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Review Paper

Mini review on Incorporation of Cotton Seed Meal, an Alternative to Fish Meal in Aquaculture Feeds

B. Pavan Kumar [1]*, Kurva Raghu Ramudu [2], B.Chamundeswari Devi [3]

[1] *Fisheries Development Officer, Uppada, A.P., India*
[2] *Scientist (On contractual Basis), Fisheries Research Station, Sri Venkateswara Veterinary University, Kakinada-533 002, A.P., India*
[3] *Principal Scientist & Head, Fisheries Research Station, Sri Venkateswara Veterinary University, Kakinada-533 002, A.P., India*
**Corresponding author E-mail: bpavankumar2@gmail.com*

Abstract

Fish nutrition has advanced dramatically in recent years with the development of new balanced commercial diets that promote best fish growth and health. Feed accounts for a major part (30-70%) of the total operation cost of an average fish farm. Traditionally, animal protein sources, particularly fishmeal have been the major ingredient of aqua feeds. Fishmeal is one of the most expensive ingredients in formulated fish feeds. Due to increasing demand, decreasing supply and the high cost of fish meal, fish nutritionists have concentrated their efforts to find alternative protein sources to substitute fish meal in the diet of fish. Thus, cottonseed meal (CSM), a by-product of the cotton fiber and cottonseed oil industries, may be used to replace fish meal partially or totally in fish diets. However, the cottonseed meal was evaluated by its anti-nutritional factors and its impact on the growth, survival, carcass composition and histopathology of fishes. It is observed that the more research is concentrated on the gossypol content in the cottonseed meal which is described as the anti-nutritional factor that shows high impact on the growth, carcass composition and pathological changes in the fish. Hence, considering these problems it is advised to use low levels of cottonseed meal in the aqua feeds. The gossypol level can be minimized by the solvent extracted cottonseed meal and be counteracted by the fortification of lysine and adding up of required iron levels. Further research may be required in histopathological studies to assess the toxicity levels in the tissues of the fish due to the gossypol factor.

Keywords: *Cotton Seed Meal, Fish Meal, Gossypol.*

1. Introduction

Worldwide aquaculture industry depends on the availability of low cost, high quality feeds. Due to increasing demand, decreasing supply and the high cost of fishmeal, fish nutritionists have concentrated their efforts to find alternative sources of proteins to substitute fishmeal in the diet of fish. However, interrelationships between nutrition, immunity and disease resistance in fish are poorly understood. Feed costs have been identified as an important constraint for the aquaculture development. Coyle et al. (2004) reported that feed costs account for more than 50% of total production costs in aquaculture because of the use of the expensive protein source, fishmeal. Many studies have been conducted to search for less expensive protein sources to replace fishmeal.
Plant proteins are widely used in feeds for aquaculture species. Global availability and relatively low cost compared to ingredients of animal origin and their most obvious positive attributes. Properly processed plant products and by-products generally also have the high protein digestibility. They can often be used in combination to replace more expensive ingredients like fishmeal without exception. Robinson and Li (1994) recommended that plant proteins can be used as a total replacement for animal protein without detrimental effects. Protein of plant origin is preferred as compared to animal origin protein in the culture of carps (Singh et al. 2004). Complex mixture of plant ingredients can serve as a replacement for fishmeal (Borgeson et al. 2006). Hardy (2006) reported that dietary replacement of fishmeal by plant origin by-products, such as soybean meal, cottonseed meal and rapeseed meal has been increasing in the aquaculture industry because of their low price, high market availabilities and sufficient protein contents.

2. Cotton seed meal

Cottonseed, *Gossypium hirsute* Linnaeus, is the third leading plant protein by weight (after soybean and rapeseed) used worldwide (Gatlin et al. 2007) and is available at relatively lower cost than animal proteins (Lovell 1989). According to National Cottonseed Production Association (NCPA) 450 Kgs of cottonseed meal can be extracted from a ton of cottonseed crushed. Cottonseed meal can be obtained in two methods from cottonseed; one is through mechanical and the other by solvent extraction. However, the meal extracted from the both crude protein must contain not less than 36 percent (Blasi and Drouillard 2002) and the Proximate Composition of Cottonseed meal is showed in table. 1 (NRC, 1993).
Owing to its high protein value for human consumption (Alford et al. 1996) and animals, as well as low market price in comparison with other legumes and fishmeal, cottonseed meal (CSM) consequently has an immense potential for incorporation in high-protein aqua feeds (Gatlin et al. 2007). Nutritionally, cottonseed meal contains high levels of proteins (Forster and Cahloun 1995) and is very palatable to fish (Robinson and Li 1995).
The amount of CSM that can be included in feeds depends on the animal species, developmental stages, dietary protein, available

