

## **Use of Whole Cotton Seed and Cotton Seed Meal as a Protein Source in the Diet of Ruminant Animals: Prevailing situation and opportunity**

**N. P. Osti<sup>1</sup> and S. B. Pandey<sup>2</sup>**

National Animal Science Research Institute

ANIMAL NUTRITION DIVISION

Email: nposti@narc.gov.np

P.O.Box 1950, Kathmandu, Nepal

### **Abstract**

**The whole cotton seed and cotton seed meal have great value in animal production. However, such a valuable cotton seed products are not very much used in Nepal. Though agronomic work of cotton was started from very beginning with establishment of cotton development board in Nepalganj but the board have lack of multidisciplinary approaches. The valuable cotton seed products have been used elsewhere outside the country. In this connection review of literature, on whole cotton seed, cotton seed meal, and other related products, available in different libraries, institution and electronic media were accomplished to explore its importance in ruminant animal production.**

Key words: Cotton seed, ruminant animal production

### **Introduction**

Cotton (*Gossypium hirsutum*) ranks next to corn and wheat in value in most of the western countries (Morrison, 1956), but its value in Nepal is localized in western side especially Dang, Banke, Bardia, Surkhet, Kailali and Kanchanpur. In Nepal, farmers produced cotton is collected by government owned cotton mill and separated cotton fibers, lint and cottonseed. From one tone of cotton 2/3<sup>rd</sup> portion is cotton fiber, and 1/3<sup>rd</sup> portion is cottonseed and lint mixed. Every year about 600 tons of cottonseed (Figure 1.) is produced in Nepal (CBS, 2001). The cottonseed is purchased by local buyers and sold to India, there is limited use of cotton seed in Nepal.

Cotton is grown primarily for the fiber, but cottonseed meal and cake secured in the production of oil from cottonseed are among the most important feeds for livestock. From one ton of cottonseed can produce cottonseed meal (CSM) or cake 954 lbs, crude oil 303 lbs, hulls 514 lbs and lints or short fiber 110 lbs, and remaining 119 lbs are dirt and loss in manufacturing process (Morrison, 1984). The importance of whole cotton seed (WCS), cotton seed meal, and their by products for ruminant production is reviewed in this paper.

### **Linted or lintfree cottonseed**

In the process of cotton separation 1/3<sup>rd</sup> portion is lint and 2<sup>rd</sup> portion is lintfree whole cottonseed (WCS). Now a day lintfree WCS is available, Pima, a variety of long staple cotton that yields seeds that are naturally lint free. The Pima, seed is slightly higher in protein and lipids than that of linted cotton varieties (Sullivan et.al., 1993). Coppock et.al. (1985) postulated that the absence of lint changes the stratification of cottonseed within the rumen resulting in less extensive rumination.

