Harmful Natural Constituents Present in Livestock Feedstuffs

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Antinutritional Factors and their Classification

- **Antinutritional Factors (ANFs)**:
- Defined as those substances present in the diet which by themselves or their metabolic products arising in the system interfere with the feed utilization, reduce production or affects the health of the animal.

- These anti-nutritive substances are often referred to as **"toxic factors"** because of the deleterious effects they produce when eaten by animals.

- Toxic substances of natural origin can be classified based on their chemical properties and on the basis of their effect on utilization of nutrients.

(A) According to their Chemical Properties

- **Group I : Proteins**
  1. Protease inhibitor
  2. Haemagglutinins (Lectins)
- **Group II : Glycosides**
  1. Saponins
  2. Cyanogens
  3. Glucosinolates (Goitrogens) or Thioglucosides
- **Group III : Phenols**
  1. Gossypol
  2. Tannins
- **Group IV : Miscellaneous**
  1. Antimetals
  2. Antivitamins

(B) **<u>On the Basis of Nutrients they Affect Directly or Indirectly</u>**

1. Substances depressing digestion or metabolic utilization of proteins:

- Protease inhibitor (Trypsin and Chymotrypsin inhibitor)
- Haemagglutinins (Lectins)
- Saponins
- polyphenolic components

2. Substances reducing solubility or interfering with the utilization of minerals:

- Phytic acid
- Oxalic acid
- Glucosinolates (Thioglucosides)
- Gossypol

3. Substances increasing the requirements of certain vitamins:

- Anti-vitamin: A,D,E,K.
- Anti-vitamin: $B_{1,}$ $B_{6,}$ B_{12} and nicotinic acid

4. Substances with a negative effect on the digestion of carbohydrates :

- Amylase inhibitors
- Phenolic compounds
- Flatulence factors

PROTEASE INHIBITOR

- Substances that have the ability to inhibit the proteolytic activity of certain digestive enzymes.
- e.g. legume seeds: soyabean, kidney bean, mung bean.
- Protease inhibitors are concentrated in the outer part of the cotyledon mass.
- Protease inhibitors are two types:
  a. kunitz inhibitor (inhibits only trypsin)
  b. Bowman-birk inhibitor (inhibits trypsin and Chymotrypsin).
- The inhibitory substances are mostly heat labile and thus proper heat treatment inactivates the protease inhibitors.
- Overheating can damage some nutrients such as amino acids and vitamins
- Quality control tests have been developed to assess the adequacy of heat treatment. These include trypsin inhibitor and urease assays.

- Trypsin inhibitor of soybean interferes with the availability of methionine from the raw soybean.
- Young chicken fed raw soybean developed hypertrophy of the pancreas.
- Pancreatic hypertrophy and hyperplasia not observed in large animal species such as pigs, dog and calves.
- The important factors controlling trypsin inhibitor destruction are:
- 1. temperature
- 2. duration of heating
- 3. particle size
- 4. moisture level.
- The trypsin inhibitor activity of solvent extracted SBM was destroyed by exposure to steam for 60 minutes, or by autoclaving under the following conditions. 5 psi for 45 min, 10 psi for 30 min and 15 psi for 20 min. duration.

Haemagglutinins (Lections)

- Soybean Castor bean (ricin) and other legume seeds contain haemagglutinins
- These are found in both plant and animal tissue
- These toxic substances are able to combine with the glycoprotein components of red blood cells (RBC) causing agglutination of the cells
- Ricin is extremely toxic. It causes severe inflammatory changes in the intestines, kidney, thyroid gland etc
- Lectins are resistant to digestion by pancreatic juice.
- Lectins are resistant to destruction by dry heat & are destroyed by steam

Saponins

- These are glycosides characterized by bitter taste, forming in aqueous solution and haemolyse RBC.
- They are able to form complexes with sterols. including those associated with the plasma membranes of animal cells.
- Generally, saponins are less important because their levels are low in most common feed ingredients for monogastric animals.
- Their toxicity is related to their activity in lowering surface tension in ruminants.
- The important common forages which cause saponin poisoning of livestock are Lucerne ,soybean etc.
- Average Saponin content of the leaves are twice as much as those of the stems and that the saponin content declines as the plant become older.

- Excess feeding of green lucerne or legume forages saponins lower the surface tension of ruminal contents leading to accumulation of gas, condition is known as “bloat” This is also know as tympany/tympnitis.
- The presence of saponins has been cited as one of the factors responsible for formation of foam in the rumen and thereby gas is trapped in the rumen contents with the result of which animals can not eliminate it by belching.
- The rumen distension impedes the blood flow and anorexia develops which is responsible for respiratory failure.
- Turpentine and paraffin oil are helpful in reducing bloat.
- For ruminants 1 to 2 kg dry fodder should be fed before letting the animals for legume pastures or before excessive feeding of green legume fodders as a preventive measure.

