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Review Article

Nutritive and Feeding Value of Cottonseed Meal in Broilers – A Review

Govindasamy Thirumalaisamy[1*], Manikam Ragavan Purushothaman[2], Periyannan Vasantha Kumar[2], Palanisamy Selvaraj[3], Amirthalingam Natarajan[4], Subramaniyan Senthilkumar[2], Pasuvalingam Visha[3], Dhinesh Kumar Ramasamy[1], Thulasiraman Parkunan[1]

[1]ICAR – National Dairy Research Institute, Karnal, India; [2]Department of Animal Nutrition; [3]Department of Veterinary Physiology; [4]Animal Feed Analytical and Quality Assurance Laboratory, Veterinary College and Research Institute, Namakkal, TANUVAS, India.

Abstract | Cottonseed meal (CSM) is a by-product from cotton oil extraction industry. The protein content of CSM varies depending on the extent of hulling and the oil extraction process. Modern cottonseed processing industries are equipped to decorticate cottonseed and hence the meals obtained are higher in protein and lesser in fibre than the undecorticated cottonseed meal. CSM had low calcium (0.15 - 0.25%) and high total phosphorus (0.95 - 1.71%), essential amino acids like lysine (1.76 - 2.13%), threonine (1.24 - 1.58%) was lower and comparable methionine (0.48 - 0.78%) when compared to conventional protein source *viz.*, soybean meal (SBM). Similarly the mean digestibility coefficient of essential amino acids, dry matter digestibility and nitrogen retention was found to be lower. Gossypol is an anti-nutritional factor that decreases the utilization CSM. The total and free gossypol content of CSM as reported by various authors varied from 1.16 – 1.52 and 0.024 – 0.82 percent respectively. Various studies showed that CSM inclusion in broilers has improved feed intake, body growth and carcass characters. Gossypol binds with epsilon group of lysine, it unavailable to the bird's utilization and also bind with free iron in the plasma, it causes anaemia, while supplementation of synthetic lysine, iron supplementation has improved blood biochemical profile and their performance. CSM inclusion reduces the cost of feed when compared to other conventional protein sources. Comparatively few researches on the utilization of CSM in poultry nutrition have been undertaken. In this review, the chemical composition, nutrient and feeding value of CSM in poultry are discussed.

Keywords | Cottonseed meal, Lysine, Iron supplementation, Growth performance, Cost effectiveness

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***Correspondence** | Thirumalaisamy G, ICAR – National Dairy Research Institute, Karnal, India; **Email:** nutritionthirumalai@gmail.com
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The worldwide competitiveness of the poultry industry requires finding alternative to major feed ingredients used in broiler feeding to reduce the cost of feeding (Batonon-Alavo et al., 2015; 2016). Soybean meal is a major protein source, corn and wheat grains are energy source used in the least cost feed formulation for poultry (Ravindran, 2013a). The gap between local supply and demand for these major feed ingredients is expected to widen over the coming decades (Ravindran, 2013b). A strong increasing trend and high variation prices of conventional protein sources have been observed in the most recent years.

Cotton is one of the principal cash crops of India and plays a vital role in the country's economic growth by providing substantial employment and making significant contribution to export earnings. Cotton is the fourth largest oil crop in the world, after soybean, rapeseed and oil palm. The production of cottonseed in India has increased from 3.3 million metric tonnes (MMT) in 2000 to 12.29 MMT in 2013. In 2013, India ranked second in cottonseed production after China (12.62 MMT) (FAO, 2014).