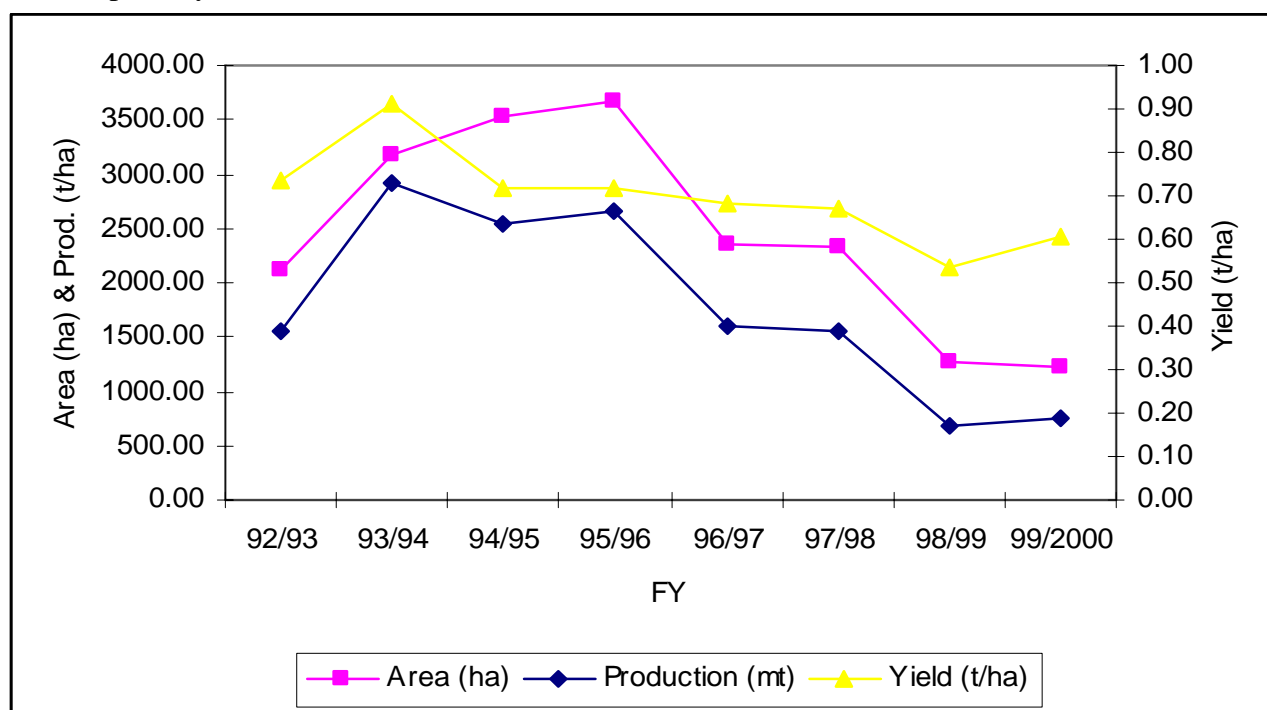
Zinn, (1995) assessed the characteristics of ruminal and total tract digestion of Pima cottonseed compared with a conventional linted variety (Delta Pine 61, DP) in growing finishing diet for feedlot

---

<sup>1</sup> Senior Scientist (S3), Animal Nutrition Division (NARC), Khumaltar

<sup>2</sup> Director, National Animal Science Research Institute, Khumaltar

cattle and found that energy value of lint free Pima cottonseed was similar to that of linted varieties provided that it was ground before feeding. However, it was anticipated that grinding will increase ruminal nitrogen degradability by 20 percent. Furthermore, Zinn (1995) indicated that depending up on the level of incorporation in the diet, ground Pima cottonseed may decrease ruminal microbial growth and net ruminal protein efficiency. In this assessment, the Pima cottonseed was also found higher in crude protein (CP) (10%), lipid (9.5) and ash (41.1%) and lower in acid detergent fibre (ADF) (%.3%) than linted (DP). Coppock and Wilks (2000) reviewed the feeding value of linted WCS, whole pima seed (WPS), and cracked pima seed (CPS) for lactating dairy cows and found a small advantage of the WPS over WCS for CP (22.4 vs. 19.3%) and fat (21 vs. 17.5 %). They also postulated that feed intakes and milk yields were similar with a small advantage for CPS over WCS for 3.5 percent fat corrected milk (FCM) (33.04 vs. 31.39 kg/d). The Pima seed has been passes slightly fast from gastrointestinal tract than that of WCS. Therefore, Pima seed has been found to have similar feeding value to that of WCS, especially if it is cracked.



**Figure 1. Cotton production, area, and productivity from 1992/93 to 1999/2000 in Nepal.**

### Manufacturing processes

At the oil mills, after cleaning and removal of the short lint covering of the cotton seed the leathery hulls of the seed are cut by machines, and the kernels can drop out. The kernels are separated more or less completely from the hulls by shakers and beaten, containing metal screens. After the kernels are crushed, and extracted the oil using by one of the oil milling methods, the remaining is cottonseed meal or cake. The most common method of extraction of oil from cottonseed is expeller method in Nepal, but solvent extraction method is also used.

### Chemical composition and nutritive value

The chemical composition of cotton seed meal and other cotton products reported by Church (1991) are given in table 1. According to the table 1, there are differences in the nutrient contents between the types

of cotton seed products and also between methods used to extract the oil from the whole cotton seed. For example crude protein (CP) contents of cotton seed hulls, whole cotton seeds and cotton seed meals mechanically extracted and solvent extracted have 4.1, 23.9, 44.3 and 45.2 percent respectively.