Cyanogens

- Cyanide in trace amounts is present in the plant kingdom.
- It occurs mainly in the form of cyanogenic glycoside.
- In plants the Glucoside is non-toxic in the intact tissues.
- These glycosides can be hydrolyzed to prussic acid or hydrocyanic acid (HCN) by the enzyme usually present in the same plant or as they are being are being digested by animals.
- This reaction can take place in the rumen by microbial activity.
- The HCN is rapidly absorbed and some is eliminated through the lungs, but the greater part is rapidly detoxified in the liver by conversion to thiocyanate.
- Excess cyanide ion can quickly produce anoxia of the central nervous system inactivating the cytochrome oxidase system and death can result within a few seconds.

There are three distinct glycosides:

Glycoside	Plant source
• Amygdalin:	Almonds
• Dhurrin:	Jowar and other immature grasses
• Linamarin:	Pulses, Linseed, cassava.

- Ruminants are more susceptible to HCN poisoning than are horses and pigs because the enzyme required for the release of HCN is destroyed in horses and pigs by the gastric HCl.
- Cattle are most susceptible than sheep.

- Jowar, sudan fodder, linseed: may develop toxic levels of HCN in the new growth that follows either a period of drought or a period of heavy trampling or physical damage by frost, etc.
- Heavy nitrate fertilization followed by an abundant irrigation or rainfall may increase the potential of HCN poisoning of these crops.
- Feeding of immature jowar green fodder should be a avoided to prevent HCN poisoning.
- Animals which have not shown much evidence of toxicity may be injected:

➢ for cattle: I/V with 3.0g sodium nitrate and 15.0 g sodium thiosulphate in 200 ml. H_2O

➢ for sheep: I/V with 1.0g sodium nitrate and 2.5 g sodium thiosulphate in 50 ml H_2O.

Glucosinolates

- Most plant of cruciferae family (Cabbage, turnips rutabaga, rapeseed and mustard green) contain these substances.
- These glucosinolates are responsible for the pungent flavors found in plants belonging to the genus Brassica.
- Their main biological effect is to depress the synthesis of the thyroid hormone (Thyroxine, T4) and Triodothyronine (T_3) thus producing goiter.
- Goiter is not caused by the glucosinolates *per se* but by their products of hydrolysis.

- The glucosinolates occur in the root stem leaf and seed and are always accompanied by the enzyme myrosinase (thioglucosidase) , which is capable of hydrolyzing them to thiocyanates, glucose and acid sulphate and isothiocyanates or nitriles depending on pH.
- These volatile isothiocyanates undergo cyclization in the presence of myrosinase to vinyloxazolidinethione which is potently goitrogenic.
- These cause depressed iodine uptake with an enlargement of the thyroid gland and liver damage.
- Growth depression and enlargement of liver and kidneys are also observed in chicks and pigs.
- Ruminants appear to be less susceptible to the toxic effect of glucosinolates compared to pigs and poultry.
- This is probably the result of the glucosinolates being relatively unhydrolysed in the rumen.

- Myrosinase is present not only in the plant and in the seed but also intestinal bacteria have appropriate enzyme systems for glucosinolate hydrolysis.
- Because of the presence of myrosinase in the intestine inactivation of myrosinase in the seed is not an appropriate way to eliminate the antinutritional effects of glucosinolates.
- High-or-low-glucosinolate cultivars of rapeseed are available.
- Double-zero cultivars were developed in Canada.

Gossypol

- In genus Gossypium gossypol is present in pigment glands of leaves, stems roots and seeds.
- These pigments can exist either in a free form or as a gossypol-protein in complex.
- It is highly toxic to monogastric animals. Pigs and rabbits are more sensitive than poultry.
- Horses are resistant.
- Ruminants are more resistant due to the formation of stable complexes with soluble protein in rumen which are resistant to enzymatic breakdown.
- Gossypol form complex with metals like iron and the toxic effect can be overcome by supplementing iron as ferrous sulphate.
- Whole cotton seed contain gossypol: a total 1.09 to 1.53% of which free form is 0.19%

The physiological effects of free gossypol are:

- reduced appetite
- loss of body weight
- accumulation of fluid in the body cavities
- cardiac irregularity
- reduced oxygen carrying capacity of the blood (reduced haemoglobin content)
- adverse effect on certain liver enzymes
- Decreased egg size and decreased egg hatchability
- Free gossypol content of 0.06% depresses growth in chicks while 0.1% causes severe effect
- In laying hens, 0.15% free gossypol reduced egg production

- In laying hens:

➢ 0.15% free gossypol reduced egg production. Egg yolk will have an olive green colour.

