AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly e Newsletter
Volume 3 – Issue 1
Online ISSN: 2582-368X
www.agriallis.com

# FORAGE QUALITY ATTRIBUTES AND ANTI-QUALITY FACTORS: A NUTSHELL DISCUSSION

Article Id: AL202129

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When it comes to fodder production; there has always been an unseen tug-war between land allocation for food crops (for human) and fodder crops. This is often more prominent in countries which have both large human population and along with large herds of cattle. India should be considered as an ideal example of such a scenario. On the one side, we are worlds second most populated nation, and on the other; we are also accommodating worlds largest livestock population; in addition to that, the cultivable land is also shrinking. This scenario leads us to a condition when the quality of fodder comes second to quantity. The consequence is an overall reduction in animal performance, illness and sometimes even death.

Forage quality designates a fodder's overall characteristics to meet the nutritional necessity of livestock which are consuming them. In general, green fodder and concentrates are two key components which fulfil the overall nutritional demand of the animal. The forages are a much cheaper option of nutrition than concentrates; hence its quality has the utmost importance in animal nutrition. The forage quality generally consists of three key factors; **selection of appropriate maturity stage of harvest, suitable forage species selection and customized nutrient management**. Forage quality characters significantly influence the digestibility and voluntary feed intake both have significant role animal performance as it has been said merely having all nutritional factors present in forage are not enough as the presence of anti-quality factors can limit overall digestibility.

The quality and anti-quality factors in forages; both have their origin from the plant cellular mechanism and biochemical synthesis mechanism. There are mainly three biochemical components which are essential in plant nutrition per se; this are**1. Carbohydrates, 2. Proteins, and 3. Lipids**. However; these are not the only biochemical components present in forage plants instead there are two more sets of biochemical

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Online ISSN: 2582-368X
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compounds; the first set consists of nucleotide molecules such as DNA and RNA which are although extremely important from plants perspective however have little value when it comes to providing a food source for the animal due to their meagre quantity. On the other hand, the other set comprises of non-nutritional components **anti-quality** components like lignin, tannin, phenolic compounds etcetera. Most animals cannot digest these components, hence having no utility in energy supply, although their mere presence can reduce the availability of other essential components.