**Table 1. Chemical composition of cottonseed meal & other cotton products (on dry matter basis)**

Description	DM %	Percent on dry matter basis							
		CP	CF	NDF	ADF	Ca	P	ME	TDN
Cottonseed hulls	91	4.1	48	90	64	0.15	0.09	1.52	42
Cottonseeds	92	23.9	21	39	29	0.16	0.75	3.47	96
Cottonseed meal									
Mech. extd. 41% CP	93	44.3	13	28	20	0.21	1.16	2.82	78
Solvent Extd. 41%CP	91	45.2	13	26	19	0.18	1.21	2.75	76

Source: NRC 1988 in Church, 1991.

### Effect of CSM on body weight gain

In a study done by Worrell, et.al. (1990) on CSM and rye grass based grazing system, when 96 crossbred yearling steers were given diets with or without CSM 0.45 kg/day + lasalocid 150 mg/day. In the study it was found that CSM increased ( $p < 0.05$ ) average daily gain (ADG) early in the grazing season but not later. Addition of lasalocid increased ( $P < 0.05$ ) ADG during the spring grazing period and for the entire grazing season feed containing rapidly degraded nitrogen through the grazing season and that supplementing steers with CSM containing lasalocid improved seasonal weight gains. In an another study conducted by Brosh, et.al. (1990) on isoenergetic (ME 11.4 MJ/kg DM) diet containing wheat silage 480 g/kg not supplemented or supplemented with nonprotein nitrogen, fish meal, soybean oil meal and cotton seed oil meal were given to male calves about 145 days old (digestibility trial) and male calves about 5.5 months old (feeding trial). In this study it was found that the apparent digestibility on organic matter were 0.709, 0.708, 0.704, 0.68 & 0.667 kg/kg DM and daily nitrogen retention were 0.20, 0.65, 0.65, 0.64 & 0.68 g/kg0.75 for the unsupplemented and non-protein nitrogen, fishmeal, cottonseed oil meal, and soybean oil meal supplemental diets, respectively. Unsupplemented cattle gained significantly less than those of the supplemented cattle.

### Effect of CSM on voluntary intake, digestibility and protein degradability

Capper, et.al (1989) studied on voluntary intake and digestibility trials using Awassi sheep given straw from 7 barley varieties with supplemented with barley grain and CSM. From the study it was found that straw supplemented with CSM improved straw organic matter intake but there was no significant difference on organic matter digestibility between supplemented and unsupplemented diets. In another study daily feed dry matter intake (DMI) was not affected by the addition of WCS from 0 percent to 20 percent of the diets for lactating cows (Coppock et.al. 1985; Depeters et.al 1985; Horner et.al. 1986). However, when WCS increased to 20 percent of the diets the DMI decreased significantly (Coppock et.a., 1985). The protein degradability of CSM was found 57 percent at a rumen outflow rate of 0.05 per hour (RAO, et.al. 1989).

### CSM as a source of nitrogen for ruminal micro-organisms

Cottonseed oil meal can also be used as nitrogen source for ruminal organisms, in a study CSM had no significant effect on concentration of ammonia in rumen fluid which on average of 3.5 mg per 100 ml of fluid, but when 2.5 and 5 percent of urea was added to the molasses, rumen ammonia increased to 7.6 and 22.3 mg per 100 ml respectively (Sambrook and Rome, 1980).

