PHENOLIC COMPOUNDS

Definition [adapted from Lewis' Dictionary of Toxicology 1998]

Phenolic compounds: A class of aromatic derivatives – aryl alcohols of benzene that have one or more hydroxy groups attached directly to the benzene ring. Their behaviour is distinctly different from other alcohols. They include by-products of petroleum refining, tanning and textile, dye and resin manufacturing such as phenol itself, cresols, flavonoids, xylenols, cinnamic acid, coumarin, resorcinol and naphthols. Chlorinated phenols have been used as wood preservatives for their fungicidal and insecticidal properties. Plant phenols are numerous and very diverse.
Saponin (saponic glycoside): Bitter-tasting steroidal glycosides of plant origin. The aglycone is a steroid alcohol (a sapogenin). Saponins for non-alkaline colloids in water that characteristically produce froth or foam when shaken. They are gastrointestinal irritants that are not readily absorbed through the intact alimentary mucosa. They are haemolytic.
Tannin: Any of a heterogenous group of acidic materials derived from gallic acid, a hydroxyphenol. Tannic acid is a glycoside yielding gallic acid and glucose on hydrolysis.

☑ *Gossypol*

Core data

Common sources: pigment glands of cotton seeds
Animals affected: pigs, pre-ruminants > ruminants
Mode of action: cardiomyopathy
Poisoning circumstances: excess gossypol in rations
Main effects:

- heart failure (myocardial necrosis)
- liver necrosis

Diagnosis: access + pathology
Therapy: remove excess gossypol from diet
Prevention: add iron or calcium to diet

Chemical structure:

A polyphenolic pigment. The gossypol content of cotton seed varies 0.002% to > 6.0%, most in range 0.5 – 1.6%

Sources:

- pigment glands in seeds of ***Gossypium*** **spp**. (cotton). Note that some strains of cotton do not have glands in seeds.

Toxicity:

free gossypol is toxic; protein-bound gossypol is non-toxic
free gossypol binds to dietary proteins (including the amino acid lysine), limiting their absorption
Australian cotton seed has similar free gossypol content to American (0.5-1.6%)
gossypol content = 0.055-0.075% in Australian CSM
effects usually from **chronic intake** - occur after weeks-months
monogastric and pre-ruminant animals more susceptible, but ruminants affected

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Horses: given that monogastric animals are said to be more susceptible than ruminants to gossypol toxicity, there is a curious lack of data in the literature on gossypol toxicity to horses. In fact, no reports of gossypol poisoning of horses appear to exist ["Horses are relatively resistant" (Os346, Humphreys 234)] and the literature describes the use of cotton seed meal as ration components for horses (Potter 1981, Moise & Wysocki 1981, Godbee 1983). Horses tolerate 0.2% free gossypol (Potter 1981).

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toxic dietary concentrations (free gossypol):
pigs >100 mg/kg
pre-ruminant calves, lambs (<6 months-old) >100 mg/kg
poultry 200-400 mg/kg
mature ruminants >1000-1500 mg/kg
gossypol in ruminants, humans, can → ↓ sperm production, ↓ sperm motility, ↑ proportion of abnormal sperm
research results on effects on fertility in cattle & sheep are conflicting (possibly due to variation in mineral content of diets)
The widespread feeding of livestock in Australia with whole cotton seed as a protein source provides potential for reproductive effects, but there are no definite reports from Australia to date

Mode of action: cardiac muscle necrosis possibly mediated through hypokalaemia
Organ systems affected:
Heart
Reproductive system (including poultry eggs)
Conditions of poisoning:
whole cotton seed or cotton seed meal fed to livestock
cotton seed as large proportion of diet (e.g. drought feeding)
pigs in New South Wales fed 10% or more cotton seed meal → premature births (gestation length <111 days) and poor piglet survival