The major products arising from cottonseed processing are

Table 1: Proximate principles (in per cent) of Cottonseed meal (CSM) *vs* Soybean meal (SBM)

	SBM					CSM					
	NRC (1994)	NRC (1994)	NCPA (2002)	Sterling et al. (2002)	Watkins et al. (2002)	Sahin et al. (2006)	Tang et al. (2012)	Salas et al. (2013)	Sun et al. (2013)	Zotte et al. (2013)	Thirumalaisamy et al. (2015)
Dry Matter (%)	89.00	90.00	89.10	90.5	91.36	90.00	88.23	-	87.20	91.90	89.86
Crude Protein(%)	44.00	41.40	47.60	44.00	44.96	26.00	46.52	50.67	46.20	30.90	39.02
Crude Fibre (%)	7.00	13.60	11.20	-	10.03	25.00	10.21	12.88	-	26.20	11.92
Ether Extract (%)	0.80	0.5	2.20	7.18	1.46	8.00	1.08	1.94	1.09	0.60	3.07
Total Ash (%)	-	-	7.50	-	6.53	5.50	6.02	9.46	-	6.03	7.15
Total gossypol	-	-	1.16	-	-	-	-	1.52	-	-	2.62
Free gossypol	-	-	0.140	0.024	0.130	0.080	0.820	0.160	-	0.082	0..40
*NDF (%)	-	-	17.30	-	-	-	-	-	-	49.20	-
*ADF (%)	-	-	24.50	-	-	-	-	-	-	33.40	-

***NDF:** Neutral detergent fibre; **ADF:** Acid detergent fibre

cottonseed oil (16%), cottonseed hulls (26%), CSM (45.5%) and linters (8.5%) (O'Brien et al., 2005). Increase in cottonseed production in India has resulted in a greater availability of CSM which is the common protein source for livestock in cotton producing areas. The main limitation of the use of cottonseed meal for poultry is the presence of anti-nutritional factors (ANF) *viz*., gossypol and cyclopropenoid fatty acids (CPFA) (Nayefi et al., 2014; 2015). Free gossypol is toxic and chemically reactive. When free gossypol covalently binds to amino acids mainly lysine, it becomes non-toxic and is known as bound gossypol. The availability of lysine in CSM is lower because the free gossypol binds with lysine in meal during processing resulting in bound gossypol (Mahmood et al., 2011). Also having high fibre content (NCPA, 2002), relatively low protein digestibility (Zaboli et al., 2011) and poor protein quality (Sahin et al., 2006; Zotte et al., 2013). The availability of large quantities of CSM at cheaper price has attracted poultry entrepreneurs to use this material as an alternative protein source for broilers (Heuze et al., 2013).

In recent year's demand of animal protein have been increased for human consumption, simultaneously the cost of conventional feed ingredients also drastically increased. It hypothesized alternative protein source (CSM) inclusion has reduces the cost of feed when compared to other conventional protein sources. Comparatively few researches on the utilization of CSM in poultry nutrition have been undertaken. In this review, the chemical composition, nutrient and feeding value of CSM in poultry are discussed.

NUTRIENT CONTENT OF COTTONSEED MEAL

The crude protein (CP) of CSM as reported by various authors varied from 26 to 50.67 %. The low CP in CSM (26 and 30.90%) as reported by Sahin et al. (2006) and Zotte et al. (2013) also had high crude fibre (CF) (25 and 26.20%) in undecorticated CSM. But when it decorticated increased the CP content up to 50 per cent and lowered the CF (11.92%) content (NCPA, 2002; Mishra et al., 2015; Thirumalaisamy et al., 2015).

CSM had low calcium (0.15 - 0.25%) and high total phosphorus (0.95 - 1.71%) i.e Ca: P in the ratio of 1:6 when compared to soybean meal (SBM) which contained 0.36 and 0.66 per cent of calcium and total phosphorus (1:2), respectively. Also CSM had low lysine (1.76 - 2.13% *vs* 2.69%), threonine (1.24 - 1.58% *vs* 1.72%) and comparable methionine (0.48 - 0.78% *vs* 0.62%) when compared to SBM. The proximate principles, mineral profile and critical amino acids content of cottonseed meal are presented in the Table 1, 2 and 3, respectively.

