±2.75 ^b	31.62±2.31 ^{de}	28.20±1.87 ^e	42.36±2.73 ^b	35.29±1.52 ^{cd}	36.12± 3.66 ^c

Figures in each row with different superscript are significantly different at $p < 0.05$ from each other, AOMD: Apparent organic matter Digestibility, APD: Apparent protein digestibility, AED: Apparent energy digestibility, ALD: Apparent lipid digestibility, AFD: Apparent fibre digestibility, ACD: Apparent carbohydrate digestibility

(Smith *et al.*, 1980; Hossain and Jauncey, 1989b; Mukhopadhyay, 2001). The values of apparent digestibility of protein and lipid for the control diet obtained during the experiment were almost similar to those obtained by Hossain and Jauncey (1989a), Mukhopadhyay (2001). The values of apparent digestibility of protein and lipid of the test diets containing raw sesame seedmeal were comparable to those found by Hasan (1986) in common carp fry diets containing different proportions of mustard, Linseed and sesame seed meals. Hossain and Jauncey (1989b), Mukhopadhyay (2001) found similar result in *Cyprinus carpio* diets containing graded level of raw sesame seed meal. There was significant reduction in apparent digestibility of nutrients with increasing level of inclusion of sunflower and sesame seed meal; a similar observation were made by Mukhopadhyay (2001) and Hossain and Jauncey (1989a). The little variation of their results with this under study could be attributed to variability of nutrients as well as differences in nutrient processing experimental methodology and faeces sampling technique (Jauncey, 1993). The lower digestibility coefficient recorded for crude fibre and carbohydrate in *Clarias gariepinus* fed control diets and test diets might not be unconnected to the physiological requirement of *Clarias gariepinus*. It is a carnivorous fish. The low carbohydrate digestibility recorded in this study was similar to that reported by Adeparusi and Jimoh (2002) for *Oreochromis niloticus* fed lima bean. The digestibility of carbohydrate has been to vary with their complexibility of carbohydrate has been to vary with their complexibility, source treatment and level of inclusion in the diet (Phillip, 1972; Lovell, 1977; Cho and Slinger, 1979). The organic matter digestibility coefficient reported in this study was slightly higher than the value reported by Fagbenro (1998) the variation may be attributed to processing methods and or the variation may be attributed to processing methods and or experimental methodology; different seed meal and fish species was used as it is known that digestibility of nutrients are species specific however the result closely related to that reported in Martinez-Palacios *et al.* (1988) and Yue and Zhou (2008) for juvenile hybrid tilapia fed cottonseed meal. No significant variation ($p < 0.05$) occurred in lipid digestibility by *Clarias gariepinus* fed diets CTR, RSM₁₅ and RSF₁₅. Although, the lipid digestibility of the fish fed other test diets was so high. The result was in conjunction with what was reported by Hossain *et al.* (1992) for rainbow trout range of 76 to 97% feed digestibility of various sources of fat had been reported for channel catfish (Lovell, 1977). Andrew *et al.* (1979) reported that the ability to digest fat appears to be influenced by temperature and the level of fat in the diet. Sunflower and sesame oil has excellent nutritional properties. They are practically free of toxic composition. The high proportion of PUFA renders sunflower oil as a popular source of essential fatty acids in the diet (Lanstraat, 1976). Lower

apparent protein digestibility recorded in this study was not in line in what was reported in Olvera-Novoa *et al.* (2002) who fed the same seed meal to *O. niloticus* and the study of Stickney *et al.* (1996) which found that apparent protein digestibility of sunflower was similar or slightly lower than the apparent protein digestibility of fishmeal. Lall (1991) reported that digestibility data are useful only when ingredients do not contain anti-nutritional factors that may influence the digestibility of various nutrients in the diets and give erroneous result. The raw sunflower and sesame seed meal without doubt contain same levels of anti-nutrients. Tacon (1992) and (1997) reported that sunflower contains protease inhibitors, saponins, tannin, Arginase inhibitor while sesame is reported to contain high amount of phytase. The lower apparent digestibility coefficient by *Clarias gariepinus* fed diets containing those ingredients might not be unconnected to negative effect imparted by the anti-metabolite present in them.