### **Milk yield and composition**

According to Tashev & Todorov, (1981) when CSM was incorporated in dairy animal diet, there were no differences in intake of feed units per kg milk corrected for weight gain during the 90 days in milk protein, sugars and minerals among groups. However, butter fat was significantly greater in milk of cows given cottonseed meal especially 40 to 50 days after calving. Also the study indicate that feeding WCS depressed the protein percentage of milk. Coppock and Wilks (1991) summarized four causes, which have been proposed for the lowered casein, which occurs when supplemental fats are fed. The most possible suggestion is a reduced microbial protein production (Dunkley et.al., 1977), because two studies with ruminally protected methionine and lysine showed milk casein restored when supplemental fats fed. An economic alternative to ruminally protected amino acids is to increase undegradable intake protein (Palmquist, 1987). In a study conducted by Belibasakis and Tsirgogianni (1995) with Friseian cows fed WCS and soybean meal concentrate in maize silage straw based diet it was reported that the milk protein content and yield, as well as content of lactose, total solids and solid not fat were not significantly affected by the diet. They further reported that WCS supplementation increased actual milk yield, fat-corrected milk yield, milk fat content, and milk fat yield. No significant differences were observed in blood plasma concentration of glucose, total protein, urea, sodium, potassium, calcium, phosphorous, and magnesium. Increase in concentration of plasma triglycerides, cholesterol, and phospholipids were observed in the same study.

In a study conducted at Livestock Research Complex Khumaltar, Lalitpur, Nepal on response of lactating cross-bred cows to feeding CSM on milk yield for a period of 39 days by replacing 25 percent concentrate mixture by CSM, it was found that there was no significant effect on total milk yield (Panday, et.al. 1996).

Beneficial result on milk yield during early lactation was observed with increasing dietary CP levels from 13.8 to 17.5 percent and undegraded intake protein by the addition of WCS in 24 multiparous Holstein cows. Increasing dietary CP above 17.5 showed little benefit in milk yield and also increased blood urea nitrogen, plasma amino acids, and milk non protein nitrogen (Grings, et.al., 1991).

### **CSM on wool production**

In a study conducted at School of Agriculture Revenina-Murrey Institute of Higher Education Australia on supplementation of weaned merino lambs grazing ryegrass subterranean clover pastures with 37.5 g/day of a pellet containing CSM plus hydroxymethyl-methionine plus vitamins and minerals for 3 months it was found that there were increases in wool growth (+7%) and live weight gain (+38%) compared with wethers fed control (Vitamins plus minerals) pellets. The synthesis of milk fatty acids C6 - C12 was depressed as WCS increased in the diet, the yields of stearic and total oleic acids doubled on a 25 percent WCS diet compared to the basal diet (Smith et.al. 1981).

### **Mycotoxin Contamination**

Infestation of mycotoxins quite common in feedstuffs affected with under field condition fungi, or during storage if conditions are favourable for their growth (Lynch, 1972). Dollear et.al (1968) showed that ammonia reduced aflatoxins in peanut meal and in CSM (Gradner et.al., 1971). Amoniation also reduced aflatoxin in WCS (McKinney et.al. 1973) and feeding value of this WCS fed at 15 percent of the diet showed similar result for milk yield and composition (Lough, 1981). It is recommended that

storing at less than 10 percent moisture, force air through the seed, shelter from rain and store on concrete with a slope help minimise increase in aflatoxin during storage of CWS.

### **Cyclopropene fatty acids**

Palvacic and steric acids are two cyclopropene fatty acids (CPFA) which occur at about 1 percent of the oil in cottonseed (Phelps et al., 1965). Cook et al. (1976) showed that when these acids were protected from ruminal hydrogenation in lactating cows, their inhibition of desaturase enzymes increase the portion of stearic acid at the expense of oleic acid. If these acids were unprotected in the rumen, their effect on stearic acid was much less. More recently, Hawkins and others (1985) showed that in cows fed diets of 18.5% WCS, milk fat contained 59.6 æg/g of CPFA and adipose tissue lipids, 148.5 æg/g. Both milk fat and adipose tissue lipid had more stearic and less oleic acid than in cows not fed WCS. Therefore, significant amounts of CPFA apparently escape ruminal hydrogenation under feeding conditions commonly used. However, the long-term nutritional significance of these acids to the cow or to humans who drink that milk is not known and this is the area for further study.