lysine (Martin 1990) and levels of anti-nutritional factors. The level of cottonseed meal inclusion in fish varies widely among fish species such as tilapia, *Sarotherodon mossambicus* (Jackson et al. 1982), *Oreochromis niloticus* (Ofojekwu and Ejike 1984; El-Sayed 1990; Rinchard et al. 2000; Mbahinzireki et al. 2001), Channel catfish, *Ictalurus punctatus* (Dorsa et al. 1982; Robinson et al. 1984b; Robinson and Brent 1989; Robinson and Li 1994; Robinson and Tiersch 1995), Chinook salmon, *Oncorhynchus tshawytscha* and Coho salmon, *Oncorhynchus kisutch* (Fowler 1980), Rainbow trout, *Oncorhynchus mykiss* (Dabrowski et al. 2000a,b; Dabrowski et al. 2001; Blom et al. 2001) and *Labeo rohita* (Usmani et al. 1997).

Table 1: Proximate Composition of Cottonseed Meal According to National Research Council (NRC). (NRC, 1993).

Proximate Composition of Cottonseed meal Solvent Extracted	
International Feed Number 5-01-619	
Typical Dry Matter	92%
Crude Protein	41.7%
Crude Fat	1.8%
Crude Fat	11.3%
Ash	6.4%
Amino Acid Composition	
Arginine	3.97%
Histidine	0.83%
Isoleucine	1.15%
Leucine	1.8%
lysine	1.8%
Methionine	0.5%
Cystine	0.45%
Phenyl alinine	2.1%
Tyrosine	0.8%
Threonine	1.02%
Tryptophan	0.42%
Valine	1.68%
Mineral Composition	
Calcium (%)	0.17
Phosphorus (%)	1.17
Potassium (%)	1.39
Chlorine(%)	0.04
Magnesium (%)	0.41
Sodium (%)	0.04
Sulphur (%)	0.30
Copper (mg/kg)	19.00
Iron (mg/kg)	208.0
Magnesium (mg/kg)	21.0
Selenium (mg/kg)	0.06
Zinc (mg/kg)	61
Vitamin Composition	
Biotin	0.97mg/kg
Choline	2764 mg/kg
Folacin	1.4 mg/kg
Niacin	41 mg/kg
Pantothenic acid	13.7 mg/kg
Pyridoxine	7 mg/kg
Riboflavin	3.3 mg/kg
Thiamine	6.6 mg/kg
Vitamin B12	-
Vitamin E	16 mg/kg
Vitamin K	-

3. Anti-nutritional factors

The presence of anti-nutritional factors such as phytic acid, gossypol and cyclopropenoid acid limits the utilization of cottonseed meal in aquaculture diets.

3.1. Phytic acid

About 70 % of the phosphorous in feedstuffs of plant origin is in the form of phytate, and its availability to fish is negligible (Ketola 1985). Phytates act as strong chelators and form protein-phytic acid complexes that may reduce the bio-availability of protein (Spinnelli et al. 1983) and minerals, such as zinc, manganese, copper, molybdenum, calcium, magnesium, and iron (Smith 1977).

3.2. Cyclopropenoic fatty acids

Cottonseed meal is the primary source of the cyclopropenoic fatty acids (CFAs) (sterculic acid and malvalic acid) in fish diets. CFAs are present in all varieties of cottonseed meal and are not completely removed by the oil extraction process (Mickelsen and Yang 1966). Dietary CFAs caused lesions, increased glycogen deposition, and elevated saturated fatty acid concentration in the liver in rainbow trout (Struthers et al. 1975a, b). The CFAs are powerful carcinogens when fed in combination with aflatoxins for rainbow trout (Hendricks et al. 1980) and sockeye salmon (Wales and Sinnhuber 1972). These compounds also induced hepatomas without aflatoxins in rainbow trout (Hendricks et al. 1980). Dietary CFAs alter the activity of several liver enzymes (Eisele et al. 1983), including the inhibition of fatty acid desaturases (Roehm et al. 1970) which may explain the accumulation of saturated fatty acids found in the liver of fish fed CFAs.

