Constraints in the utilization of tropical feeds and strategies to overcome those constraints

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Grim scenario....

1. Growing world population (8 billion by 2020).

2. Arable land decreasing

3. People likely to consume more animal products as the economy of a country develops and its GDP grows.

4. Urbanization will change the pattern of food intake to higher consumption of animal products.

(IFPRI, 1997)

A possible solution...

- Efficient use of agriculture byproducts & tree foliage
- Introduction of new or relatively lesser-known seed-bearing and fodder producing plants & trees, capable of growing in poor soils

Benefits...

- Economic benefits to farmers
- Lower environment pollution
- Control of soil erosion
- Creation of jobs
- Diversification of traditional agriculture
- Conservation of biodiversity

Tree foliage as ruminant feeds
– perspective and properties

In context of

- ***Increasing human population***
- ***Decreasing land availability for forage crop production***
- ***Increasing dependence of ruminants on 'low quality' basal feed resources***
- ***Competition for the available protein meals***

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Tree foliages are increasingly seen as potential protein supplements

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40 – 50 % total feed available
in mountainous and arid areas

Potential roles of tree foliage

- *High quality, high digestibility biomass*

- *Supplement to provide nutrients deficient (protein, sulphur and phosphorus) in the basal diet [browses/tree leaves have higher CP than herbaceous legumes and grasses]*

- *Source of rumen by-pass protein ?*

Antinutritional factors are substances of plant origin, which by themselves or their metabolic product(s) arising in biological system interfere with nutrient utilization leading to decreased animal productivity, affecting animal health and/or causing toxicity

Why a plant produces ANFs? **Defense**

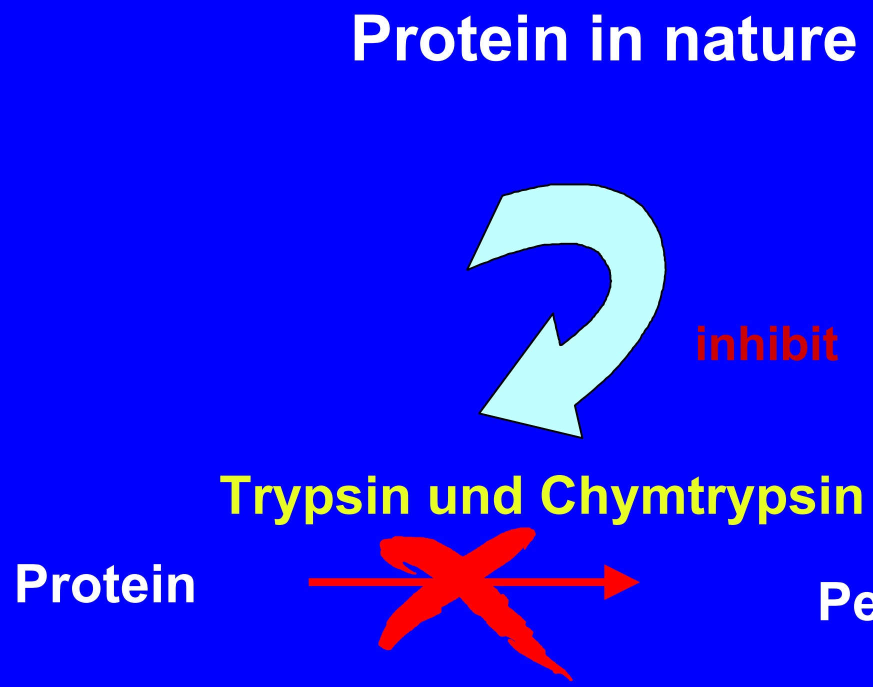
Stress conditions → Enhance synthesis of ANFs

Why it is important to study ANFs, and what is their significance in the tropics?

In the tropics:

- **plants are under higher stress**
- **scarcity of feed**
- **need to feed by-products (high in ANFs)**

1. Protease inhibitors



Soyabean,
Groundnut,
Beans

Group 1: MW 6000 – 10000 Da; high in di-sulphide bridges (inhibit both Trypsin and Chymotrypsin)

Group 2: MW 20000 – 25000 Da; low in di-sulphide bridges (inhibit only trypsin)

Biological effects of Protease Inhibitors

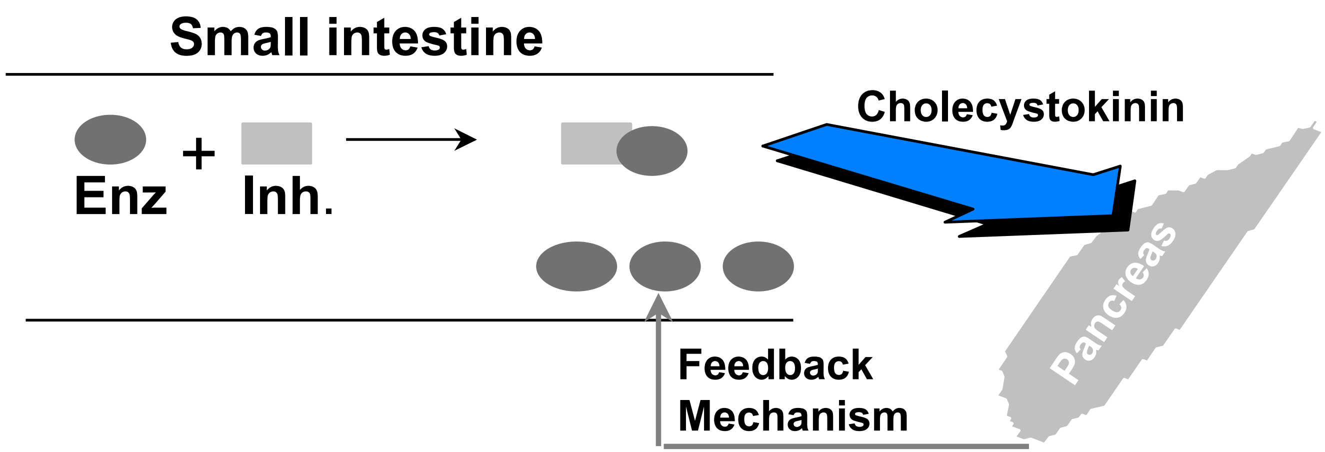
Monogastric animals

Decrease in growth
Decrease in feed utilization
Increase in pancreas size (rat and chicken but not in pigs)
Decrease in proteolytic activity in intestine