### **Gossypol toxicity and reduction of toxic effect**

Cotton seed meal (CSM) or meal contain gossypol ( $C_{30}H_{30}O_8$ ) which is toxic to farm animal. Gossypol is produced in the pigment glands of the roots, leaves, stems, and seeds of the cotton plant genus *Gossypium* (Berards and Goldblatt, 1969). Species and varieties of cotton plants differed in concentration of gossypol present in the seed. Pondey and Thejappa, (1975) reported a mean gossypol content of the seed was positively correlated with rainfall and negatively correlated with temperature. Further more the concentration of gossypol present in cotton seed cake is influenced by method of oil extraction. High temperature and pressure favor the formation of stable bonds between gossypol and other molecules. This 'bond gossypol' is inactive for toxicity. Screw pressed method of oil extraction is better then other solvent extraction method for inactivation of gossypol (Jones, 1981). Gossypol is toxic factor indigenous to the cotton plant genus *gossypium*. Concentration of free gossypol contained in feedstuffs such as whole cottonseed and cottonseed meals vary considerably. Nonruminants and preruminants are more sensitive to gossypol toxicosis, but ruminant animals are some what resistant to toxicity.

During the early 1900s, ruminants also were considered to be susceptible to the toxic effects of gossypol as "cottonseed meal injury". In the 1930s, however, such symptoms were shown to result from vitamin A deficiency rather than from gossypol. Reiser and Fu, (1962) reported that the ability of ruminants to detoxify free gossypol was caused by binding of soluble proteins with in the rumen to free gossypol. This protein-bound gossypol was found to be physiologically inactive. Mature dairy cattle fed excessive amounts of cotton seed meal (6.6 and 42.7 mg of free gossypol/kg body weight/day) plasma concentrations of gossypol were elevated (1.7 & 1.8 vs. 0 µg/ml) compared with control cows fed soybean meal (Lindsey, et.al., 1980). Concentration of free gossypol in livers was also higher in cows fed cottonseed meal diet than in control cows. Death of one cow fed cottonseed meal diet was attributed to gossypol toxicity. Smalley & Bichnell (1982) reported a case study of gossypol toxicosis in mature dairy cattle fed relatively high amounts of ammoniated whole cottonseed (2.7 to 4.5 kg/cow/day). Postmortem examination revealed that oedema of the lungs and abomasum, presence of straw-colored fluid in the thoracic and peritoneal cavities, liver with nutmeg appearance, and degenerating, hypertrophy muscle fibers in the heart. Mature ruminants indicate that ingestion of free gossypol at high levels may overwhelm ruminal detoxification and hence result in the absorption of quantities of free gossypol that may potentially toxic. This is further supported by findings of erythrocyte fragility in

feeder lambs (Calhoun, et.al., 1990) and heifers (Gray, et.al., 1990) fed moderate amounts of cottonseed products containing free gossypol. Gossypol toxicity is also a potential problem when cotton products are fed to young calves with functionally undeveloped rumens (Leighen et.al., 1953; Holberg et.al., 1988; Hudson et.al., 1988; Kerr, 1989).

The possible reduction of gossypol toxicity can be achieved by using iron salts. Iron salts bind gossypol in the gastrointestinal tract of swine and poultry fed CSM (Smith and Clawson, 1965), but this is not confirmed in ruminant animals. A preliminary report showed that when calves fed 50 percent WCS and 500 ppm of added Fe as FeSO<sub>4</sub>·H<sub>2</sub>O all calves grew well up to 16 weeks of age (Hawkins, et.al. 1985; Barraza et.al. 1991). Whole cottonseed contain 1.17 percent gossypol in the kernel, which is toxic level to the calf. Pelleting of feed by using heat also bound gossypol and reduces the toxic effects (Coppock and Wilks, 2000). Nagalakshmi, et al. (2003) compared raw, cooked, Ca(OH)<sub>2</sub> treated, and iron treated cotton seed meal in fattening lambs and found cooked cotton seed meal fed group proved to be the best in terms of body weight gain and iron treated group suffered from toxicity and reduced growth rate.

### **Reproductive problems of gossypol toxicity**

Reproduction is impaired in male and female when cottonseed products are fed to nonruminant animals. But, ruminant females are relatively insensitive to dietary gossypol, but males show marked testicular damage (Randel et.al. 1992). If raw cottonseed oil is used in human diets gossypol causes amenorrhea and impotent in male. In a study reported by Liu & Segal, (1985) in the rural area of China these problems were occurred when crude cottonseed oil was used for cooking and resulted “burning fever” and fertility problems in young couples.

