THE UTILIZATION OF COTTON SEED MEAL AS ALTERNATIVE SOURCE FOR FISH MEAL IN PRACTICAL DIET OF TILAPIA

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Abstract: The global aquaculture production has increasing continuously. A balanced nutritional composition of feed is for normal development of farmed fish, ensuring good fish health and generating a healthy product for consumers. Tilapia is one of the important candidate spp. in aquaculture because of its better growth and consumer acceptance and feed on a low trophic level. The cost of fish meal has been increasing constantly, thus making it the most expensive protein source in aquafeed causing the price of commercial fish feed increase sharply. The, continued growth of aquaculture production is fundamentally unsustainable if fish meal remains the primary protein and oil sources used in aquafeed. Cottonseed meal is the residue produced after oil extraction from cottonseed. Cottonseed meal ranks third in tonnage among the plant protein concentrates produced globally. Cottonseed meals are among the most available plant protein sources in the world. Therefore, Cotton seed meal can adequately substitute fish meal in aqua-feeds as the later is scarce and expensive. This review attempts to compile all principal information available regarding the nutritional requirement for tilapia along with the past nutritional studies of the researchers to replace the valuable fish meal with easily available cotton seed meal to sustain the supply of fish meal in near future.

Keywords: Cotton seed meal, Tilapia, Fish meal.

Introduction: The global aquaculture production has increased 12 times during last three decades (1980–2010), which intern has enhanced the demand of aquafeed (FAO 2012). A balanced nutritional composition of feed is for normal development of farmed fish, ensuring good fish health and generating a healthy product for consumers. Tilapia is one of the important candidate spp. aquaculture because of its better growth and consumer acceptance and feed on a low trophic level. The cost of fish meal has been increasing constantly, thus making it the most expensive protein source in aquafeed causing the price of commercial fish feed increase sharply. The, continued growth of aquaculture production is fundamentally unsustainable if fish meal remains the primary protein and oil sources used in aquafeed. Supplies of fishmeal and oil are finite, making it necessary for the aquafeed sector to seek alternative ingredients from plant sources whose global production is sufficient to supply the needs of aquafeeds for the foreseeable future. Thus, there is an urgent need to find alternative protein sources to make up for the shortage of fish meal and to secure a stable supply for commercial diets. Due to the escalating price and unstable supply of fishmeal, numbers of studies have been conducted to replace it by easily available, low cost protein source. Among these alternative protein sources, soybean meal, cotton seed meal etc. appears to be excellent substitution and their utilization in tilapia feed has been increased at a past rate recently.

Cottonseed meal is the residue produced after oil extraction from cottonseed (Hertrampf and Piedad-Pascual, 2000). Cottonseed meal ranks third in tonnage among the plant protein concentrates produced globally (Swick and Tan, 1995). Cottonseed meals are among the most available plant protein sources in the world.

Tilapias are very good aquaculture species particularly because they are omnivorous meaning that they feed on a low trophic level. The primary genus reared for aquaculture is *Oreochromis* which includes Nile Tilapia (*O. niloticus*), Mozambique Tilapia (*O. mossambicus*), and Blue Tilapia (*O. aureus* and *O. urolepis hornorum*) (Fitzsimmons, 1997). *O. mossambicus* was first introduced into the pond ecosystem of India in 1952 and soon it was stocked in the reservoirs of south India (Sugunan, 1995).

World production of tilapia: World tilapia production has been booming during the last decade, with output doubling from 830000 tonnes in 1990 to 1.6 million tonnes in 1999 and to 3.5 million tonnes in 2008 (FAO 2012). China is by far the main tilapia producing country, with 1.1 million tonnes production in 2008. Egypt reported an impressive increase between 2007 and 2008. Production in Indonesia and the Philippines, too, increased significantly during the past decade to over 300 000 tonnes each. Total tilapia production is mainly Nile tilapia (*Oreochromis niloticus*). All new countries entering tilapia production concentrate on this species, which is easy to grow. In 2008, about three quarters of world tilapia production were Nile tilapia.