GOSSYPOL CONTENT OF COTTONSEED MEAL

Total and free gossypol content of CSM varied from 1.16 – 1.52 and 0.024 – 0.82 per cent respectively (NCPA, 2002; Salas et al., 2013; Tang et al., 2012). Gossypol concentration is mainly controlled by the genetics of the cotton plant (Percy et al., 1996), but it also influenced by growing conditions, high temperatures throughout the development and maturation period depressed the gossypol content (Stansbury et al., 1956) and method of oil extraction process. The solvent extracted CSM had higher level (0.1 – 0.5%) of free gossypol when compared to mechanical (0.02 – 0.05%), pre-press solvent (0.02 – 0.07%) and when expanders were used in the solvent process (0.06 – 0.1%) (Calhoun et al., 1989).

NUTRIENT UTILIZATION

The mean digestibility coefficient of essential amino acid in

Table 2: Mineral Profile of CSM *vs* SBM

	SBM		CSM						
	NRC (1994)	NRC (1994)	NCPA (2002)	Sahin et al. (2006)	Tang et al. (2012)	Salas et al. (2013)	Sun et al. (2013)	Zotte et al (2013)	Thirumalaisamy et al (2015)
Calcium (%)	0.36	0.15	0.22	0.24	0.25	0.24	0.25	0.24	0.22
Total Phosphorus (%)	0.66	0.95	1.20	1.10	1.11	1.71	1.21	0.79	1.16
Copper (mg/kg)	22.00	18.00	12.50	-	-	-	-	-	9.88
Iron (mg/kg)	120.00	110.00	126.00	-	-	-	-	-	120.00
Manganese (mg/kg)	29.00	20.00	20.10	-	-	-	-	-	58.30
Zinc (mg/kg)	40.00	70.00	63.70	-	-	-	-	-	61.00

Table 3: Amino acid composition (as per cent of protein) of CSM *vs* SBM

	SBM	CSM					
	NRC (1994)	NRC (1994)	NCPA (2002)	Sterling et al. (2002)	Watkins et al. (2002)	Tang et al. (2012)	Sun et al. (2013)
Lysine %	2.69	1.76	1.96	1.95	1.97	2.13	2.07
Methionine %	0.62	0.51	0.78	0.75	0.72	0.56	0.48
Threonine %	1.72	1.34	1.58	1.46	1.31	1.45	1.54

CSM was found to be 67 per cent which was lower than SBM (91.67%). The digestibility coefficient of three critical amino acids for broilers namely lysine, methionine and threonine were found to be 65, 72 and 64 per cent in CSM and the corresponding values for SBM were 93, 94 and 88 per cent (Fernandez et al., 1995). Similarly, Salas et al. (2013) reported the mean digestibility of essential amino acid of CSM as 72.03 per cent and digestibility of lysine, methionine and threonine were 64.6, 76.6 and 74.9 per cent, respectively.

The study of Shrivastav et al. (2003) also confirmed that the nitrogen retention was reduced (0.939 *vs* 1.036 g/bird/day) when CSM was used at 10 per cent level in place of soybean meal but the dry matter digestibility was comparable. However, Elangovan et al. (2006) reported that the nitrogen retention and dry matter digestibility coefficient of diet containing CSM at 10 per cent level was comparable to CSM free diet.

EFFECT OF COTTONSEED MEAL FEEDING ON PRODUCTION PERFORMANCE OF BROILERS

Watkins et al. (1993) incorporated low free gossypol containing CSM in isocaloric and isonitrogenous broiler diet at the level of 0, 10, 20 and 30 per cent. They observed comparable weight gain but feed intake was increased (3826 *vs* 3689g) in 30 per cent CSM group and feed conversion ratio (FCR) was poor (1.86 *vs* 1.75) when the level of CSM exceeds 10 per cent. However, Abdulrashid et al. (2013) reported CSM can be used up to 30 per cent in broiler diet without affecting weight gain, feed intake and FCR.