Clinical signs:
Cardiac and associated effects:
Pigs – ill-thrift, weakness, dyspnoea, cyanosis, death
Cattle – weakness, dyspnoea, brisket oedema, distended jugular veins, depression, death ± haemolysis
Reproductive effects:
Ruminants – infertility
Pigs – premature birth and poor piglet survival
Poultry – ill thrift, reduced hatchability
- red-brown discoloration of yolks
Pathology:
Cardiac and associated effects:
cardiomyopathy (cardiac dilation ± pale myocardial streaking; histologically cardiac muscle necrosis)
pulmonary oedema, fluid in thorax and abdomen
periacinar hepatic congestion and necrosis
mild nephrosis
Reproductive effects:
testicular cessation of spermatogenesis
Diagnosis:
access + pathology
assay feed for free gossypol (note that the relevant feed batch may no longer be available)
Therapy:
remove excess gossypol from diet
supportive therapy with high quality diet supplemented with lysine, methionine and fat-soluble vitamins
Prevention & control:
pig and pre-ruminant diets should contain <0.01% gossypol (100 mg/kg)
cattle fed whole cotton seed should be supplemented with lime ($CaCO_3$) plus an additional energy source (grain, molasses)
dietary **iron and calcium bind free gossypol**
add iron (e.g. ferrous sulphate) to diets at a ratio with gossypol of 1:1
provide lime @ 12 g per kg whole cotton seed for every 0.5% free gossypol present
rule-of-thumb for dairy cattle: do not exceed 20 g free gossypol/head/day = about 2.5-3.5 kg whole cottonseed/head/day (F. Galey, personal communication VETTOX 1999)

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☑ *Dianthrone derivatives (hypericin, fagopyrin)*

Core data

Syndrome names:

- primary photosensitisation
- hypericism
- fagopyrism

Common sources:

- *Hypericum perforatum* (St.John's wort)

Animals affected: horses, ruminants
Mode of action: hypericin produces cytotoxic singlet oxygen and free radicals when exposed to sunlight
Poisoning circumstances: Hypericum most toxic when flowering (summer)
Main effects:

- primary photosensitisation (no liver damage present)
- CNS dysfunction
- hyperthermia

Diagnosis: syndrome + plant access
Therapy: general therapy for photosensitisation
Prevention: deny access through

- plant control – herbicides, biological control agents
- strategic grazing with goats or sheep

Syndrome names:

primary photosensitisation (*q.v.*)
hypericism
fagopyrism

Chemical structure:

Helianthrone pigments (polyhydroxy phenols)

Sources:

Hypericin

Family Clusiaceae (Guttiferae)

Hypericum perforatum (St.John's wort, goatweed [USA], Klamath weed [USA], aran) [Se60; Bourke1998, 2000] - introduced from Europe as a garden plant in the 1850s; a declared noxious weed; infests large areas of NSW, VIC, Tas + small areas of SA, WA.
There are two biotypes (varieties):

- broad-leaved: leaf 10-12 mm wide, early flowering, thick stems, large seed capsules
- narrow leaved: leaf 7-9 mm wide, late flowering, thin stems, small seed capsules

Hypericum triquetrifolium (tangled hypericum, curled-leaf St.John's wort, wavyleaf St.John's wort, dirnach [Arabic]) has been associated with primary photosensitisation of sheep, goats and cattle in Israel (Bale 1978); occurs in Victoria (Parsons & Cuthbertson 2001), but there are no record of toxicity in Australia.

Hypericum tetrapterum (St.Peter's wort, square-stemmed hypericum [NZ], square-stemmed or winged St.John's wort [UK]); contains hypericin (Connor 1977) and suspected of toxicity.

Hypericum androsaemum (tutsan, sweet amber [UK]) is suspected of one incident of poisoning in cattle in New Zealand, but failed to intoxicate experimental animals (Connor 1977). It is naturalised in parts of temperate Australia (Parsons & Cuthbertson 2001). There are no records of toxicity here.

Hypericum perforatum (St.John's wort). Left. Whole plant [RAM Photo]

Hypericum perforatum (St.John's wort). Inflorescence. [RAM Photo]

Fagopyrin

Family Polygonaceae

Fagopyrum sagittatum [= *F. esculentum*] (buckwheat)

Organ systems affected:

- skin
- CNS

Toxicity:

Hypericum perforatum

- susceptibility cattle (effective dose =1% of body weight) > sheep (ED = 4% body weight) (Southwell & Campbell 1991); descending order of susceptibility – horses > cattle > sheep > goats
- *H. perforatum* is used as an effective herbal anti-depressant in humans, but mild photosensitisation and significant polyneuropathy are reported side effects if patients are exposed to strong light sources (Brockmöller *et al.* 1997; Bove 1998)
- hypericin is proposed as an antineoplastic drug for treating equine sarcoids through photodynamic therapy (Martens *et al.* 2000)

Mode of action:

Hypericin

- hypericin produces cytotoxic singlet oxygen and free radicals when exposed to sunlight. These reaction products cause lipid peroxidation damaging cell membranes (Bourke 1998) and may damage myelin, causing polyneuropathy (Bove 1998; Duran & Song 1986)
- hypericin affects the nervous system by inhibition of catechol-o-methyl transferase (COMT) and monoamine oxidase (MOA) → accumulation of adrenaline, noradrenaline, serotonin and dopamine to various degrees at neural junctions within the CNS; particularly noradrenaline in hypothalamus and to a lesser extent, the limbic system (Bourke 1998)

Conditions of poisoning:

Hypericum perforatum

- hypericin-type pigments (polyhydroxyphenols) are in highest concentration in flowers (2000 mg/kg) → most toxicity in summer during flowering, but toxicity can occur in any season (Southwell & Campbell 1991). Hypericin/pseudohypericin content of soft growth material most likely to be selected by browsing herbivores increases from a winter minimum of less than 100 mg/kg in both broad- and narrow-leaved biotypes to a summer maximum approaching 3000 mg/kg in broad-leaved and approaching 5000 mg/kg in narrow-leaved biotypes (Southwell & Bourke 2001).
- dried plant retains toxicity, e.g. in hay; sun-drying reduces toxicity by *ca.* 80% (Bourke 2000)

Clinical signs:

Hypericum perforatum

primary photosensitisation (*q.v.*)

- affected animals remain photosensitive for
  > 7 days after ingestion ceases (Duran & Song 1986)
  4 days after a single dose of plant (Bourke 2000)
- effects on nervous function have been seen in experimental sheep (Bourke 1998, 2000): restlessness, confusion, reduced awareness of surroundings and response to sight and sound, hyperthermia (see particularly Bourke 2000), increased respiratory & heart rates, ataxia, intermittent hind limb paresis (dog-sitting), intermittent knuckling of hind fetlocks, intermittent sternal recumbency, intermittent catalepsy
- photosensitised sheep (from any reason, not hypericin alone) may display bizarre behaviour on contacting water (creek crossings, plunge dips), presumably due to the very sensitive nature of their skin lesions; this behaviour is not convulsive in the strict sense (Bourke 1998) and may interfere with mustering or handling of sheep
- other effects on sheep include abortion or agalactia/reduced milk production (Bourke 1998)

Pathology:

primary photosensitisation (*q.v.*)

Diagnosis:

syndrome + plant access

Therapy:

general therapy for photosensitisation (*q.v.*)

Prevention & control:

Hypericum perforatum

- control of the plant (Parsons & Cuthbertson 2001)
  - **herbicides** (ploughing on arable land) + **active pasture improvement** (phalaris + subterranean clover)
  - **biological control**: 37 insect species attack the plant in Europe, 8 of these were liberated in Australia between 1929 and 1955, 4 have established
    - *Chrysolina (Chrysomela)* beetles (*C. hyperici, C. quadrigemina*); can be effective in open country; need pasture improvement measures as follow-up to prevent re-infestation
    - *Agrilus hyperici* (restricted to small rear around Mudgee, NSW)
    - the gall midge *Zeuxidiplosis giardi* (reduces seed production; has little effect)

- **strategic grazing** using goats or sheep (cattle are too susceptible) may be effective if hypericin concentrations are low enough for a significant period of the year (late autumn-early spring) and animals are sufficiently resistant to poisoning (some genetic variation is known) (Bourke 1998, Anon.2001). This approach is useful on steep land inaccessible to machinery where boom-spraying with herbicides or cultivation are not practical. Flowering , growth and vigour of *H. perforatum* can be significantly reduced by applying heavy grazing pressure (greater than 50 dry sheep equivalents/ha) during dormant or slow-growth periods. Grazed areas must be frequently monitored so that stock can be removed before flower spikes reach 5-10 cm tall and hypericin content reaches toxic concentrations. Sheep suitable for this technique are adult Merinos from a fine (<20 micron fibre diameter) or superfine (<17 micron) bloodline, non-pregnant, non-lactating and carrying at least 4 months' wool growth. Sheep must be frequently inspected for signs of photosensitisation and immediately removed to shade if they occur. Heavy grazing at times of minimal hypericin content needs to be integrated with other measures including herbicide application, biological control agents and establishing desirable vigorous competitive pasture species.