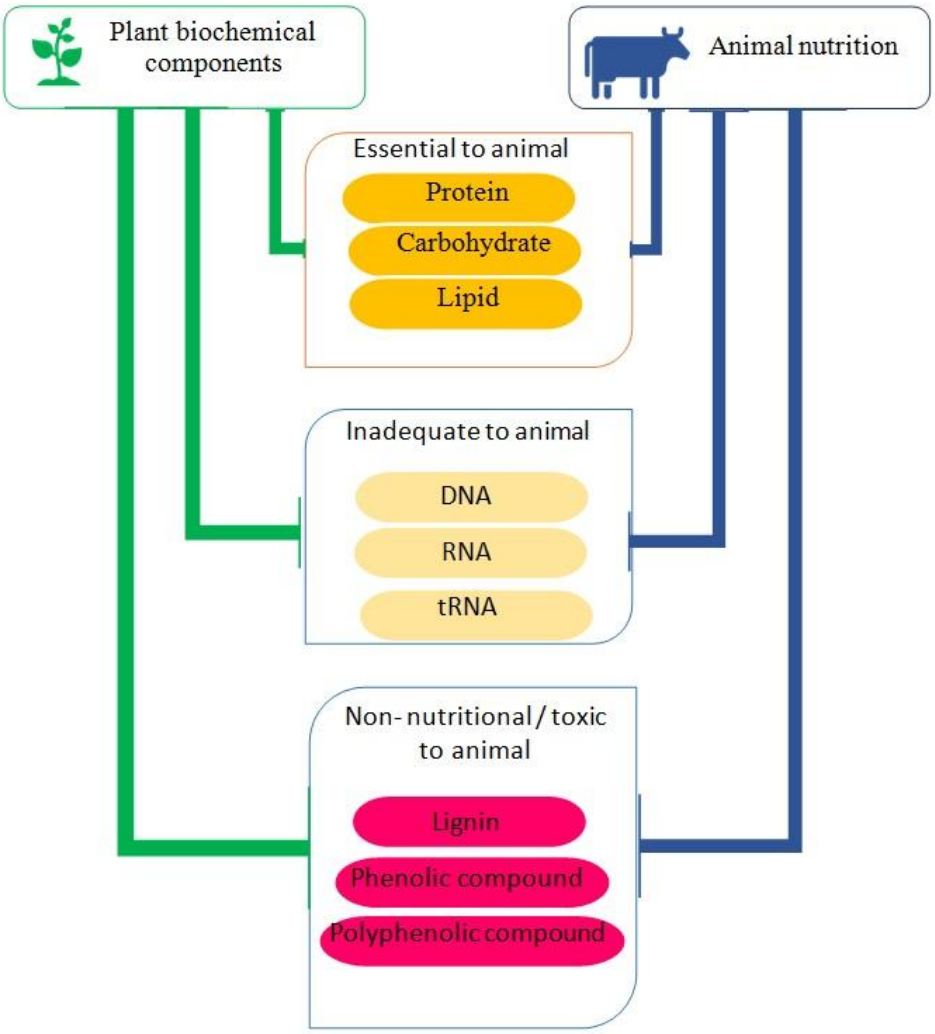


**Figure 1:** Different biochemical component found on forage plants and their utility on animal nutrition

Although seen as negative attributes from animals' nutrition's perspective, these anti-quality attributes have a significant role to play in plant physiology, metabolomics, and eluding mechanism against adversaries. In addition to that, minerals and vitamins can also play a positive role in playing plant production and animal nutrition.

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## Forage enzyme proteins

Protein enzymes are the most significant nutritional component of forages from the plant's perspective as other critical components like carbohydrate, protein, and lipids depend on enzymes for their synthesis. Among these enzymes, ribulose bisphosphate carboxylase **(RuBisCO)**is the front runner constituting 40-60% of whole leaf protein. The essentiality of RuBisCOlies in $CO_2$ fixation and glucose phosphate production are the starting point of energy or building blocks.

Proteins found on the seeds are somehow different from found in vegetative parts; although most forages are harvested before the reproductive stage, RuBisCO remains the most crucial enzyme protein. Majority of the forages have similar amino acid composition and generally hard to change through simple genetic selection tools or molecular breeding approaches.

Modern genetic engineering tools involving the insertion of genes in forages that will resist protein degradation seem prosing. Currently, low levels of gene expression for higher Sulphur contained proteins have already been achieved in alfalfa forage, which resulted in lesser protein degradation.

## Protein loss from forages and its preventive measures

Protein is always very delicate biomolecules. In the case of forages, the highest quantity and quality of proteins is observed before the crop harvesting but immediately starts falling just after the crop harvest, which possesses an eminent management challenge. The highest concentration of forage animal accessible crude proteins (**CP)** is found on leaves highly perishable. The losses begin from the leaf fraction's mechanical damage and end with the animal's final distribution. The loss of leaf protein is higher in legume crops than cereals both in fresh and preserved condition. The loss directly correlates with dry matter content and generally higher when preserved as hay than silage. Research indicates that a legume loses 23-25% of its leaf protein on DM from harvesting to hay preparation while the loss is less than half in case of silage. The loss of CP is more in hay than silage primarily because of the loss of leaf matter in the former. However; there is catch in this otherwise simple statement, which indicates that despite the quantitative higher loss of proteins from hay; the quality of the protein is higher in hay than silage.

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The only managemental approach to control this loss of protein is improved harvesting and handling process. There has been not much development in harvesting mechanism since a long time which genuinely requires a long haul. A newer strip-off harvesting method where protein-rich leaves are separately harvested than fibre-rich stalk seems promising although it takes much longer harvesting period.