Protein requirement: Protein requirement of tilapia (2.4-3.50 g) is reported as 30-35% of the diet (Wang *et al*., 1985; Abdelghany, 2000). It is therefore of interest to replace part of fish meal with protein-rich ingredients. Many studies have been conducted to evaluate the replacement of fish meal in practical diets for tilapia with cheap, locally available plant and animal protein sources (Novoa *et al*., 1997; El-Sayed, 1998; Fasakin *et al*., 1999, 2005; Abdelghany, 2003; El-Saidy and Gaber, 2003; Richter *et al*., 2003; El-Saidy and Gaber, 2004; Borgeson *et al*., 2006; Gaber, 2006). Protein requirement of tilapia are shown in Table-1.

Table 1. Protein requirements of cultured tilapia.

Species and life stage	Weight (g)	Protein source	Require ment	References
O. niloticus				
Fry	0.012	FM	45%	El-Sayed & Teshima, 1992
	0.51	FM	40	Al Hafedh, 1999
	0.80	FM	40	Siddiqui *et al*., 1988
Fingerlings	2.4	Casein/Gelat in	35	Abdelghany, 2000a
	3.50	Casein	30	Wang *et al*., 1985
	6.1-16.5	FM	30	De Silva & Radampola, 1990
Broodstock	45-268	FM	30	Al Hafedh, 1999
		FM/SBM	40	El-Sayed *et al*., 2003
		FM	45	Siddiqui *et al*., 1998
		Casein/Gelat in	35-40	Gunasekera *et al*., 1996a,b
O.mossambicus	Fry	FM	40-50	Jauncey, 1982; Jauncey and Ross, 1982
	6-30	FM	30-35	Jauncey & Ross, 1982
O. aureus	0.30-0.50	SBM or FM	36	Davis & Stickney, 1978
	2.50	Casein/albu men	56	Winfree & Stickney, 1981
	7.5	Casein/albu men	34	Winfree & Stickney, 1981
T. zillii	1.35-1.80	Casein	35	Mazid *et al*., 1979
	1.45-1.7	Casein/Gelat in	35-40	El-Sayed, 1987; Teshima *et al*. 1978
O. niloticus X *O. aureus*	145-242	FM+CSM	20	Cisse, 1988
	0.6-1.1	FM	32	Shiau and Peng, 1993
	21	SBM	28	Twibell and Brown, 1998
O. niloticus X *O. hornorum*	1.24	--	32	Luquet, 1989
O. mossambicus X O. hornorum	8.87	--	28	Watanabe *et al*., 1990

Amino acid requirement: The values determined by Jauncey *et al*. (1983) for *O. mossambicus* are lower than those of *O. niloticus* as reported by Santiago and Lovell (1988), except for leucine. Among all of the essential amino acids required by fish in general and tilapia in particular, methionine is often one of the most limiting EAA in feeds. Hence, the determination of methionine or total sulphur amino acid (TSAA, consists of methionine and cystine) requirements of juvenile tilapia is critical to the production of cost-effective feeds. Quantitative essential amino acid requirements of *O. niloticus* and *O. mossambicus* juveniles are shown in Table-2.

Table-2 Amino acid requirement of tilapia

Amino Acid	Requirement			
	O. mossamicus[1]	*O. mossambicus*[2]	*O. niloticus*[3]	*O. niloticus*[4]
Lysine	4.05 (1.62)	3.78 (1.51)	5.12 (1.43)	---
Arginine	3.80 (1.52)	2.82 (1.13)	4.20 (1.18)	4.1
Histidine		1.05 (0.42)	1.72 (0.48)	1.5
Threonine		2.93 (1.17)	3.75 (1.05)	3.3
Valine		2.20 (0.88)	2.80 (0.78)	3.0
Leucine		3.40 (1.35)	3.39 (0.95)	4.3
Isoleucine		2.01 (0.80)	3.11 (0.87)	2.6
Methionine	1.33 (0.53)	0.99 (0.40)	2.68 (0.75)	1.3
Cystine			0.53	2.1
Phenylalanine		2.50 (1.00)	3.75 (1.05)	3.2
Tyrosine			1.79	1.6
Tryptophan		0.43 (0.17)	1.00 (0.28)	0.6