  Suggested grazing periods
  - for the broad-leaved type of *H. perforatum* – May 1 to October 14
  - for the narrow-leaved type of *H. perforatum* – July 1 to September 14

References: Se8, 60

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☑ *Steroidal or lithogenic saponins*

Core data

Common sources:
- *Panicum* spp. (French millet, Bambatsi panic, *etc.*)
- *Brachiaria* spp. (signal grass)
- *Tribulus terrestris* (caltrop)

Animals affected: ruminants
Poisoning circumstances:
- young animals (particularly lambs)
- stressed crops/pastures

Main effects:
- crystals blocking intrahepatic bile ductules, cholangitis
- secondary (hepatogenous) photosensitisation

Diagnosis: histopathology
Therapy: basic (as above)
Prevention: utilise pasture with adults

Syndrome names:

Secondary or hepatogenous photosensitisation

These toxins produce **crystal-associated cholangiohepatopathies**, known by various names:
- `yellow bighead' of sheep (Australia)
- `geeldikkop' [Afrikaans = yellow thick head] & `dikoor' [Afrikaans = thick ear] (South Africa)
- `alveld' [Norwegian = elf fire; elves were thought to be responsible for the disease when first recognised] (Norway)
- 'yellowses', 'head gleet', 'plochteach' (Scotland)
- 'saut' (Cumbria)
- 'hard lug' (Antrim, Northern Ireland)

Chronic weight loss without photosensitisation has been reported in cattle in Brazil as associated with crystal-containing granulomatous lesions of liver, spleen, intestinal submucosa and lymph nodes (Riet-Correa *et al.* 2002).

Chemical structure:

Sapogenins in plants associated with this syndrome are based on the sapogenins **diosgenin** and **yamogenin**, being the only sapogenins capable of being metabolised to epismilagenin and episarsasapogenin (Miles *et al.* 1994a,b; Meagher *et al.* 1996). In contrast saponins based on ruscogenin, tigogenin, neotigogenin, gitogenin and neogitogenin do not appear to be lithogenic (Miles *et al.* 1994a,b; Wilkins *et al.* 1996).

Sources:
- important species in Australia in bold

Family Poaceae (Graminae): panicoid grasses including

***Panicum* spp.**

- ***Panicum coloratum*** (coolah grass, bambatsi panic) [DM53]; cultivated
- ***Panicum miliaceum*** (French millet) [DM54]; cultivated
- ***Panicum gilvum*** [= *P. schinzii*] (sweet grass) (Lancaster 1999)
- ***Panicum effusum*** (hairy panic) (Litchfield 1948) – increasing in density in the Riverina as a weed of crop stubbles (Morton A, personal communication, 2000)
- *Panicum maximum* (guinea grass); cultivated & weedy
- *Panicum decompositum* (native millet)
- *Panicum queenslandicum* (Yabilla grass)
- *Panicum whiteii* (pepper grass)
- *Panicum dichotomiflorum* (smooth witch grass) (Meagher *et al.* 1996)
- *Panicum laevinode*
- *Panicum virgatum* (Puoli *et al.* 1992)

***Brachiaria* spp.**

- ***Brachiaria decumbens*** (signal grass) (Meagher *et al.* 1996; Riet-Correa *et al.* 2002); cultivated
- *Brachiaria brizantha* (signal grass) (Briton & Paltridge 1940; Riet-Correa *et al.* 2002); cultivated
- *Brachiaria humidicola* (koronivia grass); cultivated

[South Africa, New Zealand, Australia, North America, South-east Asia, South America]

Family Zygophyllaceae:

- ***Tribulus terrestris*** (caltrop, goat-head, cat-head [NSW], dubbeltjie [Sth Afr], gokhru [India], kanti [India], Malta cross [Europe], puncture vine [NZ, UK, USA])

