The anti-nutritional factors in forages - A review

P.A. Smitha Patel**, *S.C. Alagundagi* and *S.R.Salakinkop

Department of Agronomy, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India

*E-mail:smitha.agron@gmail.com

ABSTRACT

The toxicity due to the consumption of various forages is very common among the farm animals. The anti-nutritional factors present in the forages are mainly responsible for this. In this review paper, the common anti-nutritional factors *viz.,* nitrates, oxalates, HCN and tannins present in different fodder crops have been discussed with reference to their toxic levels, symptoms and preventive measures to be taken for their safe feeding to dairy animals.

KEY WORDS: Anti-nutritional factors, cyanogens, nitrates, oxalates, tannins

The term 'antiquality component' is synonymous to anti-nutritional factor (ANF) as well as to incriminating factor but not to the toxic factor. There are many such components may not be actually toxic in the real sense, but may interfere directly or indirectly in the proper utilization of fodders by the farm animals. The anti-nutritional factors may be defined as those substances generated in natural feed stuffs by the normal metabolism of species and by different mechanisms (*e.g.,* inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed which exert effects contrary to optimum nutrition) (Kumar,1991). Being an ANF is not an intrinsic characteristic of a compound but depends upon the digestive process of the ingesting animal, *e.g.,* Trypsin inhibitors, which are ANFs for monogastric animals, do not exert adverse effects in ruminants because they are degraded in the rumen.

The aim of the nutritionist is also to identify component of fodder, which may limit the animal productivity. Livestock production can sometimes be hampered by the presence of so called toxic or antiquality components that may cause toxicity in animals. The deleterious role of antiquality components depends upon its rate of degradation by the microbes and accordingly it will influence the growth and the performance of the animal. This review paper covers the major antiquality components that adversely affect the nutritional value of the forages.

Nitrates

Nitrate toxicity of cattle was noted as early as 1895 with corn-stalk poisoning. However, nitrate was not recognized as the principle toxicant during that period. In the late 1930s, after an outbreak of oat-hay poisoning in the high plains region, an indictment of nitrate was finally made (Launchbaugh, 2001).

Some of the fodder crops such as sudan grass, pearl millet (Andrews and Kumar, 1992) and oats (Singh *et al.,* 2000) can accumulate nitrate at potentially toxic levels. Nitrate poisoning is better described as nitrite poisoning. When livestock consume forages, nitrate is normally converted in the rumen from nitrate to nitrite to ammonia to amino acid to protein. When forages have an unusually high concentration of nitrate, the animal cannot complete the conversion and nitrite accumulates. Nitrite is absorbed into the bloodstream directly through the rumen wall and converts haemoglobin (the oxygen carrying molecule) in the blood to methaemoglobin, which cannot carry oxygen. The blood turns to a chocolate brown color rather than the usual bright red. An animal dying from nitrate (nitrite) poisoning actually dies from asphyxiation, or lack of oxygen (Benjamin, 2006).

Factors affecting the severity of nitrate poisoning are the rate and quantity of consumption, type of forage, energy level or adequacy of the diet. Benjamin, 2006, reported that sheep and cattle fed poor diets seem to be more susceptible to nitrate poisoning. A critical level at which the nitrate toxicity effects is presented in Table 1 (John Andrae, 2008). Most of the nitrate accumulates in stem, followed by leaves and very little in the grains (Singh *et al.,* 2000). In general, application of excessive amount of nitrogenous fertilizers leads to accumulation of nitrates in plants.

Singh *et al.* (2000) studied the effect of application of different levels of nitrogenous fertilizers on the accumulation of nitrate in the oat fodder. The oat crop was grown in two groups. Four levels of nitrogen fertilizer were applied in two and three splits in each group (Table 2). From both the groups, the fodder was harvested first at 70 days after sowing and the second cut was taken at 50 per cent flowering stage. The results indicated that the concentration of nitrate-N was higher with two splits compared to three splits at each level of nitrogen application. All the values of nitrate-N decreased markedly when the crop was harvested at 50 per cent flowering (Table 2). The above findings showed that the each level of nitrogen fertilizer applied in three splits was quite safe from toxic levels of nitrates even during the early stages of fodder growth.

Oxalates

Various tropical grasses contain soluble oxalates in sufficient concentration to induce calcium deficiency in grazing animals. These include buffel grass (*Cenchrus ciliaris*), pangola grass (*Digitaria decumbens*), setaria (*Setaria sphacelata*) and kikuyugrass (*Pennisetum clandestinum*). Guinea grass, bajra and napier bajra hybrid contain oxalate content within safe limits, however, they may prove toxic if fed over for extended period of time. Oxalates react with calcium to produce insoluble calcium oxalate, reducing calcium absorption. This leads to a disturbance in the absorbed calcium: phosphorus ratio, resulting in mobilization of bone mineral to alleviate the hypocalcemia. Prolonged mobilization of bone mineral results in nutritional secondary hyperparathyroidism or osteodystrophy fibrosa (Rahman and Kawamura, 2011).