3.3. Gossypol

Many studies have showed that the amount of cottonseed meal (CSM) that can be used in fish feed depend mainly on the level of dietary free gossypol and available lysine content (Jones 1987; Robinson and Li 1994). CSM contains gossypol, a yellow cottonseed gland pigment, which is toxic to fish (Herman 1970; Rinchard et al. 2000) and terrestrial animals (Colin-Negrete et al. 1996) leading to a restriction of its use as a feed ingredient. Gossypols are polyphenols, present in the pigment glands of plants, mostly confined to the genus *Gossypium* (FAO 1983; Francis et al. 2001). The amount of gossypol in cottonseed varies according to the cotton species and certain environmental factors (Boatner et al. 1949; Cherry et al. 1978). Gossypol is available in either bound or free form; the bound form being non-toxic and of little significance since it is unavailable and passes through the gastro-intestinal tract unabsorbed (Evans 1985 and Tanksley 1990) but the free form is highly toxic (Ogunji 2004).

A dietary level of 0.03% free gossypol suppressed growth rate and a level as low as 0.01% caused liver damage in rainbow trout (Herman 1970). Growth depression occurred in channel catfish fed diets containing more than 900 mg free gossypol/kg diet (Dorsa et al. 1982). However, some fish species can tolerates higher gossypol concentrations, for instance tilapia has been fed up to 0.18% free gossypol with no adverse effect (Lovell 1998). CSM with low levels of gossypol performed excellently when fed to *Oreochromis mossambicus* (Jackson et al. 1982).

Gossypol appears to have detrimental effects on growth and feed efficiency parameters. Free gossypol is reported to be a membrane-active agent with cytocidal properties and the ability to inhibit membrane bound enzymes, causing hemolytic anemia at high concentrations (Makinde et al. 1997). Feeding diets containing gossypol causes negative effects, such as growth depression, intestinal and other internal organ abnormalities (Berardi and Goldblatt 1980). Gossypol has been shown to affect growth, feed intake, reproductive efficiency, erythrocyte numbers and oxygen-carrying activity, respiration efficiency, and liver function (Lindsey et al. 1980 and Brocas et al. 1997). The toxic systemic effects of gossypol include reduced hematocrit, hemoglobin, reproductive capacity as well as lesions in liver, kidney, spleen and gonads in various fish species have been documented but the mechanisms behind the reduced growth and nutrient digestibility's are unknown (Anon 2009).

Gossypol can be partially or totally inactivated by heat treatment (Herkelman et al. 1991; Bollini et al. 1999; Elmaki et al. 2007), soaking (Rani and Hira 1993; Duhan et al. 2002; Elmaki et al. 2007), fermentation (Marfo et al. 1990; Antai and Nkwelang 1998) or supplementation of diets with enzymes hydrolysing specific antinutrients (Southern et al. 1990; Sandberg and Svanberg 1991; Cheng and Hardy 2002; Portz and Liebert 2004; Sajjadi and Carter 2004), amino acids (Li and Robinson 1998; Fagbenro 1999) or minerals (Jones 1987; Martin 1990; El-Saidy and Gaber 2004). The amount of free gossypol in cottonseed meal depends upon processing (Lovell 1981). During processing, free gossypol is bound to cottonseed protein resulting in bound gossypol and unavailable amino acids. This binding reduces the protein quality, especially regarding to lysine availability. Lysine is believed to be the primary amino acid that is bound to free gossypol (Kuiken and Lyman 1948; Baliga and Lyman 1957; Conkerton et al. 1957). It is observed that supplementation of the Iron, as ferrous sulphate, has been used to bind with the toxic free gossypol and thereby reduce the toxicity for monogastric animals (Jones 1987; Martin 1990) and fish (Sealey et al. 1997; Barros et al. 2002). El-Saidy and Gaber (2004) observed improved growth, feed utilization, and blood parameters among fish fed a CSM diet containing 1:1 iron to free gossypol than among fish fed a CSM diet without iron supplementation. High levels of supplemental iron used to counteract the toxicity of gossypol may be harmful to fish because it has been suggested that a delicate balance exists between the need of iron for host defense mechanisms and the need of iron to sustain microbial growth (Barros et al. 2002). The effect of gossypol concentration studied by Lim and Lee (2008) supports the notion that lysine and iron supplementation into CSM containing diets reduce gossypol toxicities in fish (Robinson 1991; Robinson and Li 1994; Dabrowski et al. 2000a,b; Lee et al. 2006). Noteworthy is that acetone extraction apparently decreases gossypol and aflatoxin levels in the cottonseed meal more efficiently than hexane extraction and results in improved crude protein and amino acid digestibilities (Cheng and Hardy 2002). Yet the authors suggested a maximum inclusion level of 10% of acetone extracted cottonseed meal in diets for rainbow trout.