Ruminants

No effect on feed intake and feed utilization

Protease inhibitors: Mechanism of action



Rich in sulphur-containing amino acids

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Loss in endogenous sulphur-containing amino acid

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Decrease in animal production

How to inactivate Protease Inhibitors

1. Heat treatment
2. Infra-red treatment
3. Fermentation
4. Germination
5. Addition of sulphur-containing amino acids

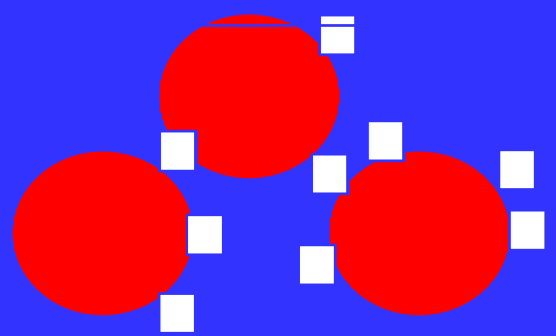
2. Lectin (haemagglutins)

Lectin → Protein

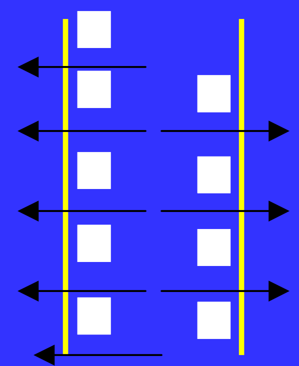
Glyco-protein —Covalent binding→ Sugar + protein

Molecular weight: 60000 – 100000 Da

Lectin (■): Mechanism of action



Red blood cells



Interference in absorption of nutrients

Intestinal wall

■ Curcin —Inhibits→ Ribosomal protein synthesis

Biological effects of Lectin

1. Decrease nutrient flow through intestine
2. Decrease activity of brush border hydrolases
3. Increase catabolism of muscle and liver proteins
4. Decrease growth
5. Higher effects in monogastrics and lower in ruminants

Soyabean, groundnut, beans, rhizinus, jatropha, chickpea

How to inactivate Lectin?

1. Heat treatment

2. Infra-red treatment

3. Fermentation

4. Germination

3. Phenolics

Tannin phenolics (which bind proteins)

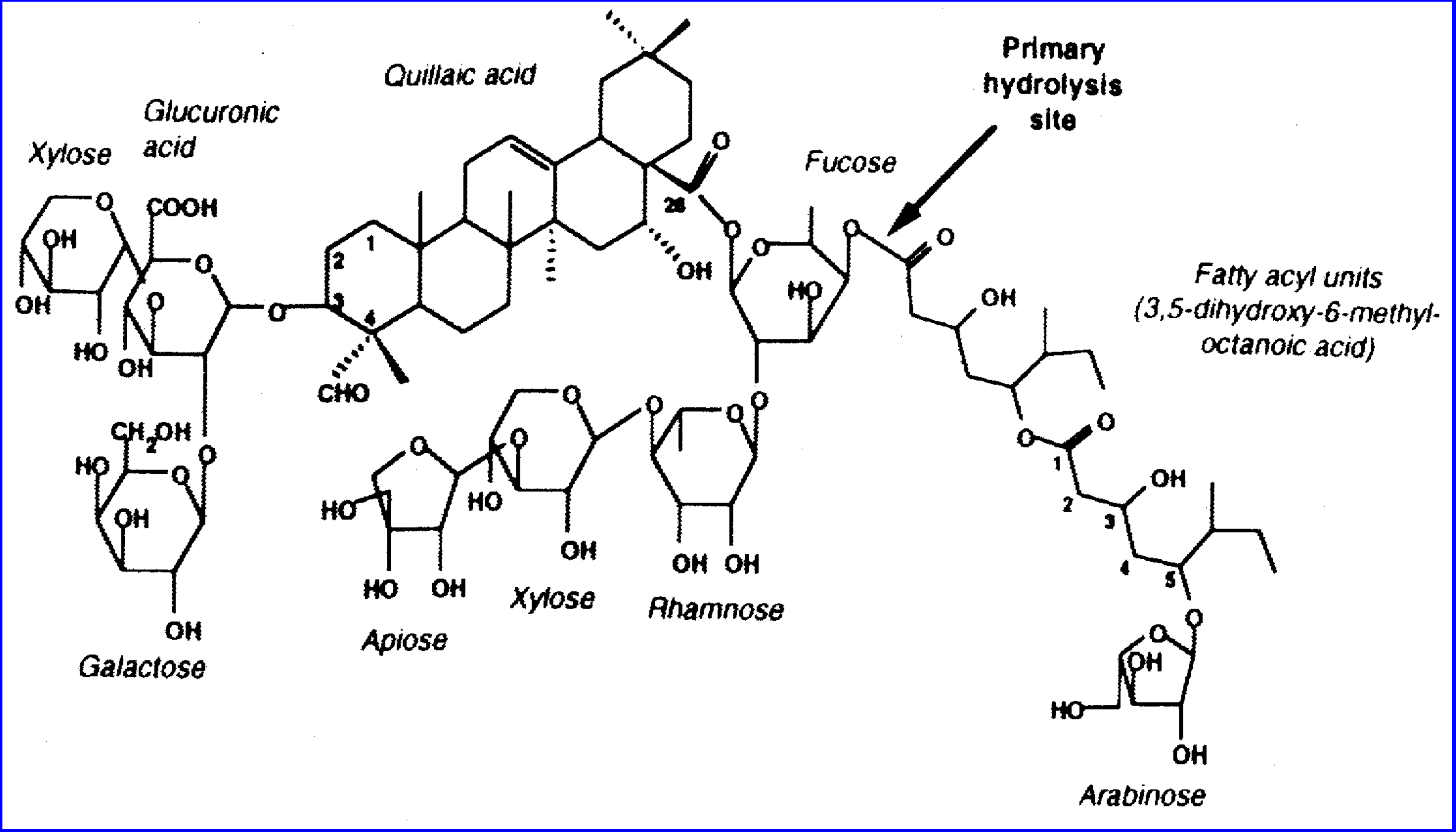
- **Hydrolysable Tannins** (Esters of polyhydroxy alcohol for example sugar and Gallic or Ellagic acids)
  - → Gallic acid or Ellagic acid + Sugar
- **Condensed Tannins** (Polymers of Flavan 3-ols and/or Flavan 3,4-diols)
  - → Difficult to break