CONCLUSION

It can be concluded that significant variation ($p < 0.05$) in Apparent Organic Matter Digestibility (AOMD), Apparent Protein Digestibility (APD), Apparent Energy Digestibility (AED) Apparent Carbohydrate Digestibility (ACD) between the fish fed control diet and the fish fed test diets. However, there was no significant difference ($p > 0.05$) in apparent lipid and fibre digestibilities of fish fed control diet and test diets RSF₁₅ and RSM₁₅. Hence, further research could be focused in processing technique that could be applied to these ingredients such that these anti-metabolites might be removed and their nutritive potential evaluated in fish feed.

REFERENCES

- AOAC., 1990. Official Method of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC.
- Adeparusi, E.O. and W.A. Jimoh, 2002. Digestibility coefficient of raw and processed Lima bean diets for Nile Tilapia, *Oreochromis niloticus*. J. Applied Aquacult., 1: 89-98.
- Andrew, J.W., M.W. Murray and J.M. Davies, 1979. The influence of dietary fat levels and environmental temperature on digestibility energy and absorbability of animal fat in channel catfish. J. Nutri., 108: 749-752.
- Borghesi, R., L. Portz, M. Oetterer and J.E.P. Cyrino, 2008. Apparent digestibility coefficient of protein and amino acids of acid, biological and enzymatic silage for Nile tilapia (*Oreochromis niloticus*). Aquacult. Nutr., 14: 242-248.
- Cho, E.Y. and S.L. Slinger, 1979. Apparent Digestibility Measurement in Foodstuff for Rainbow Trout. In: World Symposium on Fin Fish Nutrition and Fish Feed Technology, Halver, J.O. and K. Tiews (Eds.), Heinemann, Berlin, Germany, pp: 239-247.
- Davies, S.J., O.A. Fagbenro, A. Abdelwaritho and I. Diller, 1999. Use of soybean products as fishmeal substitute in African catfish, *Clarias gariepinus*. Applied Trop. Agric., 14: 10-19.
- De Silva, S.S. and T.A. Anderson, 1995. Fish Nutrition in Aquaculture. Chapman and Hall, London, UK., ISBN-13: 9780412550300, Pages 319.
- Fagbenro, O.A., 1998. Apparent digestibility of various legume seed meals in Nile Tilapia diets. Short Commun. Aquac. Int., 6: 83-87.
- Fagbenro, O.A., T.T. Akande and O.O. Fapounda, 2003. Use of Roselle (*Hibiscus sabdariffa*) Seed Meal as a Soybean Meal Replacer in Practical Diets for Fingerlings of African Catfish (*Clarias gariepinus*). Proceeding of the 3rd International Conference on African Fish and Fisheries, November 10-14, 2003, Cotonou, Benin, pp: 73-79.