However, gossypol also has several desirable properties, including anti-parasitic, anti-bacterial, anti-viral, and antioxidant properties (Bickford et al. 1954; Margalith 1967; Montamat et al. 1982; Wichman et al. 1982 and Heidrich et al. 1983). Gossypol or other compounds present in CSM may have a beneficial effect by improving the immune response and the resistance of juvenile channel catfish against *Edwardsiella ictaluri* infection as evidence by increase in macrophage chemotaxis, improved survival and continued consumption of diets containing CSM (Barros et al. 2002). The Commission of the European Communities limits the amount of free gossypol in feed materials (with the exception of cottonseed, cottonseed meal and cottonseed cakes) at 20 mg kg^{-1} which did not cause reductions in growth and nutrient digestibility. However, the limits for cottonseed and cottonseed meal are 5,000 mg kg^{-1} and 1,200 mg kg^{-1}, respectively (Anon 2009). The inclusion of cottonseed meal can be evaluated by the growth, survival, carcass composition and histopathology of fishes.

4. Growth

The term growth will signifies change in magnitude. The variables undergoing change may be the length or other physical dimensions, including volume, weight, or mass either of an organism's whole body or its various tissues or it may relate to lipids, protein content, or other chemical constituent of the body (Weatherly and Gill 1987).

The growth and feed conversion ratio (FCR) of a fish is remarkable tool to compute the acceptability of artificial feed. Barros et al. (2002) reported that the cottonseed meal (CSM) has a lower nutritional value than soybean meal (SBM), but CSM has some other important advantages such as lower FCR. This better performance might be attributed to its higher fibre quality. Sahzadi et al. (2006) suggested that cottonseed meal, because of growth performance and better FCR (2.17) can be included in the feed for hybrid fingerlings (*Catla catla* x *Labeo rohita*). Gui et al. (2010) studied on weight gain, food conversion ratio (FCR) and total tract apparent digestibility (CTTAD) of the crucian carp (*Carassius auratus gibelio*) and observed a positive effect on growth and feed utilization when cottonseed meal hydrolysate (CMH) was used. They suggested that an approximate supplementation of CMH in practical diets is up to 50g/kg. Usmani et al. (1997) observed that inclusion of glanded cottonseed meal more than 5.41% in the diet resulted in depressed growth in rohu, *Labeo rohita*.

The literature available on the effects of feeding CSM to tilapia is contradictory. Ofojekwu and Ejike (1984) reported a much lower weight gain and feed efficiency of *Oreochromus niloticus* fed with cottonseed cake diet compared with fishmeal based diet. Robinson et al. (1984a) reported that neither glanded nor glandless cottonseed meals appeared to be as high in nutritive value for *Tilapia* sp. as soybean and peanut meals. However they reported that tilapia can tolerate gossypol acetate supplemented to purified diets up to 0.2% with no decrease in growth. Jackson et al. (1982) obtained good growth of tilapia (*Sarotherodon mossambicus*) when 35.2% prepressed, solvent extracted CSM (0.03% free gossypol) was used as a substitute for 50% of fishmeal protein. Viola and Zohar (1984) found that low gossypol cottonseed meal could be included in feeds for hybrid tilapia *Oreochromis niloticus* x *Oreochromis aureus* at the same levels as soybean meal. El-Sayed (1990) demonstrated that CSM could be used as a main dietary protein source for *Oreochromis niloticus*. Mbahinzireki et al. (2001) recommended that CSM can partially replace FM as a main source of protein in feed for tilapia at not more than 50%. Yue and Zhou (2008) conducted experiment on *Oreochromis niloticus* x *O.aureus* for replacement of soybean meal with cottonseed meal. They revealed that up to 60% of SBM could be replaced by CSM without causing a significant reduction in growth. Rinchard et al. (2002) recommended that CSM can be replaced up to 50% of fishmeal protein without compromising growth of tilapia. Nelson (2008) reported cost effectiveness of the diets containing mixtures, particularly those containing equal proportions of oilseed meals and higher proportion of CSM replacing between 50 to 75% fish meal protein. Based on growth performance, nutrient utilization and economic benefits the diet with heat processed oilseed meal mixtures (containing equal proportions of soybean meal, cottonseed meal and groundnut cake 16.67% each) at 50% inclusion has the best prospects for replacing FM protein in diets of *Oreochromis niloticus*.