Ojewola et al. (2006) replaced SBM with CSM part by part, the incorporation of CSM was 7.25, 14.5, 21.75 and 29 per cent in broiler diets and they observed comparable body weight gain and FCR at the end of 8 weeks trial even at 29 percent CSM inclusion. However, the feed intake was comparable only up to 7.25 per cent and higher feed intake was observed with higher levels of CSM inclusion. Hassanabadi et al. (2009) incorporated CSM replacing SBM at 5, 10, 15 and 20 per cent and observed weight gain, feed intake was lower and FCR was poor.

Comparison of different cottonseed varieties in an isocaloric and isonitrogenous broiler diet at 10 per cent level, Elangovan et al. (2003) documented comparable body weight gain, feed intake and FCR in Bt (*Bacillus thuringiensis)*, Non Bt and commercial CSM, but National check variety CSM had poor weight gain (1149 *vs* 1676g) and poor feed intake (2370.5 *vs* 3472.4g). Similarly, Mandal et al. (2004) and Elangovan et al. (2006) reported comparable body weight gain, feed intake and FCR when commercial (NHH44), BG (Bollgard) II and Non BG II parental CSM and Bt and Non Bt CSM were compared by the respective authors.

Assessment of feeding value of CSM at 0, 10, 20 and 30 per cent with the ME assumed to be 2400 and 2100 ME kcal/kg for CSM in isonitrogenous diet had comparable weight gain, feed intake and FCR in the study carried by Watkins et al. (1994).

Inclusion of CSM at 16.8, 25.6 and 34.48 per cent in broiler diets containing 17, 20 and 23 per cent crude protein respectively, resulted in increased weight gain (1800 – 2000g), comparable feed intake and better FCR (2.56 – 2.25) as the level of protein increased (Sterling et al., 2002).

The low level of lysine in CSM when compared to conventional protein source in broiler diet namely SBM had made researchers to supplement lysine and make the diet isolysine. In this regard the work of Azman and Yilmaz (2005), wherein lysine was added at 1.5 or 3.0 per cent of CSM protein resulted in comparable weight gain, feed intake and FCR in birds fed 20 per cent CSM in conventional corn-soya diet. Similarly, Hassanabadi et al. (2009) supplemented lysine at 0.5 per cent of the CSM protein and the level of CSM used were 5, 10, 15 and 20 per cent, addition of lysine at all levels improved weight gain and FCR when compared to the unsupplemented group and was comparable to the control.

Inclusion of CSM at 25.64 per cent replacing SBM in isocaloric, isonitrogenous diet supplemented with synthetic lysine to match the lysine level resulted in poor weight gain, higher feed intake and poor FCR. In subsequent experiment the level of lysine was increased from 0.86 to 1.35 per cent with increment of 0.07 per cent resulted in better weight gain, comparable feed intake and improved FCR when the lysine level was 1.04 per cent (5.22% of the protein level) in 20 per cent CSM fed diet (Sterling et al., 2002).

Fernandez et al. (1995) added CSM at 0, 10, 15 and 20 per cent and balanced to the diet in terms of energy, protein, total lysine and total methionine, they observed comparable weight gain, feed intake and feed efficiency up to 15 per cent inclusion level but at 20 per cent inclusion of CSM the weight gain (252 *vs* 271 – 267g) and feed efficiency were poor (615 *vs* 656 – 648g/kg) in layer chicks. The bioavailability of amino acids in the CSM was reported as 25 per cent less in Janssen et al. (1979) study.

Studies on lysine supplementation based on digestible values of amino acids in broiler diet was undertaken by Fernandez et al. (1995) using 5, 10, 15 and 20 per cent CSM, the levels of digestible lysine and digestible methionine in the diets were same. The authors documented that, the body weight gain, feed intake and feed conversion ratio were comparable in layer chicks even up to 20 per cent of CSM level.