## Non-Protein Nitrogen (NPN) and its management

Formation of NPN and its management is a significant challenge in forage production and management. Once the plant with higher true protein values harvested, wilting begins, further initiating proteolysis, which finally produces NPN. During any average wilting scenario;8-18% of the total protein converts to NPN. This is a particular issue of concern in the hay, especially if the drying condition is not optimal. In the case of silage, this primarily depends on fermentation and acid production as lower pH inhibits proteolytic activity. Although the proteolytic activity cannot be ceased entirely; it can be significantly reduced if the pH drops to 3.8- 4.0. Since acidic condition prevents proteolytic activity in silage; hence manual addition of acids like formic acid can significantly lower the NPN even by one-third of the supposed concentration. Another promising method is the addition of red clover, which contains polyphenol oxidase (PPO) responsible for inhibiting proteolysis. Red clover, although have this promising characteristic but has lower DM yield. A genetic modification of plants to produce more PPO can be a promising way out.

## Forage carbohydrate, its components and management

Carbohydrate is the primary source of digestible energy in forages. The carbohydrates in forage crops are divided into two groups, i.e., **Structural** and **non-structural carbohydrates**. Structural carbohydrates are referred to as polysaccharide, responsible for providing structural integrity to the plant and often found in the cell wall. Non-structural carbohydrates are generally storage food materials of the plants like starch, fructans and sucrose—all kinds of carbohydrates originate from photosynthesis and production of glucose.

When it comes to foraging quality, the structural carbohydrate has a special place as it generally decreases the digestibility. The cell wall-related carbohydrates require additional discussion. The cell walls of forage crops are a large pool of potential energy; however, their recovery is complicated. Among all these components of cell walls, **Cellulose** is the most

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copious one. **Pectins** are another group of complex carbohydrates which are more prominent in legume forages than grasses. Cell-wall carbohydrates often entangle with lignin and hydroxycinnamic acids which are non-carbohydrate components and strongly reduce forage crops' digestibility. The forages raised on the stressed condition and facing moisture, and nutritional deficiency has higher lignin content. Moreover, the lignin content increases over time hence delayed harvesting results in more lignin accumulation.

## Common forage secondary metabolite anti-quality factors

Some of the secondary metabolites which plant produces are outright harmful to the animals. As a result, these compounds are highly influenced by the selection of fodder crops, season and managemental practices. Major anti-quality factors generally found in forages are discussed below:

## Polyphenolic compound

In general, notion, **tannins** are a common type of anti-quality polyphenolic compound found in forages. Tannin,a secondary product of the shikimic acid pathway, has a specific chemical nature that can precipitate the proteins. Tannins are of two types, i.e., **hydrolyzable tannin**and **condensed tannin**. Hydrolyzable tannins are generally consisting of different phenolic acids and its adjuvants like gallic acid with a hexose. However; hydrolyzable tannins are not as much noxious as condensed tannins which are more relevant to forage quality. Tannins in plants generally occur in leaves, stems and roots and found more in legumes than grasses. From the plant sciences, standpoint, tannins and polyphenols play a specific role such as Anthocyanidins adds different colour pigments in flower petals that attract insects for pollination. Some other condensed tannins also help the plant deter overgrazing and plant damage and play an antimicrobial agent.

The concentration of tannins is dependent on several factors such as genetic makeup, environment and climate etc. The effects of seasonal variation on tannins are not universal as some of the forages have higher tannin concentration in summer while some other have in winter but in general, a winter season forage will have more tannin in summer vice versa. Nutritional deficiency is another important factor. Absence of nutrients such as phosphorus and Sulphur significantly hike the tannin content. In the case of Pearl millet; boron deficiency also increases tannin concentration.

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Presence of condensed tannins in forages creates multiple problems including suppressing microbial population in the rumen and inhibiting digestive enzymes. Tannin also bonds with protein with hydrogen bonds and hinders its utilization. A higher concentration of tannin (5% and above on a DM basis) reduces the animal's voluntary feed intake. Concentrations up to 40 g condensed tannins $kg^{-1}$DM are ideal for forage crops. Additionally, tannin presence also prevents plants' decomposition in case of green manuring and exhibits allelopathic effects.