Cattle and sheep are less affected because of degradation of oxalate in the rumen. However, cattle mortalities from oxalate poisoning due to acute hypocalcemia have occurred on setaria pastures and sheep have been poisoned while grazing buffel grass. Levels of 0.5 per cent or more soluble oxalate in forage grasses may induce nutritional hyperparathyroidism in horses. Levels of 2 per cent or more soluble oxalate can lead to acute toxicosis in ruminants. The oxalate content of grasses is highest under conditions of rapid growth with concentrations as high as 6 per cent or more of dry weight (Cheeke, 1995).

Seasonal variation strongly affects the level of oxalate in saltbush plants. Abu-Zanat *et al.* (2003) observed that oxalate levels of *Atriplex* species were 8.29 and 4.92 per cent of dry weight in spring and fall seasons, respectively. Plant tissue obtained in the early summer exhibited higher oxalate content compared to similar samples obtained later in the season (Rahman *et al.*, 2006). Rahman *et al.* (2009b) also reported that leaf and stem tissues obtained in the early summer exhibited nearly equivalent levels of oxalate. As the season advanced, the oxalate content in leaf tissue decreased gradually, whereas the decrease was more rapid in the stem tissue. Singh (2002) reported that the high values of oxalate observed in a napier bajra hybrid during the month of June and July might be due to the peak in growth during summer and rainy seasons (Table 3).

Young plants contain more oxalate than older plants (Jones and Ford, 1972). During early stages of growth, there is a rapid rise in oxalate content followed by a decline in oxalate levels as the plant matures (Davis, 1981). Rahman *et al.* (2009b) observed that the oxalate content of napier grass can be manipulated by varying the harvesting interval, and that oxalate content declined as the harvest interval increased (Table 4).

The distribution of oxalate in plants is uneven. Several researchers reported that oxalate content is highest in leaf tissue, followed by stem tissue (Jones and Ford, 1972; Marais *et al.*, 1997; Rahman *et al.*, 2006). Bamboo has three times the content of oxalate in younger parts of the shoot compared with older parts. In contrast, leaf and stem tissues exhibited nearly equivalent levels of oxalate when napiergrass was harvested in early summer (Rahman *et al.*, 2006), possibly due to peak growth in summer and rainy seasons. Dhillon *et al.* (1971) reported that oxalate content in napier grass (cv. Pusa Giant) is directly related to the thickness of the stem: the thicker the stem the higher the oxalate content. Ruminants, particularly small ones, tend to prefer leaves rather than stems, but because leaves usually contain more soluble oxalate than the other parts of the plant, careful attention should be paid to plant materials consumed by grazing animals.

The oxalate content also varies with the genotypes. Chaudhary *et al.* (2007), in PAU Ludhiana, evaluated different pearl millet genotypes for oxalate content. They tested 10 genotypes of pearl millet. Among these, PCB-164 contained maximum oxalate(2.5%) whereas, PCB-2527 and PHB-2584 exhibited minimum quantity of oxalate (1.9%).

Cyanogens

Cyanogens are glycosides of a sugar or sugars and cyanide containing aglycone. It can be hydrolysed by enzymes to release HCN by enzymes that are found in the cytosol. Damage to the plant occurs when the enzymes and glycoside form HCN. The hydrolytic reaction can take place in the rumen by microbial activity. Hence, ruminants are susceptible to CN toxicity than non- ruminants. The HCN is absorbed and is rapidly detoxified in the liver by the enzyme rhodanese which converts CN to thiocyanate (SCN). Excess cyanide ion inhibits the cytochrome oxidase. This stops ATP formation, tissues suffer energy deprivation and death follows rapidly (Sarah robson, 2007).

The lethal dose of HCN for cattle and sheep is 2.0-4.0 mg per kg body weight. The lethal dose for cyanogens would be 10-20 times greater because the HCN comprises 5-10 per cent of their molecular weight. For poisoning, forage containing this amount of cyanogens would have to be consumed within a few minutes and simultaneous HCN production would have to be rapid. Recorded accounts of livestock poisoning by cyanogenic plants show that such situations do arise and the prussic acid concentration in forages and their potential effects on livestock is represented in Table 5 (Rocky Lemus,2009).