Total sulfur amino acid requirement: Total sulfur amino acid requirement of tilapia can be met by methionine alone or a proper mixture of methionine and cystine (Shiau, 2002). This requirement, expressing as percentage of dietary protein, has been determined for Mozambique tilapia (3.2%: Jackson and Capper, 1982). In Nile tilapia, TSAA requirement in semi-purified diet has been determined by several investigators. However, the reports covered a wide range of values. For example, Santiago and Lovell (1988) determined that TSAA requirement of Nile tilapia fry was 0.9% of the diet (consisted of 0.75% methionine and 0.15% cystine) or 3.22% of dietary protein while Kasper *et al*. (2000) concluded that this requirement for the same species was only 0.5% of the diet or 1.56% of dietary protein. Since Nile tilapia is one of the most popular cultured fish species in the world, feed cost must be reduced as much as possible by using inexpensive and locally available plant and animal protein sources. Quite often, diets formulated from these protein sources are limited in methionine. Consequently we must re-determine TSAA requirement that may allow the use of the feed ingredients that have low levels of methionine. TSAA requirement in semi-purified diet for juvenile Nile tilapia has been re-determined to be 3.04% of dietary protein (Nguyen *et al*., 2009). When TSAA requirement in semi-purified diet for tilapia has been determined, it is also critical to confirm its requirement in practical diet in order to transfer the result to tilapia feed industry. Methionine requirement in practical diet (using soybean meal, cottonseed meal and gelatin as protein sources) of juvenile Nile tilapia was 0.49% of the diet or 1.75% of dietary protein, in the presence of cystine at 0.45% of the diet or 1.61% of dietary protein (Nguyen *et al*., 2009).

Cystine is a non-essential amino acid but required for protein synthesis. Since cystine can only be synthesized metabolically from methionine precursor, its presence in the diets can spare a portion of methionine requirement for maximum growth. Therefore, the determination of replacement value of cystine for methionine in tilapia is also important since we can minimize the incorporated level of methionine in practical diets without reducing biological performance and thus, minimize feed cost. The replacement value of cystine for methionine have been determined for blue tilapia (44%: Liou, 1989) and Nile tilapia (49%: Nguyen *et al*., 2009).

Overview of studies on evaluation of cotton seed meal to replace fish meal in practical diets for tilapia: El-Sayed (1990) investigated the use of cottonseed meal as a protein source for Nile tilapia, *Oreochromis niloticus*. Corticated CSM (CC) and decorticated CSM (DC), with or without crystalline L-lysine supplementation, were incorporated into practical, isocaloric diets containing approximately 30% crude protein. Fish meal (FM)-based diet served as a control. Test diets were fed to triplicate groups of *O. niloticus* (20 g) at a daily rate of 2–3% of their body weight for 130 days. Fish which received FM diet had significantly better percent gain, specific growth rate (SGR), feed conversion (FC) and protein efficiency ratio (PER) than those fed CSM diets. DC diets produced significantly better growth and FC than CC diets, while PER was not significantly different. The addition of crystalline L-lysine to CSM diets did not significantly affect fish performance. Cost/benefit analyses of the test diets indicated that CC was economically the best, followed by DC, while FM diet showed the least economic potential. Middendorp and Huisman (1995) tested two cottonseed cake feeding strategies in pond culture of male Nile tilapia, *O. niloticus,* with the objective of making better use of the algal blooms which develop when cottonseed cake is applied to a pond. It was concluded that cottonseed cake contributed to tilapia growth mainly directly as a tilapia feed rather than indirectly as a pond fertilizer via algal production.

Middendorp (1995) conducted an experiment with tilapia species – catfish species polyculture to estimate the effect of supplementary cottonseed cake on net pond production in ponds already receiving dried cattle manure as basic treatment. Three treatments were tested in duplicate in six earthen ponds of 525 m^2 each; treatment A = daily application of dried cattle manure only (266 kg ha^{-1} day^{-1}); treatment B = daily manure + cottonseed at a nominal daily rate of 3% of tilapia biomass; and treatment C = daily manure + cottonseed cake at 6% of tilapia biomass. Application of dried manure and cottonseed cake was done 6 days per week, and the culture period was 100 days. Fish were sampled every month and feeding rates were adjusted accordingly. Best fish growth was observed in treatment C (male tilapia, 0.9 $gday^{-1}$) although differences between treatments B and C were not significant.