➢ Further higher levels cause yellow brown pigments in liver and spleen due to destructive effect on red blood cells.

- In pigs:

➢ A dietary level 0.01% reduced growth rate while 0.015% showed toxic symptoms.

- New varieties of cotton seed: less than 0.01% total gossypol (0.002% in the free form) are available.
- Commercial production of cottonseed meal: heat treatment: decreases the content of free gossypol
- The availability of lysine is reduced because of the interaction of the aldehyde groups of gossypol with the amino group of lysine.

Tannins

- They are polyphenolic substance.
- The term tannin was coined by Seguin in 1796.
- Tannins are of two types.

➢ A. Hydrolysable tannins:

These can be readily hydrolysed by water, acids, bases or enzymes and yield gallotannins and ellagitannins.

➢ B. Condensed tannins:

These are Flavonoids- polymers of flavonol.

➢ Both hydrolysable and condensed tannins are widely distributed in nature

Tannin content of certain feedstuffs:

- Sorghum 20 to 10%
- Salseed meal 9.0 to 12%
- Mangoseed cake 5.0 to 7%
- Mustard oil cake 2.5 to 3.5%
- Lucerne meal 0.1 to 3.0%

➢ Tannins are astringent in nature leading to poor palatability.

➢ They cause a dry sensation in the mouth, probably by reducing the lubricant action of the glycoproteins in the saliva.

- Tannin bind the proteins and are thus inhibitors of proteolytic enzymes.
- High tannin content also depresses cellulose activity and thus affects digestion of crude fibre.
- So tannins reduce the digestibility of protein and dry matter.
- Sorghum contains high levels of condensed tannins.
- Most of the tannins are locate in seed coats. Decortication of seeds will reduce the tannin content.
- Germination of legumes also result a decrease in the tannin content.

- Tannins: in some tree leaves: form complexes with plant proteins: increasing the amount of plant protein bypassing the rumen
- When the tannin-protein complexes are dissociated in the low pH of the abomasums, an additional source of protein is made available
- But in some cases, the tannins protect the proteins from digestion even in the small intestine
- Tannins :on protein availability:-
- beneficial effect (increasing by pass protein)
- detrimental effect (depressing palatability, decreasing rumen ammonia, decreasing post-ruminal protein absorption)

- Tannins suppress: methanogenesis by reducing methanhogenic populations in the rumen:-
  - either directly
  - or by reducing the protozoal population thereby reducing methanogens symbiotically associated with the protozoal population

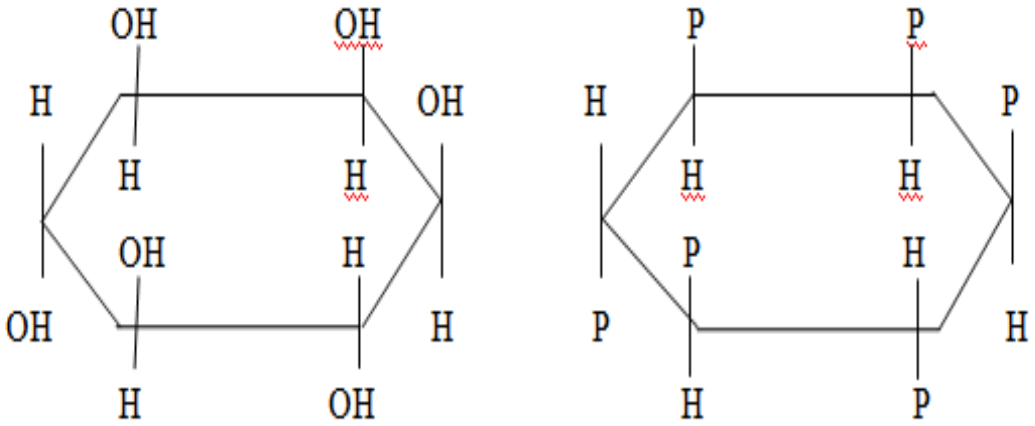
- Tannin sources containing both hydrolysable tannins and condensed tannins are more potent in suppressing methanogenesis than those containing only hydrolysable tannins.

Polyphenolic Compounds of Certain Tree Leaves

Tree leaves/Constituents	Total tannin phenolics (As tannic acid equivalent)
• Acacia auriculiformis	12.96-14.17
• Cashew	19.45-21.36
• Gliricidia	5.28
• Guava	16.18
• Jack	14.69
• Sesbania grandiflora	8.64
• Subabul	10.78
• Yellow gold mohur	11.98

Phytic acid

Phytic acid is an ester formed by combination of the 6 alcoholic groups of inositol with 6 molecules of hexaphosphonc acid. Hence its name inositol hexaphosphoric acid.