Presuming the digestibility of lysine was less by 10, 20 and 30 per cent; synthetic lysine was supplemented in each of the broiler ration containing 0, 10, 20 and 30 per cent CSM. In this study, feed intake was significantly increased and feed utilization was significantly depressed as the level of CSM in the diet increased. Additional lysine supplementation proved interactive in overcoming the adverse effect of CSM (Watkins et al., 1993). Similarly, Watkins et al. (1994) presumed that the digestible lysine was 25 per cent less and supplemented lysine in the synthetic form in diets containing CSM at 0, 20 and 30 per cent levels, they observed that in the extra lysine supplemented group the performance was better in terms of body weight gain, feed intake and FCR.

One of the major obstacles in the use of CSM for poultry is the presence of gossypol. Gossypol binds free iron in the plasma which can be inactivated by the use of soluble iron compounds. Work related to supplementation of iron sulphate ($FeSO_4 . 7H_2O$) at 2:1 ratio (iron: free gossypol) is to avoid the detrimental effect of free gossypol in CSM are as follows.

Use of semi decorticated CSM at 0, 8, 16 and 24 per cent in equal energy, nitrogen, lysine and methionine in broiler diet, resulted in comparable weight gain, feed intake and FCR at 3 and 6 weeks of age in 8 and 16 per cent CSM fed birds, however at 24 per cent incorporation resulted in poor weight gain, feed intake and FCR. Supplementation of iron sulphate at 300 and 600 ppm in 24 per cent CSM diet had ameliorate the negative effect in terms of weight gain and feed intake but FCR was poor (Boushy and Raterink, 1989).

Fernandez et al. (1995) studied with diets containing 0, 5, 10, 15 and 20 per cent CSM along with iron sulphate supplementation at 2:1 ratio (iron: free gossypol). In diet formulated, based on total amino acids content comparable weight gain, feed intake and FCR up to 15 per cent of CSM inclusion was documented, but at 20 per cent CSM incorporation fed birds showed poor weight gain and feed efficiency. In the subsequent study, the same authors formulated diets with digestible amino acids and iron sulphate supplementation, incorporation of CSM at 20 percent had comparable weight gain, feed intake and FCR but at higher levels (30 and 40%) of CSM formulated based on digestible amino acids with iron sulphate supplementation low weight gain, feed intake and poor feed efficiency were recorded (Fernandez and Parson, 1996).

In 15 per cent CSM diet, iron sulphate was added at 0.31 per cent (2:1 iron: free gossypol) and compared with corn SBM based diet. The CSM diet performed better in terms of weight gain (1611 *vs* 1537g), feed intake (3871 *vs* 4181g) and FCR (2.40 *vs* 2.72) than control (Karakas et al., 2006).

Addition of 0.04 per cent iron sulphate in broiler diet containing 5, 10, 15 and 20 per cent CSM was found to ameliorate the reduction in body weight gain and improve feed intake and FCR when compared to the respective levels of CSM diet without iron supplementation (Hassanabadi et al., 2009; Heidarinia and Malakian, 2011).

BLOOD BIOCHEMICAL PARAMETERS

The blood haemoglobin (Hb) concentration, serum protein, albumin, globulin and cholesterol did not differ statistically in birds fed CSM at 200 g/kg (Henry et al., 2001), 100 g/kg (Elangovan et al., 2003; Mandal et al., 2004).

Adeyemo and Longe (2007) observed no change in packed cell volume (PCV), Hb, serum protein, albumin and globulin when CSM totally replaced SBM.

Supplementation of iron sulphate (2:1 iron: free gossypol) in 15 per cent CSM broiler diet did not influence the Hb, but MCHC was higher (28.45 *vs* 25.59%) and erythrocyte osmotic fragility (EOF) was reduced (Karakas et al., 2006).