Nontannin phenolics (which do not bind proteins)

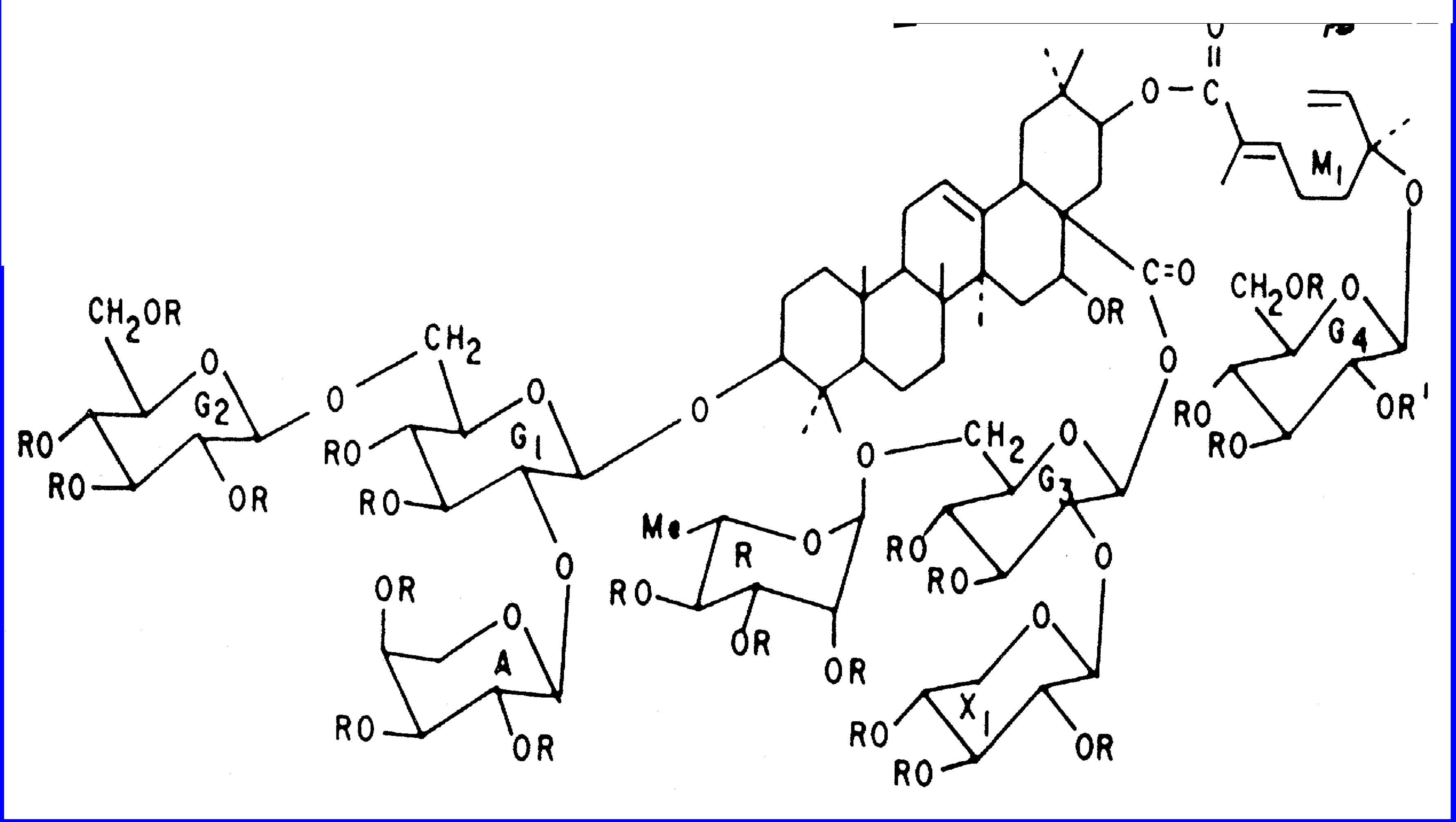
4. Saponins = Aglycone + sugar

- Steroidal saponins
- Triterpenoidal saponins

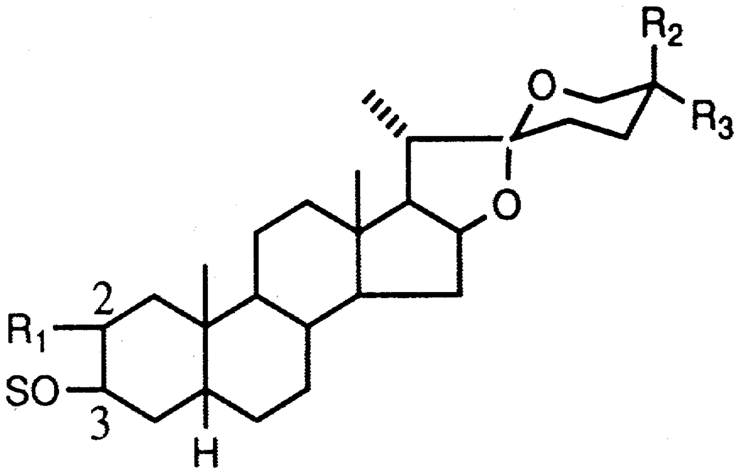
Quillaja saponin



Acacia auriculoformis saponins



Yucca saponins



aglycone, S = H

1: sarsasapogenin,

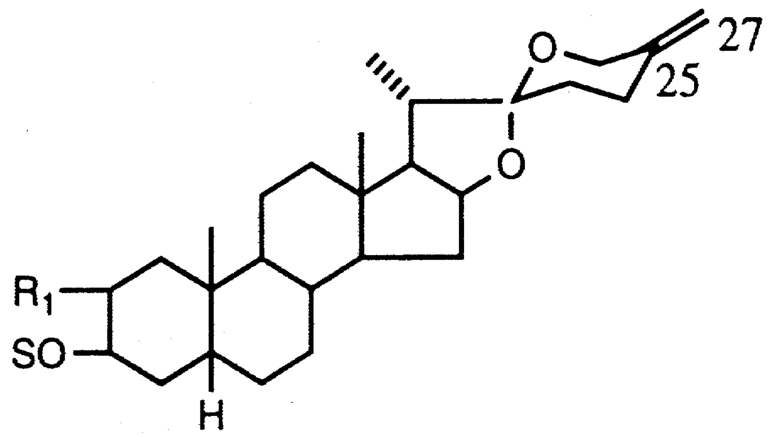
$R_1 = R_3 = H, R_2 = CH_3$

2: smilagenin,

$R_1 = R_2 = H, R_3 = CH_3$

3: markogenin,

$R_1 = OH, R_2 = CH_3, R_3 = H$



aglycone, S = H

4: 5β-spirost-25(27)-en-3β-ol

$R_1 = H$

5: 5β-spirost-24(27)-ene-2β,3β-diol

$R_1 = OH$

Some tropical plants rich in saponins

1. *Quillaja saponins*...Mexico & Southern America
2. *Yucca schidigera*....Mexico & Southern America
3. *Phytolacca dodecandra* (berry)....Zimbabwe & Ethiopia
4. *Saponaria officinalis* .... Most tropical countries
5. *Madhuca butyracea* (seeds)….India
6. *Sesbania sesban* leaves ...Asia & Africa
7. *Sapindus saponaria* ....Indonesia, India, Malaysia

Some major biological effects:

1. Haemolytic & piscicidal activity (toxicity towards fish)
2. Interaction with mucous membranes & influence on nutrient absorption
3. Effect on palatability & feed intake