- Because of the presence of the large number of phosphoric acid radicals it can form simple salts or mixed salts as well as metabolic or protein complexes.
- Sodium and potassium salts are soluble.
- Calcium, iron magnesium, copper, Zinc and lead salts (phytates) are insoluble even at pH 3-4.
- Phytate phosphorus is a poor source of phosphorus.
- Seeds of cereals, dried legumes, oilseeds and nuts are rich in phytic acid.
- Phytic concentration is more in the rind (pericarp + aleurone layer) and the embryo than the core (endosperm).

- About 67% or more of the P in cereal grains: is in form of phytin P
- Availability of P from plant feeds to non-ruminants: less than 33%
- P from inorganic mineral supplements and of animal origin are available: more than 80%
- PP is less effectively utilized than the inorganic form in poultry pigs and horses since phytin is incompletely broken down in their digestive tract.
- Dietary phytase and microbial phytase: breakdown PP.
- Addition of the enzyme phytase to the ingredients of vegetable origin can increase phosphorus digestibility
- Phytase produced by rumen microorganisms makes phytin phosphorus available to ruminants
- Phytic acid depresses the utilization of several mineral elements such as Ca, Mg, Fe, Zn, etc. It forms insoluble compounds which are eliminated in the faeces.

Oxalic acid

- Plant foodstuffs have much oxalic acid
- Foodstuffs of animal origin have relatively little oxalic acid.
- Oxalic acid is present as free and in salt form
- It is a dicarboxylic acid $(COOH)_2$
- The greater part of oxalic acid in plants is present in the form of soluble oxalates (potassium, sodium and ammonium oxalates)
- 10-20% oxalic acid appears as insoluble calcium and magnesium oxalate especially within the cells.
- The leaves are richer than other parts
- In general young leaves contain smaller quantities than mature leaves
- Ageing as well as over ripening of vegetables is accompanied by an increase in the proportion of calcium oxalate

- Cattle fed on paddy straw & napier, bajra, grasses (2% oxalate) develop: a negative calcium balance
- Rumen microflora (Pseudomonas, Streptomyces, etc.) decompose much of soluble oxalic acid and to a less extent its calcium salts.
- When dietary amount exceeds: normal degradation (by microbes) is interrupted and the excess oxalates combine with feed calcium to form insoluble calcium oxalate and thus calcium becomes unavailable for absorption
- OR excess oxalate (20-30mg per cent) may be absorbed from the rumen into the blood stream where it can combine with calcium: produce hypocalcaemia.
- The insoluble calcium oxalate may then crystalise in various tissues, specially kidneys and rumen wall.

Antivitamins

These are organic compounds which either destroy certain vitamins or combine and form unobservable complexes or interfere with digestive and /or metabolic functions.

➢ Antivitamin A:

- ✓ Raw soybean contains enzyme lipoxygenase which can be destroyed by heating 5min with steam at atmospheric pressure.
- ✓ Lipoxygenase catalyses oxidation of carotene the precursor of vitamin A.

Antivitamin E:

- Diets with raw kidney beans produced muscular dystrophy in chicks and lambs by reducing plasma vitamin E. Autoclaving destroys the factor.

Antivitamin K:

- Eating sweet clover cause fatal haemorrhagic condition in cattle. This is known as "Sweet clover disease"
- Dicoumarol present in sweet clover is responsible
- Dicoumarol reduce prothrombin levels in blood and affects blood clotting

Antivitamin D:

Rachitogenic activity of isolated soya protein (unheated) has been found with chicks and pigs. Autoclaving eliminates this rechitogenic activity.

Anti-pyridoxine:

- An antagonist of pyridoxine from linseed has been identified as 1-amino-D-proline.
- It occurs naturally in combination with glutamic acid as a peptide and it is called linatine.
- Nutritive value of linseed meal for chicks can be considerably improved after water treatment and autoclaving.

Antiniacin :

An antagonist of niacin, niacytin is found in maize wheat bran etc. which cause perosis and growth depression

Antithiamine:

Enzyme thiaminase present in bracken fern act as antithiamine factor

Alkaloids

- Alkaloids are basic substances that contain nitrogen in heterocyclic ring.
- 15-20% of all vascular plants contain alkaloids.
- Most alkaloids are derived from amino acids in their synthesis by plants.
- Amino acids are decarboxylated to amines and the amines are converted to aldehyde by amine oxides.
- Condensation of the aldehyde and amine groups then yields the heterocyclic ring.

Alkaloids with their sources

• Atropine	Deadly nightshade
• Cocaine	Leaves of Coca plant
• Morphine	Dried latex of opium poppy
• Nicotine	Tobacco
• Quinine	Cinchona bark
• Solanine	Unripe potatoes
• Strychnine	Seeds of nux vomica