Prussic acid poisoning can occur when livestock are pastured on sorghum-type plants, including grain sorghum, forage sorghum, sudangrass, sorghum-sudangrass crosses, Johnson grass, sweet sorghums, and other sorghum-type plants. Prussic acid causes asphyxiation by inhibiting the action of the enzyme that links oxygen with red blood cells (Allison, 2002). Ruminants are more susceptible than non ruminants. HCN level will be high in young seedlings rather than in matured seedlings (Sultan, 2003).

Bahrani and Deghani, (2004), reported that the forage prussic acid percentage of the second cut was significantly lower than the first cut, probably due to degradation of the acid and a higher metabolic activity of the plant due to higher temperatures during growth processes which can reduce the prussic acid accumulation, these low amounts of FPAP (Forage Prussic Acid Percentage) are not toxic to animals, but Nitrogen rates had significant effect on prussic acid content (Table 6).

Gupta *et al.* (2002), in Pantnagar, evaluated eight varieties of multicut sorghum for HCN content in leaves, the samples were collected 58 days after first harvest and analysed. The HCN content varied among the varieties, it ranged from 46.06 to 275.53 ppm. The variation was mainly because of genetic factor. Among the varieties, FS 156 contained significantly lower HCN content (46.06 ppm) compared to all other varieties (Table 7).

Tannins

These are water soluble phenolic compounds with a molecular weight greater than 500 and with the ability to precipitate proteins from aqueous solution. They occur almost in all vascular plants. Hydrolysable tannins and condensed tannins are two different groups of these compounds. Generally tree and shrub leaves contain both types of tannins (Reddy, 2001). The two types differ in their nutritional and toxic effects. The condensed tannins have more profound digestibility-reducing effect than hydrolysable tannins, whereas, the latter may cause varied toxic manifestations due to hydrolysis in rumen. Tannins may form a less digestible complex with dietary proteins and may bind and inhibit the endogenous protein such as digestive enzymes (Cheeke,1995). The tannin-protein complexes are astringent and adversely affect feed intake and all plants contains phenolic compounds but their type and concentration may cause negative animal responses.

The concentration of condensed tannins above 4 per cent has been reported to be toxic for ruminants as they are more resistant to microbial attack and are harmful to a variety of microorganisms (Waghorn *et al.,* 1990).

Many methods have been tried to over come the deleterious effects of tannins such as, alkali treatments including ferrous sulphate, Polyethylene glycol-4000 prevents formation of complexes between tannic acid and protein and helps in the breakdown of already formed complexes thus liberating protein (Reddy, 2001) and three months feeding of *Prosopis cineraria* leaves and *Cenchrus* spp with 1 per cent urea has been found to maintain adult sheep. Physical methods like soaking and drying (Reddy, 2001) and heat treatment before feeding of forage can reduce the toxic level of tannin (Nuttaporn and Naiyatat, 2009)

CONCLUSION

Numerous Anti-nutritional factors (ANFs) in forages can cause toxicity in livestock. Some of these toxins are produced by the grasses, legumes and other forages. Knowledge of various aspects of these ANFs and their effect is necessary for optimal management and utilization of forage as well as animal health.

Table 1: Level of nitrate in forage (dry matter basis) and potential effects on animals

Content of Nitrate nitrogen (ppm)	**Effect on animals**
0-1000	This level is considered safe to feed under all conditions
1000-1500	This level should be safe to feed to nonpregnant animals under all conditions. It may be best to limit its use to pregnant animas to 50 per cent of the total ration on a dry basis.
1500-2000	Feeds are fed safely if limited to 50 per cent of ration’s total dry matter.
2000-3500	Feeds should be limited to 35-40 per cent of total dry matter in the ration. Feeds containing over 2000 ppm nitrate nitrogen should not be used for pregnant animals
3500-4000	Feeds should be limited to 25 per cent of total dry matter in ration. Do not use for pregnant animals.
>4000	Feeds containing over 4000 ppm are potentially toxic. Do not feed.