4. Ammonia binding properties
5. Bloat production
6. Photosensitization
7. Insecticidal & molluscicidal
8. Human health aspects: hypocholesterolemic, anticarcinogenic, immune stimulating, antifungal, antibacterial and antiviral effects

Cheeke (1997) Adv. Exp. Med. Biol. 405, 377

Milgate & Robert (1995) Nutr. Res. 15, 1223.

Hostettmann et al (1991) Method Plant Biochem. 7, 435

Price et al. (1987) CRC Crit Rev Food Sci. 26, 27

5. Oxalate 6. Phytate

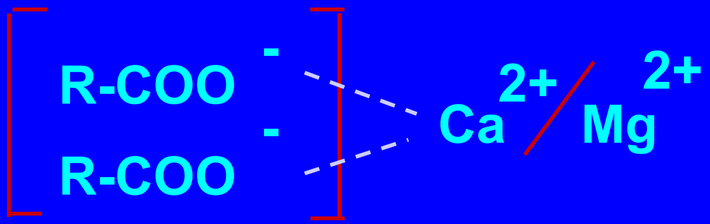
ANFs affecting metal ion utilization

Present in:

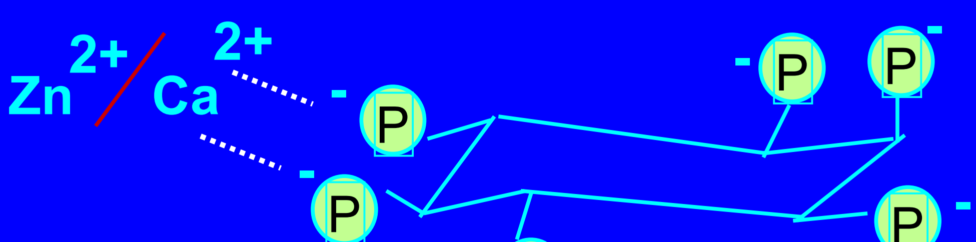
a) Oxalate: Napier grass, rice straw, water hyacinth, Atriplex and Setaria leaves

b) Phytate: Cotton seed meal, ground nut meal, Jatropha

Mechanism of action



Oxalate



Phytic acid , Hexadihydrogenphosphate

Biological effects

1. Decrease in mineral availability (Zn, Ca, Mg, Cu).

2. Formation of Calcium-oxalate in kidney

3. Decrease in availability of minerals, leading to decrease in enzyme activity → body dis-functions:
   - Reproductive function
   - Decrease in growth
   - Decrease egg production in birds
   - In extreme situation: hypocalcaemia leading to shock in animals