Although gossypol problems are reported by various researchers, but in normal supplementary feeding, it is not a big problem. This is supported by research results as health and semen quality of adult bucks was unaffected by giving 20 percent cottonseed meal for 150 days (. Similarly carcass characteristics (carcass weight, dressing percentage, fat, bone) of goats fed poultry droppings and cottonseed meal diets were comparable to other protein and energy sources of concentrate ration. (Rao, et.al., 1995).

### **Conclusion**

Cottonseed cake or meal is a by-product obtainable during the process of extracting oil from cottonseed. Chemical composition and nutritive value of cottonseed meal is very good and one of the supplementary source of protein for livestock, especially for ruminants. Production performances of ruminant animals in terms of body weight gain, milk production & fat content of the milk, wool production from sheep, are not affected but also improved by supplementing WCS and CSM on ruminant animals diets. Sexual reproduction as semen production and fertility of female animals are not influenced, if fed normal amount of cottonseed meal to the ruminant animals.

Only limiting factor of cottonseed as a feed in farm animals is gossypol, a toxic factor, which causes 'cottonseed injuries'. Calves having undeveloped rumen and nonruminants are more sensitive to gossypol toxicity than adult ruminant animals. These toxic problems exist if fed raw cottonseed. Detoxification tools are now available to reduce toxicity. One of the easy methods is the expeller extraction of oil, due to heat and pressure the gossypol is inactivated. Another method is supplementing ferrous sulphate which is easily available and inhibit the gossypol toxicity to the animals. The other

method which binds the gossypol is pelleting process, that heat pelleted gossypol bound and excreted from gastrointestinal tract.

In western Nepal, especially Dang, Banke, Bardia, Surkhet, Kailali and Kanchanpur, are potential area for cotton production. Research on utilization of cottonseed meal on farm animal's ration in Nepal is very limited. Fat percentage is the main pricing policy in Nepal, adding of fat or WCS increases fat percentage in the milk, so, there is a beneficial uses of WCS and CSM if these ingredients are incorporated in the diet of farm animal. Some of the information available from this review paper suggest that farm animals in particular cattle and buffaloes should have some proportions of the WCS or WCM in their diets. Further research in this area is also suggested.

## References

- Barraza, M. L., C. E. Coppock, K. N. Brooks, D. L. Wilks, R. G. Saunders, and G. W. Latimer, Jr. 1991. Iron sulfate and feed pelleting to detoxify free gossypol in cottonseed diets for dairy cattle. *J. Dairy Sci.* 74:(In press).
- Belibasakis, N.G. and D. Tsirgogianni. 1995. Effects of whole cottonseeds on milk yield, milk composition, and blood components of dairy cows in hot weather. *Animal Feed Science and Technology* 52:227-235 (The essential electronic agricyultrural library Disk no.135, Albert R. Mana library Cornell University Ithaca, Ny 14853 (607) 255 – 8939. In Association with the Rockefeller Foundation.
- Beradi, L.C. and L. A. Goldblatt. 1969. Gossypol in: I.E. Leiner (ed) *Toxic Constituents of Plant Foodstuffs*. pp 211 - 266. Academic Press, New York.
- Brosh, A., Holzer Z. & D. GVV. 1990. The effect of source of nitrogen used for supplementation of high wheat silage diets for cattle. *Animal Production* 51 (1): 109-114. (Nutrition Abstract & Reviews 1990 60(9): 4906 ref).
- Calhoun, M. C., J. E. Huston, S. W. Kuhlmann, B. C. Baldwin, Jr., W. Menges, B. S. Engdahl, D. N. Ueckert, and G. R. Engdahl. 1990. Increased erythrocyte fragility in cattle, sheep and goats fed whole cottonseed. *TX Agr. Expt. Sta. Consol. Prog. Rpt.* 4780, p. 30.
- Calhoun, M.C., J.E. Huston, S.W. Kuhlmann, B.C. Balwin Jr., B.S. Engdahl, and K.W. baks. 1990. Free gossypol intake and erythrocyte fragility of lambs fed cottonseed meal processed by different methods. *J. Anim. Sci.* 68(suppl.1):53 (Abstr.).
- Central Bureau of Statistics (CBS). 2001. *Statistical Year Book of Nepal*. His Majesty's Gpvernment of , National Planning Commission Secretariat, Kathmandu, Nepal.
- Cook, L. J., T. W. Scott, S. C. Mills, A. C. Fogerty, and A. R. Johnson. 1976. Effects of protected cyclopropene fatty acids on the composition of ruminant milk fat. *Lipids* 11:705.
- Coppock, C.E. and D.L. Wilks. 2000. Feeding whole cottonseed and cottonseed meal to dairy and beef cattle. Texas A & M University and Texas Agricultural Experiment Station, College station 77843-2471 (from webpage).
- Coppock, C.E., J.R. Moya, J.W. West, D.H. Nave, J.M. Labore and C.E. Gates. 1985. Effect of lint on whole cottonseed passage and digestibility and diet choice on intake of WCS by Holstein cows. *J.Dairy Sci.* 68:1198.
- Dollear, F. G., G. E. Mann, L. P. Codifer, Jr., H. K. Gardner, Jr., S. P. Koltun, and H. L. E. Vix. 1968. Elimination of aflatoxins from peanut meal. *J. Amer. Oil Chem. Soc.* 45:862.
- Gardner, H. K., Jr., S. P. Koltun, F. G. Dollear, and E. T. Rayner. 1971. Inactivation of aflatoxins in peanut and cottonseed meals by by ammoniation. *J. Amer. Oil Chem. Soc.* 48:170.