Numerous studies have been conducted to determine the level of cottonseed meal that can be incorporated in channel catfish diets without affecting their growth performance (Dorsa et al. 1982; Robinson and Rawles 1983; Robinson et al. 1984a; Robinson and Daniels 1987; Robinson and Li 1994; Robinson and Tiersch 1995). Dorsa et al. (1982) recommended that glanded cottonseed meal should not exceed 12 to 15% of catfish diets. Robinson and Brent (1989) recommended that cottonseed meal can be used as partial substitute for soybean meal in catfish diets. They also suggested that cottonseed meal be limited to 15% of the catfish diet. Robinson and Li (1994) observed that cottonseed meal plus lysine can be used as total substitute for soybean meal in catfish diets. However it is not recommended that not more than 30% cottonseed meal be used in catfish feeds. Although solvent extracted SBM and CSM are often reported safe for fish, Toko et al. (2008) recommended that CSM and SBM can only partially replace fishmeal as a source of protein in compound feed for vundu catfish, *Heterobranchus longifilis* at a limited amount between 300 and 600g/kg for SBM and <300g/kg for CSM.

Fowler (1980) demonstrated that up to 34% of CSM can be used in the diet for two Pacific salmon species (Chinook salmon and Coho salmon) to replace SBM without growth depression. Cheng and Hardy (2002) reported that the acceptable level of CSM inclusion in the ration of juvenile rainbow trout should not be higher than 10% and they suggested that substitution of SBM by CSM more than 55% could result in reduced weight gain. Lee et al. (2002) suggested that CSM can be used as a good protein source by the incorporation of at least 15% in diets (25% protein of fishmeal as a replacement). Lee et al. (2006) concluded that high dietary supplementation of CSM up to 58.8/100g or its complete substitution for FM did not have detrimental effects on growth of rainbow trout brood stock. Dadgar et al. (2009) observed that Iranian CSM did not negatively affect weight gain (WG) even at 100% replacement for SBM and suggested that Iranian CSM can be included in the rainbow trout diet up to 310 g/kg. However Luo et al. (2006) stated that fish fed with diet with solvent extracted cottonseed meal at 100% level had significantly lower weight gain, specific growth rate, feed conversion efficiency and protein efficiency ratio than fish fed with other diets. They also recommended that solvent extracted cottonseed meal can be utilized in the juvenile rainbow trout diet up to 305g/kg to replace about 50% of fishmeal protein. Blom et al. (2001) recommended that CSM could be a suitable alternative for partial replacement of FM and SBM and it can totally replace them if used with supplementary lysine.

Lim and Lee (2008) concluded that the mixture of cottonseed with iron and phosphorus supplementation can be replaced up to 40% fishmeal protein in diets for olive flounder, *Paralichthys olivaceus*. However based on the tendency in growth performance, they suggested 30% of fishmeal protein replacement by CSM with supplementation of iron and phosphorus might be a safe level for commercial use. They also suggested that dietary supplementation of iron and phosphorus could increase the inclusion of CSM for fishmeal replacement in diets for marine fish species. In the same species Pham et al. (2007) shows that mixture of CSM and SBM with lysine and methionine supplementation can replace up to 30% fishmeal protein in diet for olive flounder at the early juvenile stage. However, they suggested that 20% fishmeal protein replacement by CSM (10%) and soybean meal (10%) can be optimum level as per the growth performance is considered. Lim and Lee (2009) concluded that the mixture of CSM and SBM with lysine and methionine supplementation can replace up to 20% fishmeal protein in diets for juvenile (3-22g) parrot fish, *Oplegnathus fasciatus*. In growing (55 to 120g) parrot fish, fishmeal protein can be replaced up to 30% with CSM and SBM protein. They suggested up to about 30% fishmeal protein can be replaced by an equal mixture of CSM and SBM with iron and phytase in the presence of lysine and methionine in practical diets for parrot fish.