4. Phytate can bind to Protein and decrease protein digestibility

5. Leguminous flour and seeds contain up to 66 % of their phosphorus in the form of phosphate

Detoxification

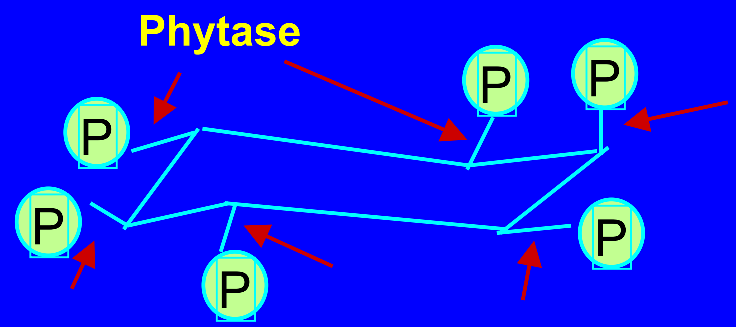
1. Heat — Not effective

2. Water treatment — Not effective

3. Slow exposure to ruminants of oxylate – adaptation (*Oxalobacter formigens*)

4. Addition of mineral mixture

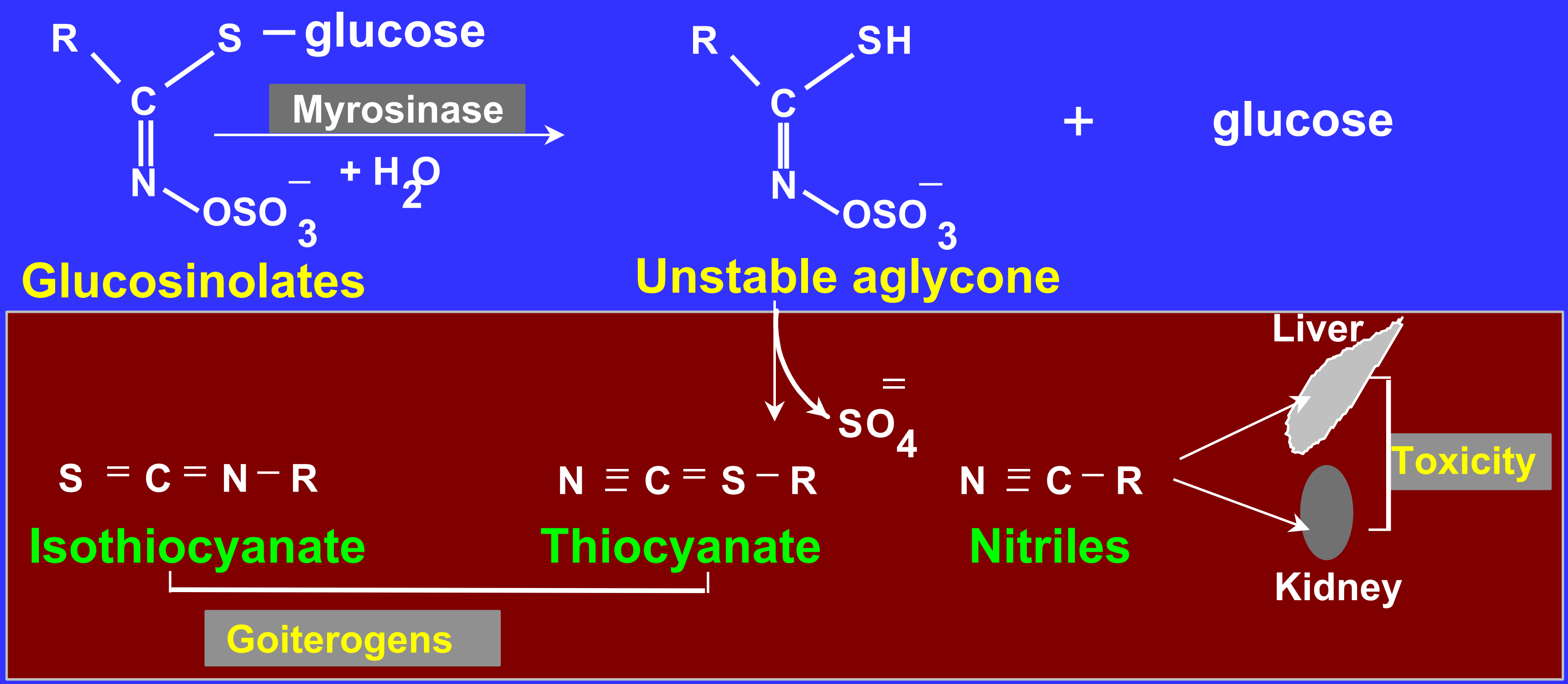
5. Addition of microbial phytase (*Aspergillus niger*)



7. (Thio)glucosinolate

Glucosinolate : 4(alpha-L-rhamnosyloxy) benzyl glucosinolate

Mechanism of action



Present in: Seeds and meal of Moringa, Brassicas, rapeseed, mustard

Biological effects of (Thio)glucosinolate

- Goiter, growth depression, decrease in reproduction rate, enlargement of liver and kidney, impairment of BMR
- Monogastrics more sensitive than ruminants (up to 10 % rapeseed in ration has no negative effects in ruminants)
- Degraded products of glucosinolates appear in milk (could have negative effects on children)

Detoxification

Heat treatment	Not effective
Water treatment	Effective
Extraction with organic solvents (50% aq ethanol/methanol)	Effective but expensive
Rapeseed (-erucic acid; - glucosin.)	Breeding
Addition of iron	Effective

What levels of Glucosinolate can be tolerated?