(John Andrae, 2008)

Table 2: Nitrate- N concentration (DM basis) in oat fodder as influenced by the level of nitrogenous fertilizer in two and three splits

Nitrogenous fertilizer (kg ha^{-1})	Nitrate-N (ppm)			
	Two splits *		Three splits **	
	70 DAS	50 % flowering	70 DAS	50 % flowering
0 (Control)	360	(38.9)	290	(31.0)

80	1280	(60.2)	990	(37.4)
160	1840	(62.5)	1320	(41.4)
240	2430	(61.7)	1670	(50.9)

DAS: Days After Sowing; *Half at the time of sowing and remaining half 30 DAS
**1/4th at the time of sowing, another 1/4th at 30 DAS and remaining after the first cut.
The values in the parentheses represent the per cent decrease in the nitrate-N when the crop was harvested at 50 per cent flowering after the first cut. (Singh, *et al.*,2000)

Table 3: Variation in oxalic acid content (% DM) in the whole plant of napier bajra hybrid- PBN-233

Particular	Oxalic acid (%)		
	Total	**Soluble**	**Insoluble**
April	2.2	0.70 (31.82) *	1.50 (68.18)
May	2.62	0.80 (30.50)	1.82 (69.50)
June	3.6	1.14 (31.70)	2.46 (68.30)
July	3.22	1.00 (31.10	2.22 (68.90)
August	2.56	0.80 (31.10)	1.76 (68.70)
At 1 m plant height	2.8	0.80 (28.60)	2.00 (71.40)
At 2 m plant height	2.3	0.88 (38.30)	1.42 (61.70)
CD (P=0.05)	0.88		

*The values in the parentheses represent the % proportion of soluble and insoluble oxalate fractions. (Singh, 2002)

Table 4: Soluble oxalate content (% DM) in plant parts of some forage species

Species	Plant part	Soluble oxalate	References
Setaria	Leaf blade	4.4	Jones and Ford (1972)
	Leaf sheath	2.9	
	Stem	2.8	
Kikuyu grass	Leaf	2.44	Marais *et al.,(*1997)
	Stem	0.98	
Napier grass	Leaf	2.78	Rahman *et al.,* (2006)
	Stem	2.05	

Table 5: Prussic acid (HCN) concentration in forages

HCN concentration (ppm)		Potential effect on livestock	
Dry matter	**Fresh harvested**		
0-500	0-100	S A F E	Forage is generally safe and should not cause toxicity
500-1000	100-200	D A N G E R O U S	Potentially toxic and forage should be fed at a restricted rate in the diet

>1000	>200	T O X I C	Very dangerous to livestock and will usually cause death. Drying, ensiling or allowing the forage to mature will reduce prussic acid concentration. Retest before feeding

(Rocky Lemus, 2009)

Table 6: Effect of N rates on prussic acid content (mg per 100 g dry matter) of the two cuts of forage sorghum

N rates (kg ha^{-1})	Prussic acid	
	1^{st} cut	2^{nd} cut
0	12.2 c	2.5
100	12.7 c	2.5
200	16.6 b	3.0
300	18.9 a	2.0
Mean	15.1 A	2.5 B

Means of each column (small) and row (capital) followed by the same letters are not significantly different (Duncan 1 %)

Table 7: HCN content of multicut sorghum varieties and hybrids

Variety/ Hybrid	HCN (ppm)
885 F	265.60 [b]
FS 156	46.06 [f]
FSH 92079	26.57 [g]
HD 19	262.00 [b]
PAC 8298	275.53 [a]
SSG 1001	132.90 [c]
SSG 5001	165.83 [c]
TNFS 9602	155.60 [d]
CD (P<0.05)	2.92

(Gupta *et al.* 2002)

REFERENCES

Abu-Zanat, M. M. W., F. M. Al-Hassanat, M. Alawi and G. B. Ruyle. 2003. Oxalate and tannins assessment in *Atriplexhalimus* L. and *A. nummularia* L. *J. Range Manage*. **56**:370-374.

Allison, 2002, Prussic acid poisoning in Livestock. Guide B-808, www.cahe.nmsu.edu

Andrews, D.J. and Kumar, 1992, Pearl millet for food, feed, and forage . *Adv. Agron.*, **48**:89-139.

Bahrani, M. J. and Deghani Ghenateghestani, A., 2004, Summer forage sorghum yield, protein and prussic acid contents as affected by plant density and nitrogen topdressing. J. Agric. Sci. Technol. 6:73-83.

Benjamin David Neale, 2006, Effects of fertilizer application and cutting interval on nitrate accumulation in bermudagrass . *M.Sc.(Agri.)*, *Thesis*: Univ.Tennessee, Martin.

Chaudhary, D.P., Bhardwaj, B.L., Manoj Sreevastava and Ajaib Singh, 2007, Comparative evaluation of forage pearl millet genotypes for dry matter and fodder quality. Forage Res., 33(2): 111-113.

Cheeke, P.R., 1995, Endogenous toxins and mycotoxins in forage grasses and their effects on livestock. Prstd symposium, Fescue and other toxic grasse: effects on livestock production. Pp: 909-916.

Davis, A. M. 1981, The oxalate, tannin, crude fiber, and crude protein composition of young plants of some *Atriplex* species. *J. Range Manage*. **34**:329-331.