- Gaya, H., Hulman B.J. & T.R. Preston. 1982. The value for milk production of different feed supplements: effect of cereal protein concentrate, poultry litter and oil seed meal. *Tropical Animal Production* 7 (2) 134-137. (Nutrition Abstract & Reviews 1983 53(2): 973 ref).
- Gray, M.L., R.D. Randel, L.W. Greene and G.L. Williams. 1990. Metabolic homeostasis and reproductive endocrine function in postpubertal beef heifers fed varying levels of dietary free gossypol. *J. Anim. sci.* 68 (Suppl.1):465 (Abstr.).
- Grey, M.L., R.D. Randel, L.W. Green and G.L. Williams, 1990. Metabolic homeostasis and reproductive endocrine functions in postpubertal beef heifer fed varying levels of dietary free gossypol. *J. Anim. Sci.* 68 (supplement 1): 465.
- Grings, E.E., R.E. Roffler and D.P. Deitelhoft. 1991. Response of daisy cows in early lactation to addition of cotton seed meal in alfalfa based diets. *J. Dairy Sci.* 74:2580-2587.
- Hawkins, G. E., K. A. Cummins, M. Silverio, and J. J. Jilek. 1985. Physiological effects of whole cottonseed in the diet of lactating dairy cows. *J. Dairy Sci.* 68:2608.
- Holmberg, C.A., L.D. Weaver, W.M. Guterbock, J. Genes, and P. Montgomery. 1988. Pathological and toxicological studies of calves fed a high concentration cottonseed meal diet. *Vet. Pathol.* 25:147.
- Hudson, L.M., L.A. Kerr, and W.R. Maslin. 1988. Gossypol toxicosis in a herd of beef calves. *J. Anim. Vet. Med. Assoc.* 192:1303.
- Jines, L.A. 1981. Nutritional values for cotton seed meal. *Feed Stuffs* 53:19.
- Kerr, L.A. 1989. Gossypol toxicosis in cattle. *Comp. on cont. Educ. For the practicin veterinarian* 11:1139.
- Leighton, R.E., W.B. Anthony, J.S. Huff, and I.W. Rupel. 1953. Relation of dreed and free gossypol levels to cottonseed meal toxicity in dairy calves. *J. Dairy Sci.* 36:601
- Linsdey, J.O., G.E. Hawkins, and L.D. Guthrie, 1980. Phygiological responses of lactating cows to gossypol from cotton seed meal rations. *J. Dairy Sci.* 63:562.
- Lough, O. G. 1981. Ammoniated cottonseed compares favorably with non-ammoniated cottonseed in University of Arizona test. *United Dairymen of AZ.* Aug.
- Lynch, G. P. 1972. Mycotoxins in feedstuffs and their effect on dairy cattle. *J. Dairy Sci.* 55:1243.
- McKinney, J. D., G. C. Cavanagh, J. T. Bell, A. S. Hoversland, D. M. Nelson, J. Pearson, and R. J. Selkirk. 1973. Effects of ammoniation on aflatoxins in rations fed lactating cows. *J. Am. Oil Chem. Soc.* 50:79.
- McMitt, J.I., 1981. Cottonseed meal in rabbit rations; A review. *J. Applied Rabbit Research.* 4 (4):115-118 (Nutrition Abstract & Reviews 1983 53(1): 484 ref)
- Morrison, F.B. *Feeds and Feeding*. 22<sup>nd</sup> Edition, CBS Publishers and Distributors
- Morrison, F.B., 1956. *Feeds and Feeding, A Handbook for the Student and Stockman*. 22nd ed. The Morrison Publishing Company.
- Nagalakshmi, D., V.R.B. Sastry and D.K. Agrawal. 2003. Relative performance of fattening lambs on raw and processed cotton seed meal incorporated diets. *Asian-Aust. J. Anim. Sci.* 16(1): 29-35.
- Nikokyris and K. Kandylis, 1991. Effects of gossupol content of cottonseed cake on blood constituents in growing fattening lambs. *J. Dairy Sci.* 74:4305 - 4313.
- Panday, S.B., R.C. Khanal, R.S. Rana and S.K. Khanal 1996. Response of milking cattle fed different levels of cotton seed meal. Technical Report 1966/97. Animal Nutrition Division, Nepal Agriculture Research Council (NARC), Kathmandu Nepal.
- Phelps, R. A., F. S. Shenstone, A. R. Kemmerer, and R. J. Evans. 1965. A review of cyclopropenoid compounds: biological effects of some derivatives. *Poult. Sci.* 44:358.