Mbahinzireki *et al.* (2001) tested the suitability of cottonseed meal as a major source of plant protein in feeds for tilapia (*Oreochromis sp*.) by examining growth and feed intake, feed digestibility, liver gossypol concentrations, feed utilization, and body mineral composition. Juvenile tilapia at an initial average size of 11.8 ± 1.6 g were divided into triplicate groups per dietary treatment and offered five different formulated diets. In these feeds fish meal protein was gradually replaced by protein from cottonseed meal (0, 25, 50, 75, and 100%; diets 1, 2, 3, 4 and 5, respectively). Their results indicated that fish meal replacement above 50% resulted in significant growth decline with time. Authors concluded that CSM could partially replace fish meal as a main source of protein in feed for tilapia at not more than 50%. The presence of gossypol in cottonseed meal was identified as the major limiting factor for acceptance and utilization of cottonseed meal-based diets in tilapia farming.

Lin *et al.* (2010) formulated four isonitrogenous (gross protein content 30%) and isoenergetic (gross energy content 15 kJ/g) diets to investigate the effects of inclusion of plant proteins on the hybrid tilapia (*O. niloticus*×*O. aureus*). The plant proteins tested were soybean meal (SBM), rapeseed meal (RSM), cottonseed meal (CSM), and peanut meal (PNM). In each diet, 30% of the protein was supplied by fish meal, and the rest of protein was supplied by the plant protein tested. Each diet was randomly fed to three groups of hybrid tilapia for 8 week in a recirculating freshwater system. The results showed that the best performance in terms of final weight, specific growth rate, feed efficiency ratio, and protein efficiency ratio were shown in soybean meal and cottonseed meal, based diets. The results showed that 39% cottonseed meal may be included in the practical diets without inhibiting fish performance. Although the inclusion of 50% rapeseed meal resulted in significantly lower growth performance, it produced histopathological damage in the liver.

Effects of dietary cottonseed meal protein levels on growth and feed utilization of Nile tilapia, (*O. niloticus*) was studied by Agbo *et al.* (2011). They conducted 56-day trial on Nile tilapia with mean initial weight 4.24±0.20 g, with four isonitrogenous, and isoenergetic test diets in which cottonseed meal protein replaced fish meal (FM) protein at levels of 0% (control), 25%, 50% and 75%. The growth experiment was conducted in plastic tanks in a recirculation system, with each dietary treatment in triplicate. After 56 days of feeding fish at 6% - 4% body weight per day, cottonseed meal protein replacements of 25% and 50% did not significantly affect growth (specific growth rate, weight gain) and feed utilization (feed intake, feed conversion ratio, protein efficiency). The study indicated that cottonseed meal could replace at least 50% of fish meal protein in the diet of *O. niloticus* without adversely affecting growth and feed utilization.

Growth response and feed utilisation in *O. niloticus* fed on cottonseed-based diets was studied by Ofojekwu and Ejike (1984). They conducted 56-day trial, where five different cottonseed-based artificial diets were evaluated against a diet containing fish meal. Fish fed with the fish meal based diet attained 81% weight gain over the experimental period and had the highest feed efficiency. The study indicated that the best growth rates and conversion efficiencies obtained with cottonseed diets were much lower (31% weight gain) fish meal control diet.

Sintayehu *et al.* (1996) conducted apparent digestibility and growth experiments with three oil seed by-products, soybean meal, cottonseed meal, and sunflower seed meal, using tilapia (*O. niloticus*) with an initial average body weight of 93 ± 5 g and 64 ± 1 g, respectively. The diets were formulated on an isonitrogeneous and isoenergetic basis. During the experimental period the fish were fed 1% and 1.5% of their metabolic body weight daily in the digestibility experiment and the growth experiment, respectively. Results of the apparent digestibilities showed that the crude protein, crude fat, as well as the gross energy digestibilities of soybean meal (93.0%, 94.6%, and 77.2%, respectively), were better than those of cottonseed meal (79.4%, 83.2%, and 57.9%, respectively) and sunflower seed meal (89.8%, 82.9%, and 49.3%, respectively). With the exception of the crude protein digestibility, nutrient and gross energy digestibilities of the cottonseed meal were found to be better than that of sunflower seed meal. Fish fed cottonseed meal diet and sunflower seed meal diet showed a relatively better, but not significantly different performance than did the fishmeal control diet.