Dhillon, K. S., 1971, A preliminary report on a peculiar type of napiergrass (*Pennisetum purpureum*) (Pusa giant) poisoning in buffalo calves. *Indian J. Anim. Sci.* **41**:1034-1036.

Gupta, S.K., Verma, M.L. and Jaiswal, R. S.,2002, Nutritional evaluation of multicut sorghum strains, *Indian J. Anim. Nutr.,* **19**(2):129-134.

John Andrae, 2008, Preventing prussic acid poisoning. *Forage Leaflet*, **13**, Clemson University.

Jones, R. J. and Ford, C. W., 1972, Some factors affecting the oxalate content of the tropical grass (*Setaria sphacelata*). *Aust. J. Experi. Agric. Anim. Husb.* **12**:400-406.

Kumar, R., 1991, Anti-nutritional factors the potential risks of toxicity and methods to alleviate them. *Animal Feed Sci. and Tech.,* **30**:145-160.

Launchbaugh, K.,2001, Risk management to reduce livestock losses from toxic plants. Fort Worth, TX: Grazing Lands Technology Institute.

Marais, J. P., A. D. Barnabas and D. L. Figenschou. 1997. Effect of calcium nutrition on the formation of calcium oxalate in kikuyugrass. In: *Proceedings of the XVIII International Grassland Congress*, Canada. pp. 45.

Nuttaporn Chanchay and Naiyatat Poosaran, 2009, The reduction of mimosine and tannin contents in leaves of *Leucaena leucocephala*. *As. J. Food Ag-Ind.* 2009, Special Issue, S137-S144.

Rahman, M.M. and Kawamura, O., 2011, Oxalate accumulation in forage plants: some agronomic, climatic and genetic aspects. *Asian Aust. J. Anim. Sci.,* **24**(3): 439-448.

Rahman, M.M., Ishii, Y., Niimi, M. and Kawamura, O., 2010, Interactive effects of nitrogen and potassium fertilization on oxalate content in napiergrass (*Pennisetum purpureum*). *Asian Aust. J. Anim. Sci., 23*(6) : 719-723.

Rahman, M. M. 2009. Studies on oxalic acid in tropical forage with special reference to the effect of fertilizer application. PhD Thesis, The United Graduate School of Agricultural Sciences, Kagoshima University, Japan.

Rahman, M. M., Y. Ishii, M. Niimi and O. Kawamura. 2009b. Effect of clipping interval and nitrogen fertilization on oxalate content in pot-grown napier grass (*Pennisetum purpureum*). *Trop. Grassl*. **43**:73-78.

Rahman, M.M., Yamamoto,M., Niimi, M. and Kawamura, O., 2008, Effect of Nitrogen Fertilization on Oxalate Content in Rhodesgrass, Guineagrass and Sudangrass. *Asian Aust. J. Anim. Sci.,* **21** (2) : 214 – 219.

Rahman, M. M., M. Niimi, Y. Ishii and O. Kawamura. 2006, Effects of season, variety and botanical fractions on oxalate content of napiergrass (*Pennisetum purpureum* Schumach). *Grassl. Sci*. **52**:161-166.

Rocky Lemus, 2009, Forage related disorders in livestock production, *Forage News*, 1-8. **http://msucares.com/crops/forages/index.html**

Reddy, D.V., 2001, *Principles of Animal Nutrition and Feed Technology*. Oxford IBM Publishing Company Pvt. Ltd., New Delhi.

Sarah Robson, 2007, Prussic acid poisoning in Livestock. www.dpi.nsw.gov.au/primefacts

Singh, A., 2002. A note on seasonal variation in oxalate content of napier bajra hybrid *Indian J. Anim. Nutr.*, **19**(3):282-284.

Singh Ajaib, Tiwana, U. S., Tiwans M. S. and Puri K.P.,2000, Effect of application method of level of nitrogen fertilizer on nitrate content in oat fodder. *Indian J. Anim. Nutr.*, **17**:315-319.

Sultan, S.I., 2003, Sorghum halepenses and its cyanide content. *Pakistan J. Nutr.*, **2**(3):123-124.

Waghorn G. C., Tavendale, M.H. and Woodfield, D.R.,1990, Methanogenesis from forages fed to sheep. Proc. *New Zealand Grassland Assoc.*, **51**:171-175.

[MS received 12 January 2013;
MS accepted 14 March 2013]

Disclaimer: Statements, information, scientific names, spellings, inferences, products, style, etc. mentioned in *Current Biotica* are attributed to the authors and do in no way imply endorsement/concurrence by *Current Biotica*. Queries related to articles should