- Pondey, S.N. and N. Theappa. 1975. Study on relationship between oil, protein and gossypol in cottonseed kernels. *J. Am. Oil Chem. Sco.* 52:312.
- Randel, R.D., C.C. Chose, JR. and S.J. Wyse, 1992. Effect of gossypol and cottonseed products on reproduction of mammals. *J. Anim. Sci.* 70:1628-1638. American society of Animal Science.
- Rao, S.M., Naidu M.M., Raghavan G.V., 1995. Effect of feeding concentrate mixture containing poultry droppings on carcass characters in goats. *Indian-Journal-of-Small-Ruminants*. 1995, vol 1: 2, 39-41; 9 ref.
- Reiser, R., and H.C. Fu, 1962. The mechanism of gossypol detoxification by ruminant animals. *J Nutrition* 76:215
- Sambrook, P.A., & Rawe J.B. 1982. Cottonseed meal as a source of nitrogen for rumen micro-organisms in sheep given a molasses based diet. *Tropical Animal Production* 7 (1):26-30. (*Nutrition Abstract & Reviews* 1983 53(1): 107 ref).
- Smith, F. H. and A. J. Clawson. 1965. Effect of diet on accumulation of gossypol in the organs of swine. *J. Nutr.* 87:317
- Sullivan, J.L., J.T. Huber, and J.M. Harper. 1993. Performance of dairy cows fed short staple, Pima and Cracked Pima cottonseed and feed characteristics. *Dairy Sci.* 76:3555.
- Swalley, S.A. and E.J. Bicknell, 1982. Gossypol toxicity in dairy cattle. *Comp. on Cont. Educ. for the Practicing Veterinarian* 4:378.
- Tashev, T, Todorov, N.A. 1981. Effect of supplementary feeding of cows with cotton and cottonseed oil meal at the beginning of lactation. *Zhivotnovdri Mavki* 18 (2): 20-27. (*Nutrition Abstract & Reviews* 1983 53(6): 3177 ref).
- Zinn, R.A. 1995. Characteristics of digestion of linted and lintfree cottonseed in diet for feedlot cattle. *J. Anim. Sci.* 73: 1246 - 1250.