- Halver, J.E., A. Yiman and R.R. Smith, 1993. Acid insoluble ash as a convenient method for estimating digestibility component in diets. Abstracts of Contribution at the International Conference for World Aquaculture, Fresh Water Fish Poster, pp: 230.
- Hasan, M.R., 1986. Husbandry factors affecting survival and growth of carp (*Cyprinus carpio* L.) fry and an evaluation of dietary ingredients available in Bangladesh for the formulation for a carp fry diet. Ph.D. Thesis, Institute of Aquaculture, University of Stirling, Scotland.
- Hossain, M.A. and K. Jauncey, 1989a. Studies on the protein, energy and amino acid digestibility of fish meal, mustard oilcake, linseed and sesame meal for common carp (*Cyprinus carpio* L.). *Aquaculture*, 83: 59-72.
- Hossain, M.A. and K. Jauncey, 1989b. Nutritional Evaluation of Some Bangladeshi Oil Seed Meals as Partial Substitutes for Fish Meal in the Diets of Common Carp, *Cyprinus carpio* L. *Aquacult. Fish. Manage.*, 20: 255-268.
- Hossain, M.A., N. Nahar, M. Kamala and M.N. Islam, 1992. Nutrient digestibility coefficients of some plant and animal protein for tilapia. *J. Aquacult. Tropics*, 7: 256-266.
- Jackson, A.J., B.S. Capper and A.J. Matty, 1982. Evaluation of some plant proteins in complete diets for the tilapia *Sarotherodon mossambicus*. *Aquaculture*, 27: 97-109.
- Jauncey, K., 1993. Advances in freshwater fish nutrition. Proceedings of the Conference on Feed Production Tomorrow II, October 25-26-27, 1993, Vietnam International, Bangkok, Thailand, pp: 16-41.
- Kenan, K. and Y. Ozdemir, 2005. Apparent digestibility of selected feed ingredients for Nile Tilapia (*Oreochromis niloticus*). *Aquaculture*, 250: 308-316.
- Lall, S.P., 1991. Concepts in the formulation and preparation of a complete fish diets. Proceeding of the 4th Asian Fish Nutrition Workshop, (AFNW'91), Asian Fisheries Society, Manila Philippines, pp: 1-12.
- Lanstraat, A., 1976. Characteristics and composition of vegetable oil bearing materials. *J. Am. Oil Chem. Soc.*, 53: 241-247.
- Lim, C. and D. Akinyama, 1992. Full fat utilization of soybean meal by fish. *Asian Fish Sci.*, 5: 181-187.
- Lovell, R.T., 1977. Digestibility of Nutrient in Feedstuffs of Catfish. In: Nutrition and Feeding of Channel Catfish, Stickney, R.R. and R.T. Lovell (Eds.). Alabama Agricultural Experiment Station, Auburn University, Auburn, AL., USA., pp: 33-37.
- Lovell, R.T., 1988. Use of soybean products in diets for aquaculture species. *J. Aquatic Prod.*, 7: 27-52.
- Martinez-Palacios, C.A., C.R. Galvan, M.A. Olivera-Novoa and C. Chavez-Martinez, 1988. The use of Jackbean (*Canavalia ensiformis* Leguminosae) meal as a partial substitute for fish meal in diets for tilapia (*Oreochromis mossambicus* Cichlidae). *Aquaculture*, 68: 165-175.
- Mukhopadhyay, N., 2001. Effect of fermentation in apparent total and nutrient digestibility of sesame (*Sesamum indicum*) seed meal in rohu, *Labeo rohita* (Hamilton) fingerlings. *Acta Ichthyol. Piscat.*, 31: 19-28.
- Olvera-Novoa, M.A., L. Olivera-Castillo and C.A. Martinez-Palacois, 2002. *Aquacult. Res.*, 33: 223-230.
- Phillip, A.M., 1972. Caloric and Energy Measurement in Fish Nutrition. Academic Press, New York and London.
- Robertson, J.A. and R.B. Russel, 1972. Sunflower: America neglected crop. *J. Am. Oil Chem. Soc.*, 49: 239-244.

- Salunkhe, D.K., J.K. Chavan, R.N. Adsule and S.S. Kadam, 1991. World Oilseeds: Chemistry, Technology and Utilisation. Van Nostrand Reinhold, New York, pp: 554.
- Sanz, A., A.E. Morales and M. de la Higuera, 1994. Sunflower meal compared with soybean meal as partial substitutes for fish meal in rainbow trout *Oncorhynchus mykiss* diets-protein and energy utilization. *Aquaculture*, 128: 287-300.
- Siddhuraju, P. and K. Becker, 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.
- Sintayehu, A., E. Matheis, K.H. Meyer-Burgdorff, H. Rosenad and K.D. Gunther, 1996. Apparent digestibilities and growth experiments with tilapia (*Oreochromis niloticus*) fed soybean, cotton seed meal and sunflower seed meal. *J. Applied Ichthyol.*, 12: 125-130.
- Smith, R.R., M.C. Peterson and A.C. Allerd, 1980. The effect of leaching on apparent digestion coefficients in determining digestibility and metabolizable energy of feedstuffs for salmonids. *Prog. Fish-Cult.*, 42: 195-199.
- Stickney, R.R., R.W. Hardy, K. Koch, R. Harrold, D. Seawright and K.C. Massec, 1996. The effect of substituting selected oilseed protein concentrates for fish meal in rainbow trout, *Oncorhynchus mykiss* diets. *J. World Aquacult. Soc.*, 27: 57-63.
- Tacon, A.G.J., 1992. Nutritional fish pathology: Morphological signs of nutrients deficiency and toxicity in farmed fish. FAO fisheries Technical Paper No. 330 FAO, Rome, pp: 75
- Tacon, A.G.J., 1997. Fish meal replacers: Review of antinutrients within oilseeds and pulses-a limiting factor for the aquafeed green revolution? Proceedings of the Workshop of the CIHEAM Network on Technology of Aquaculture in the Mediterranean (TECAM), Jointly Organized by CIHEAM, FAO and IEO Mazarron, Spain, Jun. 24-26, CIHEAM, Apodo, Spain, pp: 153-182.
- Yue, Y.R. and Q.C. Zhou, 2008. Effect of replacing soybean meal with cotton seed meal on growth feed utilization and hematological indexes for juvenile hybrid tilapia, *Oreochromis niloticus* × *O. aureus*. *Aquaculture*, 284: 185-189.