SLAUGHTER PARAMETERS

Feeding of CSM had no influence on dressing percentage at 10 per cent inclusion of Bt and non Bt CSM (Elangovan et al., 2003), 10 per cent (Mandal et al., 2004), 19.5 per cent (Adeyemo and Longe, 2007) and 15 per cent (Zaboli and Miri, 2013). Sterling et al. (2002) and Watkins et al. (2002) reported lower dressing percentage (68.6 *vs* 69.1 and 63.97 *vs* 65.32%) at 17 and 30 per cent CSM inclusion, respectively.

The liver weight of the birds was not significantly influenced by incorporation of CSM up to the level of 35.24 per cent (Sterling et al., 2002), 10 per cent (Elangovan et al., 2003; Mandal et al., 2004) and 26.05 per cent (Adeyemo and Longe, 2007); however, Bailey et al. (2000) found relatively higher liver weight (4.5 – 5.3 *vs* 3.6%) at 10 per cent inclusion of CSM moco and commercial varieties in broiler diet.

Incorporation of CSM at 10 per cent (Elangovan et al., 2003), 26.05 per cent (Adeyemo and Longe, 2007) and 15 per cent (Hassanabadi et al., 2009) did not affect the heart weight of birds, however Mandal et al. (2004) observed higher heart weight at 10 per cent inclusion of commercial varieties of CSM. On the other hand, Kakani et al. (2010) reported 3.36 per cent CSM diet containing 265.2 mg/kg free gossypol to lower heart weight (0.57 *vs* 0.65%).

Gizzard and spleen weights of birds were not significantly influenced by incorporation of CSM up to the level of 10 per cent (Elangovan et al., 2003; Mandal et al., 2004) and 26.05 per cent (Adeyemo and Longe, 2007).

Similarly, abdominal fat was not influenced by feeding of CSM at 10 (Elangovan et al., 2003; Mandal et al., 2004) and 15 per cent (Hassanabadi et al., 2009; Heidarinia and Malakian, 2011). But Watkins et al. (2002) reported lower abdominal fat (2.12 *vs* 2.81%) and Sterling et al. (2002) reported higher abdominal fat (3.07 – 2.56 *vs* 2.43 – 1.73%).

LIVEABILITY

CSM did not significantly affect the liveability at the inclusion level (in per cent) of 28 (Gamboa et al., 2001), 20 (Henry et al., 2001), 30 (Watkins et al., 2002) and 10 (Elangovan et al., 2003; Mandal et al., 2004).

However, studies with gossypol incorporated at 1600 mg/kg (Alexander et al., 2008) and 265.2 mg/kg (Kakani et al., 2010) in broiler ration was found to reduce the liveability.

COST EFFECTIVENESS ON EFFECT OF FEEDING COTTONSEED MEAL IN BROILERS

Ojewola and Ewa (2005) conducted experiment to evaluate utility of different plant proteins in broiler rations by using 30 per cent SBM in control ration and 30 per cent CSM in treatment group. They found ration containing 30 per cent CSM more economical than control group with 30 per cent SBM. In subsequent experiment, Ojewola et al. (2006), replaced 25, 50, 75 and 100 per cent of SBM and observed significantly reduction in the cost up to 20 per cent / kg of feed and per bird when compared to SBM based diet. However, Attanayaka et al. (2016) reported when inclusion of CSM up to 15 per cent level, compared with their control (SBM based) diet in broilers showed no significant difference in feed cost/kg live weight.

CONCLUSIONS

Development of modern cotton seed processing industries employs high protein and low crude fibre content in cottonseed meal. The mean digestibility coefficient of essential amino acids in CSM is low as compared to other conventional protein sources. However low gossypol level cottonseed meal that included in broilers diet in minimum level but supplementation of synthetic amino acids and iron has increased the incorporation level and also improved bird's blood biochemical picture. Inclusion of cottonseed meal in broiler diet (isonitrogenous isocaloric diet) had reduces feed cost.

CONFLICT OF INTERESTS

There exists no conflict of interest.

AUTHORS' CONTRIBUTION

All the authors contributed equally.

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