There are not many technologies available to control tannin; however, mixed or intercropping with cereal-legume, proper nutrition management and deterring plant from facing any stress can reduce tannin production.

## Phytoestrogens

These are another group of phenolic compounds sometimes found in forages. These group commonly contains **coumestans** (coumestrol, 4-methoxycoumestrol, repensol and trifoliol), Isoflavones (diaidzein, formononetin, genistein and biochanin) and Isoflavan (Equol)are generally reported to be found on alfalfa and berseem. In ideal conditions, these compounds' concentration is very less in the plant but significantly hikes in pathogenic fungal infection in plants such as *Pseudopeziza medicaginis*. The concentration of these compounds generally decreases with time; after first cutting red clover, up to 40% have been reduced. Haymaking also reduces the concentration of phytoestrogen. The negative impact of phytoestrogens on animals are mainly concerned with reproductive system as cattle shows impaired fertility, enlarged uterus, swollen vulva, cyst formation in ovaries etc.

## Cyanogenic Glucosides

These are a group of nitrogenous compounds found in some forages like sorghum, white clover etc. Plant releases HCN, a keto- sugar compound when the tissue is damaged. The lethal dose of HCN ranges from 0.5 to 3.5 mg $kg^{-1}$ body weight. However, research and modern plant breeding practices have significantly reduced the dhurrin in sorghum and linamarin and lotaustralin content in white clover. The occurrence happens in sorghum when the mean daily temperature reaches below 15°c. The dhurrin content is also higher in younger plants and the portion where regrowth happened. The occurrence of toxicity is more in grazing systems; however; in modern animal husbandry practice, mortality is rare. In certain

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rare cases, an animal may face troubling oxygen breathing, grasping, convulsions and even paralysis. Although the rumen environment can detoxify the cyanide compound, the compound can also quickly adsorb by the rumen wall, eliminating the problem. The toxicity is more if the animal is hungry and taken well above the toxin's safe limit that the rumen detoxification mechanism is overloaded.

## Alkaloids

Alkaloids are the primary nitrogenous compound contained secondary metabolites. Among all anti-equality components, Alkaloids possess one of the highest threats. The higher number of alkaloids in forage results decreased serum calcium, and magnesium as oxalates binds with Ca and Mg. Grasses such as Setaria, Buffelgrass, Sugarbeet contains alkaloids. Environmental factors significantly influence the alkaloid accumulation. Alkaloid concentration increases in the late spring season but ceased in late autumn.

## Nitrate toxicosis

Nitrogen is the basic structural building block of proteins and extremely important to both animal and plants. However, a different form of nitrogen in nitrate causes severe problems in animals such as weight loss, abortion of fetus or even death. All the plants are capable of accumulating nitrate; however, the plants growing in high nitrogen-enriched soil and facing overcast weather can accumulate very high amount of nitrate. Nitrates are very toxic to ruminants than non-ruminants. When an animal consumes high nitrate-rich forage, the microbes found in rumen convert the nitrate to nitrite and then to ammonia which finally converted to protein. This also increases the rumen microbial protein. However, in the case of excessive nitrate condition, rumen microbes get overwhelmed by the higher nitrate content; hence the cycle does not proceed smoothly, and higher accumulation of nitrites in rumen causes the toxic effect. Higher nitrate in bloodstream oxidizes haemoglobin and makes it methaemoglobin, a brownish compound incapable of transporting oxygen. The management practice includes ensiling of drought or stressed affected crops or mixing with other forages before feeding to the animal. The harvesting can also be delayed until the stress condition gets normalized.