Pigs

Negative effect on sows fertility at ≥ 4 µmol/g feed and ≥ 8 mmol/day intake

Rats

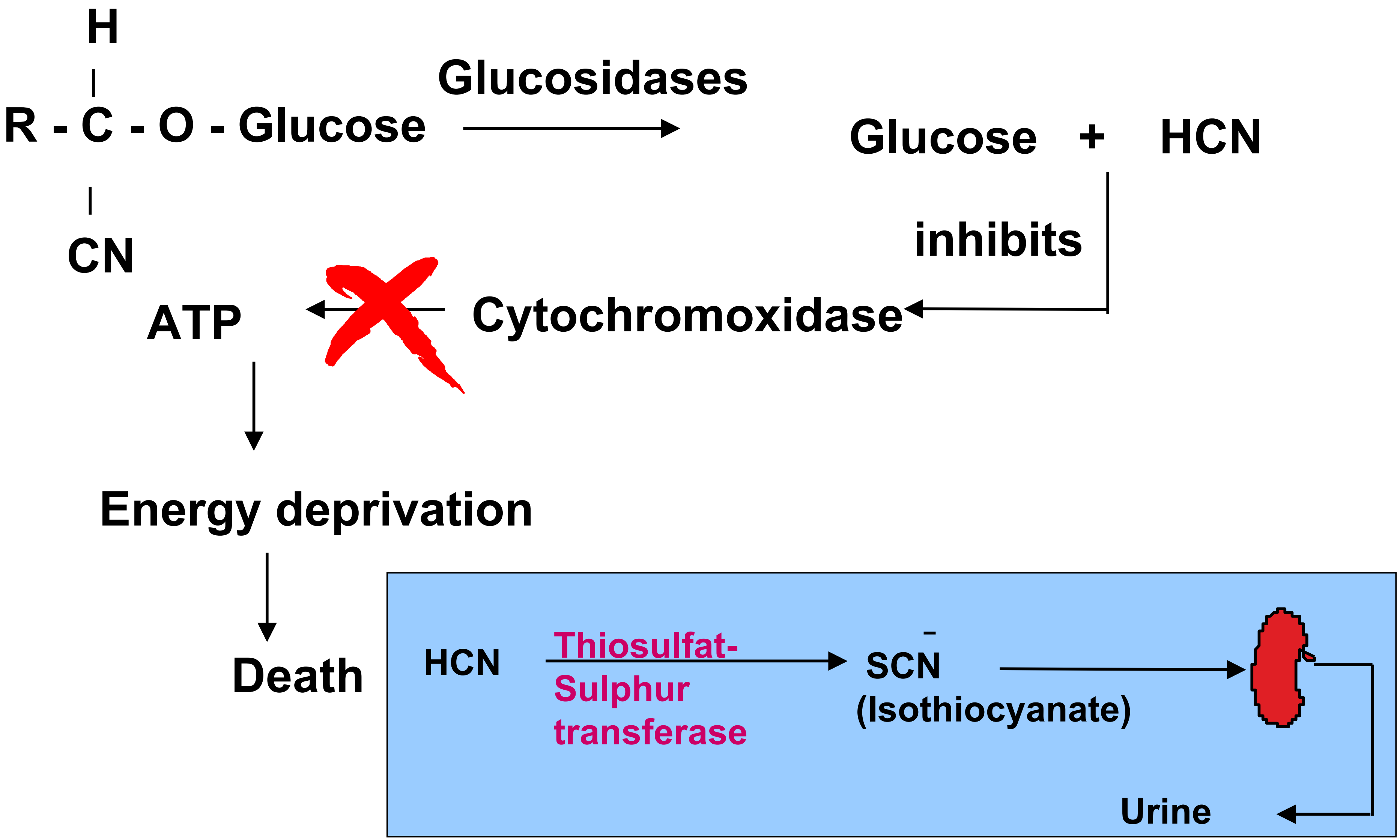
High mortality of young ones at > 2.7 mmol/g feed

Cows

Higher calving to conception interval at ≥ 75 mmol/cow/day

9. Cyanogens

Glycosides of sugar & -CN containing aglycon (generally taste bitter)



Cyanogens

Present in: Cassava, White clover, Linseed, rubber meal, young leaves of sorghum, Acacia and Bamboo

Sorghum: 250 mg HCN/100g; Bamboo: 800 mg HCN/100g

Ruminants more sensitive than monogastrics

Low pH in monogastrics inactivates plant glucosidases

Toxic symptoms: Trembling, abnormal respiration, blue coloration of mucus membrane (lips), death at high and fast intake

Detoxification:

- For Cassava:
  - Soaking in water (discard water), fermentation
- Drying in Sun
- Fermentation
- Feeding of old leaves
- Feeding of hay
- Addition of methionine

Lethal dose for sheep and cattle

2 - 4 mg/kg BW ... HCN

20 - 40 mg/kg BW …… Cyanogen

Max. permissible levels as per EU & FAO/WHO, 1991)

< 100 mg HCN/kg for cassava and almonds

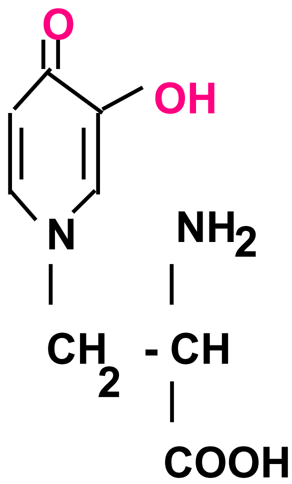
< 250 mg HCN/kg for linseed meal

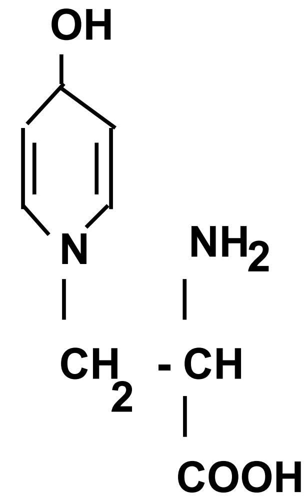
For monogastrics (except poultry) < 50 mg HCN/kg feed