South Africa (Theiler 1918; Coetzer *et al.* 1983; Kellerman *et al.* 1991; Kellerman *et al.* 1994; Miles *et al.* 1994a,b; Wilkins *et al.* 1996)

Australia (Anderson 1910, Bourke 1983; Glastonbury *et al.* 1984; Glastonbury & Boal 1985; Jacob & Peet 1987) (plants in Australia - Squires 1969, 1979)

North America (McDonough *et al.* 1994)

South America (Tapia *et al.* 1994)

Family Liliaceae:

- *Narthecium ossifragum* (bog asphodel) [Europe] (Laksesvela & Dishington 1983, Miles *et al.* 1993, Flåøyen *et al.* 1994, Flåøyen & Wilkins 1997)
- *Doryanthes palmeri* (spear lily) [Australia] (Courtney *et al.* 1954) – sarsasapogenin isolated from roots and crowns (ex Mt.Mistake; 470 mg/kg fresh weight), no poisoning cases on record (no domestic ruminant access under normal circumstances)

Family Agavaceae:

- *Agave lecheguilla* (lechuguilla) [North America]

Panicum effusum (hairy panic) [RAM Photo]

Tribulus terrestris (caltrop). Flowering and fruiting plant [RAM Photo]

Toxicity:

- **ruminants**
- **young animals** (particularly lambs) more susceptible
- sporidesmin from *Pithomyces chartarum* (see below) can enhance the effect of *Tribulus terrestris* and *Panicum dichotomiflorum*

Mode of action:

Sapogenins or saponins are metabolised either in the rumen, the liver or both, and then conjugated in hepatocytes with glucuronic acid. Glucuronides combine with Ca^{++} in bile ductule lumens to produce insoluble crystals which may block bile ductules. However, physical bile duct blockage is *not* a necessary prelude to photosensitisation (Lancaster 1999) and toxic insult to hepatocytes causing cholestasis underlies the disease with bile duct proliferation and granulomatous changes being subsequent to the death of damaged hepatocytes and bile ductules (Driemeier *et al.* 2002). The crystalline material from bile ducts of affected animals has been identified as the calcium salts of the β-D-glucuronides of epismilagenin and episarsasapogenin (Miles *et al.* 1993). Ruminal metabolism converts the diosgenin and yamogenin present in the plants into epismilagenin and episarasapogenin. (Wilkins *et al.* 1994; Miles *et al.* 1994)

Conditions of poisoning:

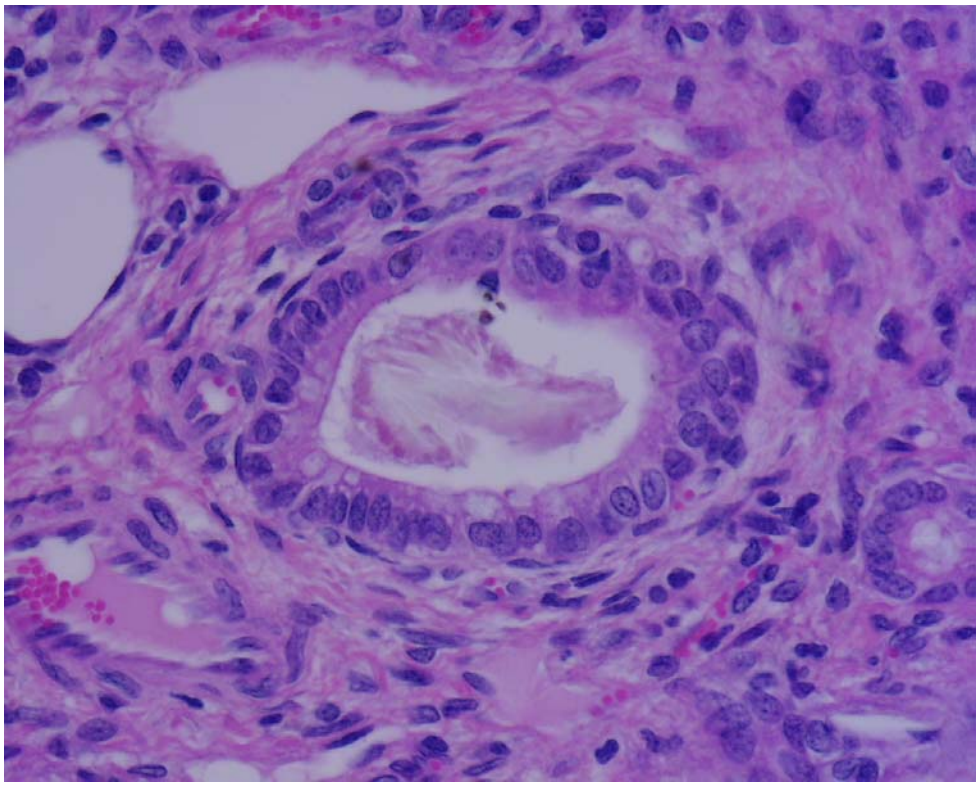
- the toxic species provides the bulk of available feed (*Panicum effusum* - Litchfield 1948)
- stressed plants (e.g. wilted) may be more toxic