Gaber (2006) tested the replacement of fish meal protein with dehulled and solvent-extracted plant by-products, soybean meal, cottonseed meal, sunflower meal, and linseed meal in diets for juvenile Nile tilapia, *O. niloticus*. Fish averaging 14.2 ± 2.9 g were divided into 18 groups and fed for 6 months on pelleted feed containing each of the plant protein meal supplemented with *Yucca schidigera* powder extract at 750 mg/kg. Methionine (1%) and lysine (0.5%) were added to each diet except the control diet (FMC), while diet FMC + Y was supplemented with yucca only. Three groups of fish were fed each of six isonitrogenous (25% crude protein) and isocaloric (4.3kcal/g) diets replacing 100% of fish meal protein and performance compared against a nutritionally balanced control and a commercial tilapia feed. After 6 months of feeding, the fish fed plant protein diets supplemented with yucca exhibited growth performance not differing significantly from that of fish fed FMC + Y, while differing significantly from the control FMC and diet linseed meal (LSM).

Cotton seed meal as substitution for fish meal :

Cottonseed meal (CSM) which is a by-product of cotton after fibre and oil production is often used as a component in domestic animal feeds due to its relatively high protein content. Besides being relatively cheap, cottonseed meal contains good protein contents (26-54%, depending on processing methods) and amino acid profile. However, it contains relatively low levels of lysine, cystine and methionine and processing conditions may also have a negative effect on the amino acid content (Lovell, 1998). Crude fibre is a limiting factor in the use of cottonseed meal as feed. It is around 10% in decorticated meals and expellers while its content in corticated meal can exceed 20%. The digestible energy of cottonseed meal is relatively low due to the high crude fibre content (Hertrampf and Piedad-Pascual, 2000). Nutrient Composition of Cottonseed Feed Products on a Dry Matter Basis and Mineral Composition of Cottonseed Feed Products are shown in Table-3 and Table-4 respectively.

Table-3 Nutrient Composition of Cottonseed Feed Products on a Dry Matter Basis:

Item	ME CSM[a]	ES CSM[a]	WCS[a]	DCS[b]	CSH[c]
Dry Matter %	92.3	89.1	91.6	90	89.9
Crude Protein %	46.1	47.6	22.5	25	5
Acid Detergent Fiber %	18.1	17.3	38.8	26	67
Neutral Detergent Fiber %	32.3	24.5	47.2	37	86.9
Crude Fiber, %	11.4	11.2	29.5	17.2	48.6
Ether Extract, %	4.6	2.2	17.8	23.8	1.9
Ash, %	7.2	7.5	3.8	4.5	2.8
Gossypol[de]-Total	1.09	1.16	0.66	-	0.107
Gossypol[de]-Free	0.06	0.14	0.68	-	0.049

Table-4 Mineral Composition of Cottonseed Feed Products:

Item	ME CSM[a]	ES CSM[a]	WCS[a]	DCS[b]	CSH[c]
Calcium %	0.21	0.22	0.14	0.12	0.15
Magnesium %	0.65	0.66	0.35	0.41	0.15
Phosphorus %	1.14	1.2	0.56	0.54	0.08
Potassium %	1.68	1.72	1.14	1.18	1.13
Sodium %	0.0007	0.14	0.0008	0.01	0.0009
Sulfur %	0.43	0.44	0.2	-	0.05
Copper mg/kg	10.9	12.5	7	11	3.6
Iron mg/kg	106	126	50	108	30.1
Manganese mg/kg	18.7	20.1	15	14	16.8
Molybdenumm g/kg	2.4	2.5	1.6	-	0.37
Zinc mg/kg	62.8	63.7	33	36	9.9

Conclusion: Cotton seed meal (CSM), because of its availability, consistent quality, high protein content with good amino acid profile and low cost, is the most studied plant feedstuff in aquaculture diets. However this contents some antinutritional factors like gossypol. Gossypol is a pigment found naturally in many gossypium species including cotton and is located in glands throughout the plant. Gossypol is in the Free State in the whole seed and is bound to lysine or other components during processing into meal. Gossypol bound in this way has generally been considered unavailable to the animal. Animal sensitivity to gossypol is considerably different between species and classes of animals. The amount of free gossypol has been the guide used by many nutritionists to make recommendations on feeding of cottonseed products.

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