For poultry < 10 mg HCN/kg feed

For human consumption < 10 mg HCN/kg cassava

10. Mimosine --Toxic amino acid





Tyrosine

Present in *Leucena leucocephala*

(CP in leaves ca 25%)

very young leaves:	up to 12 %
young leaves:	3 - 5 %
old leaves:	1 - 2 %
stems:	3 - 5 %
seeds:	4 - 5 %

Biological effects:

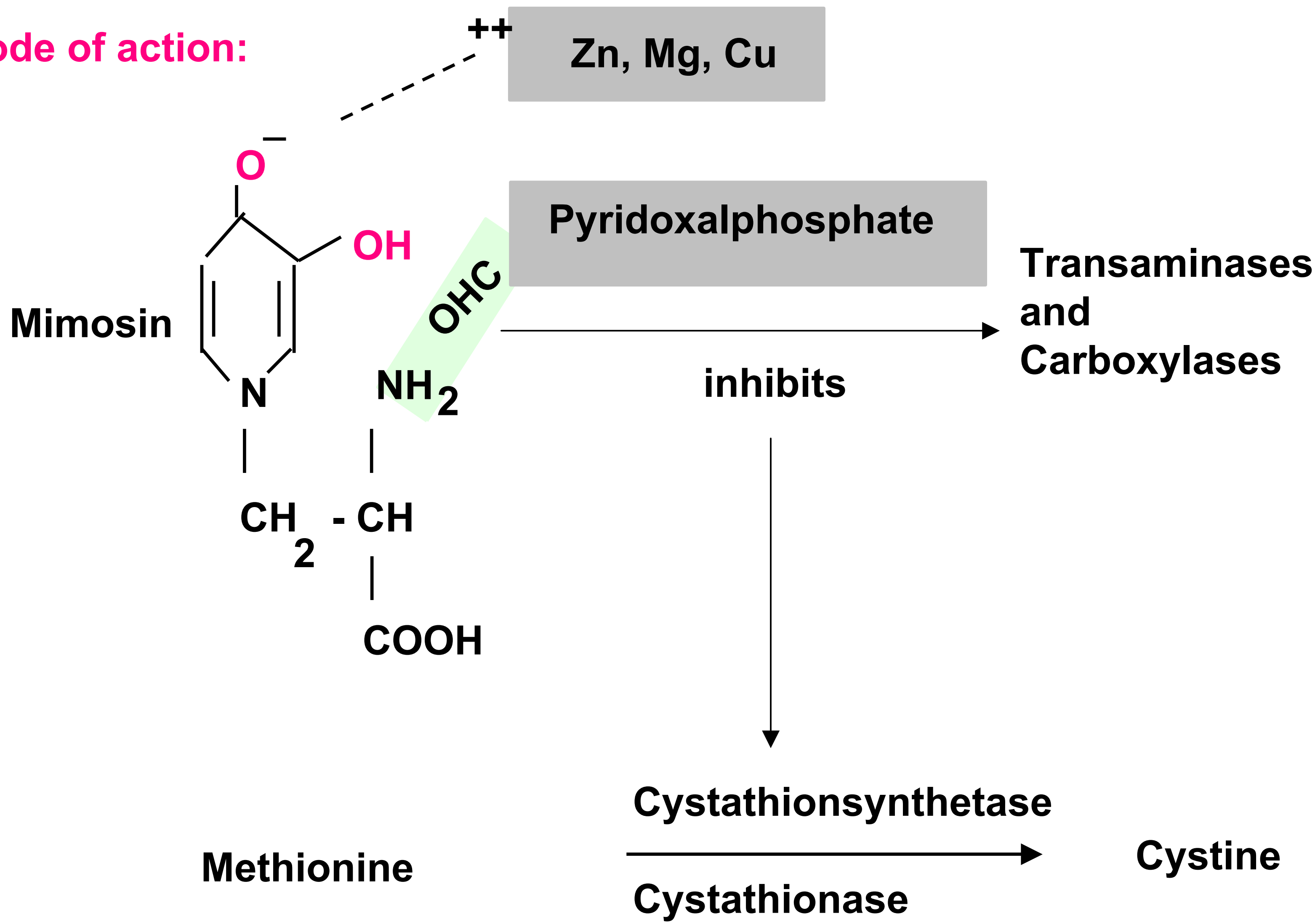
- Alopecia : hair loss; wool loss (at mimosine > 0.1 mmol/l in Plasma for 30 h)
- Growth depression
- Goiter
- Reproductive problem (long calving to conception interval & disturbed cyclicity)
- Excessive saliva production
- Decrease in feed intake

(affects both ruminants and monogastrics)