5. Carcass composition

Body composition is a good indicator of the physiological condition of a fish but it is relatively time consuming to measure. Proximate body composition is the analysis of water, fat, protein and ash contents of fish. Carbohydrates and non-protein compounds are present in negligible amount (Cui and Wootton, 1988). The percentage of water is a good indicator of its relative contents of energy, proteins and lipids. Dempson et al. (2004) reported that lower the percentage of water, greater the lipids and protein contents and higher the energy density of the fish. However, these values vary considerably within and between species, size, sexual condition, feeding, season and physical activity. Protein content, which is an important component, tends to vary little in healthy fish (Weatherly and Gills 1987).

Plant based feeds significantly raises the protein and fat levels in the carcass composition of major carps (Nandeesha et al. 1995). Both animal and plant based diets lower the moisture level (Nandeesha et al. 2002) and do not show prominent effects on ash contents (Garg et al. 2002). In Atlantic cod, phosphorus supplementation in plant protein based diets could replace 50% dietary FM without growth impairment (Albrektsen et al. 2006).

According to Usmani et al. (1997) the analysis of body composition of *Labeo rohita* revealed that the crude protein and ash content did not vary among the fish groups receiving various levels of cottonseed meal in the diet. Fat and moisture, however, showed a gradual decline in fish beyond 5.41% dietary cottonseed meal inclusion. Gui et al. (2010) observed no marked differences in the contents of lipid and ash in the body composition of crussian carp in all groups fed with cottonseed meal hydrolysate at different levels. Furthermore, the contents of Zinc and Fe increased in fish fed 50g/kg cottonseed meal hydrolysate and 100g/kg cottonseed meal hydrolysate. Toko et al. (2008) observed the whole body content of calcium (Ca), phosphorus (P), potassium (K), zinc (Zn) and manganese (Mn) were markedly affected by dietary SBM level at high inclusions while increasing dietary CSM did not affect the content of these elements in carcass. Pham et al. (2007) recommended that replacement of fishmeal protein up to 40% level by cottonseed meal and soybean meal by equal proportion with L-methionine and L-lysine supplementation did not affect the whole body compositions of Japanese flounder, *Paralichthys olivaceus*.

6. Histopathology

Although toxicant impairs the metabolic and the physiological activities of the organism, physiological studies alone do not satisfy the complete understanding of pathological conditions of tissues under toxic stress. Hence, it is useful to have an insight into histological analysis, as they act as biological markers to assess the toxicity condition (Rao et al. 1985; Tilak et al. 2001; Srivastava et al. 2008).

Evans et al. (2010) observed in their study and also those by Herman (1970) and Barros et al. (2000) that inclusion of gossypol in the diet had no statistically significant effect on liver glycogen deposition. Herman (1970) observed liver necrosis in rainbow trout fed diets containing gossypol. Barros et al. (2000) observed pancreas and liver necrosis in catfish fed diets of control or 55% CSM and suggested that more research was required to determine whether the components of CSM could cause necrosis. Roehm et al. (1967) reported that the amount of total and free gossypol were the highest in liver than in any other tissue determined in rainbow trout.

Yildirim et al. (2003) studied on the histological and histochemical changes among juvenile channel catfish, *Ictalurus punctatus*, fed purified diets containing graded levels of gossypol from gossypol–acetic acid. They observed that feed intake, feed efficiency, weight gain, whole body lipid and protein, red blood cell (RBC) counts, haemoglobin, hematocrit and serum protein decreased with increasing dietary gossypol concentration. Whole body moisture, body ash, hepatic gossypol concentrations and serum lysozyme activity were increased with increasing dietary gossypol and superoxide anion production and survival were not affected by dietary gossypol. Macrophage chemotaxis was lower for all gossypol fed fish than controls.

7. Conclusion

Cottonseed meal is a high level protein source and economically viable for including it in the aqua feeds. However, there are some detrimental effects observed in inclusion of CSM, It is obvious that the answer is not for the complete removal of CSM in the inclusion of aqua feeds since, the higher protein level and good economic viability. Hence, it is recommended that low level of CSM can be included in the aqua feeds. Besides, fortification of lysine and adding up of required iron level would increase the inclusion of CSM. Moreover it is advised to use the solvent extracted cottonseed meal rather than the glanded cottonseed meal since, the gossypol level is low and protein level is high than the latter. Apart from the physiological index of fish, impact of toxicity from the components of cottonseed meal can be understood by the pathological studies. More research is required in this aspect to know the requirement of the cottonseed meal in the diets of fishes.

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