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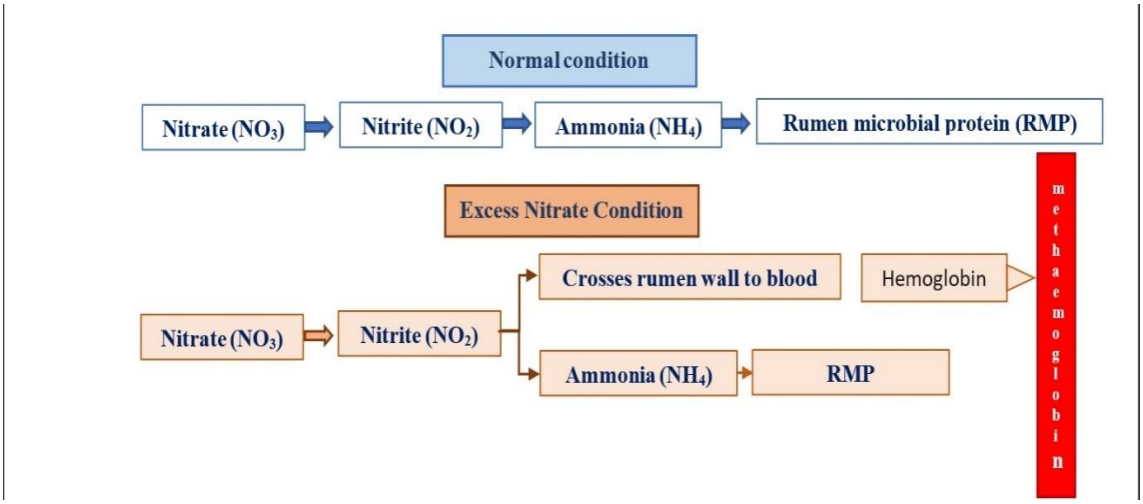


**Table 1:** Major anti-quality factors, their occurrence and management practices

| Anti-quality factor | Forages | Conditions | management |
|---|---|---|---|
| **Nitrate-nitrite** | Sorghum, Sudan grass, Oat, Barley, Turnip and Sugar beet | • Excessive supply of nitrogenous fertilizer, FYM<br>• Moisture deficit<br>• Excessive exposure to cold conditions<br>• Excessive application of 2,4-D herbicide | • Harvesting at maturity stage<br>• Silage, hay making |
| **Oxalates** | Bajra, Guinea grass, Setaria and some weed | • Young plant has more oxalates<br>• Excessive use of nitrogenous and potassium fertilizers | • Starved animal doesn't allow to graze that plant containing more level of oxalates<br>• Supplementation of mineral mixture in the animals' diet |
| **Prussic acid** | Sorghum, Sudan grass, Guinea grass, Johnson grass, Lima bean, White clover, Cassava | • Young upper leaves and new shoots<br>• Excessive use of 2,4-D herbicide<br>• Soil containing high nitrogen and low phosphorus status | • Don't allow to graze sorghum less than 45-50 cm in height<br>• Forage conservation (silage & hay)<br>• Never grazed where frost is likely to occur |
| **Tanins** | Sorghum, Subabul, Dhaincha, Lucern, Mustard oil cake etc. | Drought conditions or moisture deficit situation | Avoid tannin containing diet |

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|---|---|---|---|
| **Mimosine** | Subabul | Prolonged feeding of subabul Young leaves have high mimosine | Fed subabul by mixing with other diet |
| **Aflatoxin** | Aspergillus flavus (causing agent) | Stored feed in moisture condition (10-40%) | Avoid moistened condition for feed storage |

## Conclusions

Quality and anti-equality factors have a multitude of dimensions. Some of the biochemical compound which are considered to be anti- quality component has a significant role in plant physiology. However; advancement to the modern scientific procedure has opened new opportunities to find a middle ground to effectively curb issues related to the anti-quality factor of forages. The integration of selective modern breeding practices, with agronomic managemental approach married with better animal feeding practice, can easily overcome the issue of anti-equality factors and sustain forage quality attributes.

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Online ISSN: 2582-368X
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