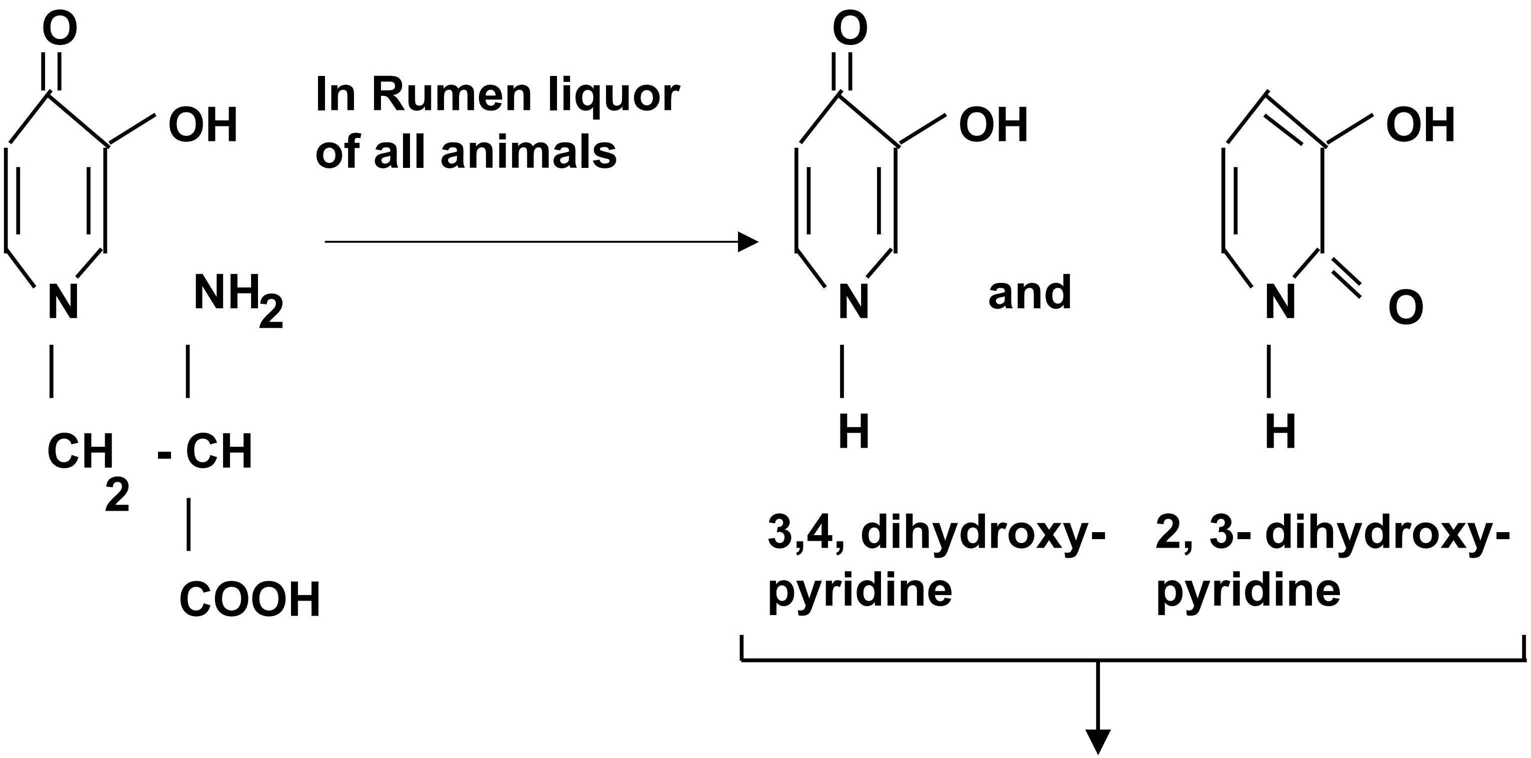
Maximum level of Leuceana in diet:

Poultry, pigs and rabbits: not more than 5 %
Buffalo and cattle: not more than 30%
Sheep: not more than 50 %

Mode of action:



Detoxification



Conversion through *Synergistes jonesii* in adapted animals → Non-toxic products

- Breeding of mimosine free/low variety(ies)
- Addition of Zinc or iron in diet ...... Not practical

Silica and Cutin--- structural role in the plant

↓

Lower extent of microbial digestion of
Cell wall polysaccharides

Other toxic amino acids

1. **Indospicine**

   Present in: Indigofera species, e.g. *I. spicata (a tropical pasture legumes)*

   Toxicity: weight loss, liver and kidney damage, and abortion

2. **N-oxalyl-L-,-diaminopropionic acid**

   Present in: Lathyrus species, Crotalaria, Acacia

   Toxicity: Neurological and skeletal diseases, spasic leg muscles, convulsions

3. **4-N-acetyl-2,4-diaminobutanoic acid**

   Present in: Acacia angustissima

   Toxicity: lower feed intake, neurological problems

Other toxic amino acids

4. Canavanine (2-amino-4-(guanidinooxy) butanoic acid)
(an analogue of arginine)

Present in: *350 species of the papilionoideae, a sub family of the Leguminosae*, seeds of *Dioclea Megacarpa, Canavalia ensiformis*

Toxicity: Immunological problems

5. 3,4-dihydroxyphenylalanine (L-DOPA))

Present in: Seeds of *Mucuna spp* and *Vicia faba*

Toxicity: haemolytic anemia, reduction in protein digestibility and growth

Recap

a) Substances themselves are not toxic, but their degraded products are toxic

1. Thioglucosinolate
2. Cyanogens

b) ANFs, for which ruminants are more sensitive than monogastrics

1. Cyanogens

c) ANFs, which are heat-sensitive and can be destroyed by heat treatment

1. Protease inhibitors
2. Lectin
3. Cyanogens (only moist heat treatment is effective)

Recap

d) ANFs, which can be detoxified by water treatment

1. Thioglucosinolate
2. Cyanogens

e) ANFs, to which ruminants can be adapted

1. Oxalate
2. Mimosine

☆ Breeding out ANFs is an attractive option, but it is environmental unfriendly, since higher amounts of pesticides need to be then used, The use of pesticides is also expensive.
An alternative approach could be the breeding of ANF-poor varieties having sufficient defense for the plant

☆ ANFs = Plant defensive compounds

☆ Stress conditions → Higher content of ANFs

ANFs are categorized in 3 groups

Recap

1. **ANFs affecting protein digestibility and absorption**
   - Protease inhibitor... are Protein..... and decrease Enzyme (Protease) activity
   - Lectin .... are Protein (Glyco-protein)
   - Tannin ... are Polyphenol

2. **ANFs affecting metal ion utilization**
   - Oxalate .... $RCOO^-$
   - Phytate ... Hexadihydrogenphosphate (negatively charged)
   - Thioglucoside...Sulphur containing Glucoside

3. **Other ANFs**
   - Cyanogens .. Glucoside of Cyanide
   - Mimosine .. Toxic amino acid, similar to tyrosine