Clinical signs:

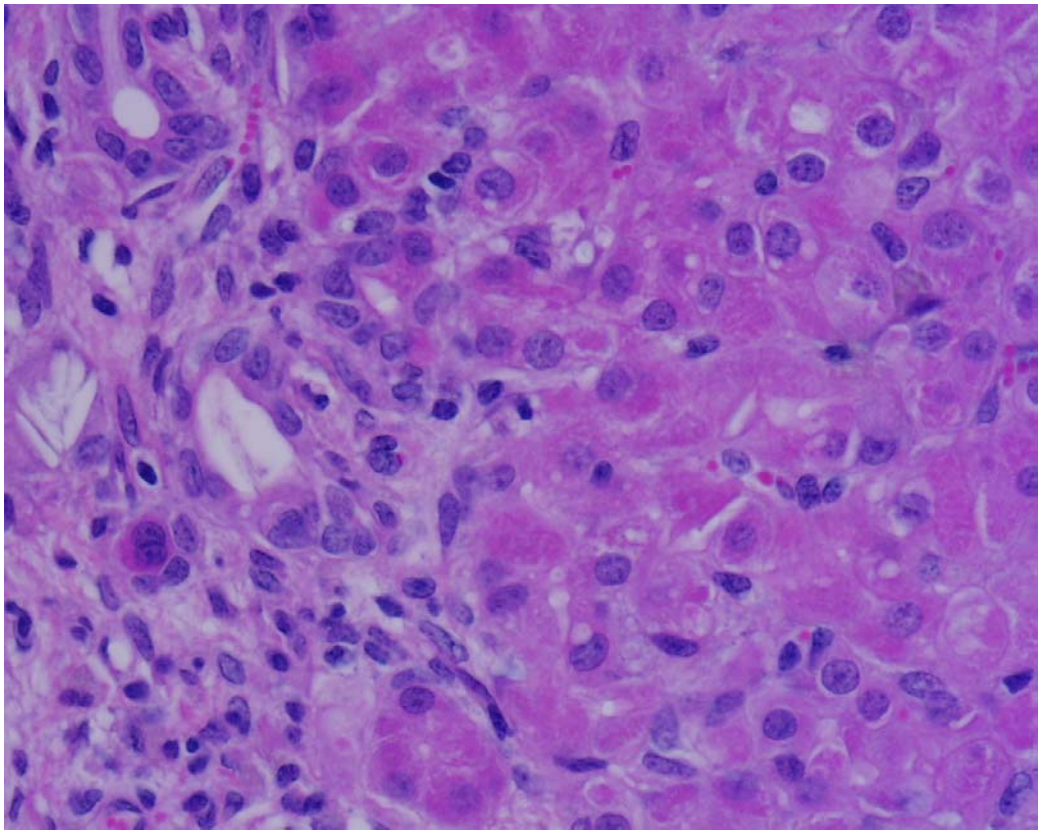
See the general account of photosensitisation elsewhere in the document. A syndrome of chronic weight loss without photosensitisation in cattle grazing *Brachiaria decumbens* or *B. brizantha* is reported from Brazil (Riet-Correa *et al.* 2002).

Pathology:

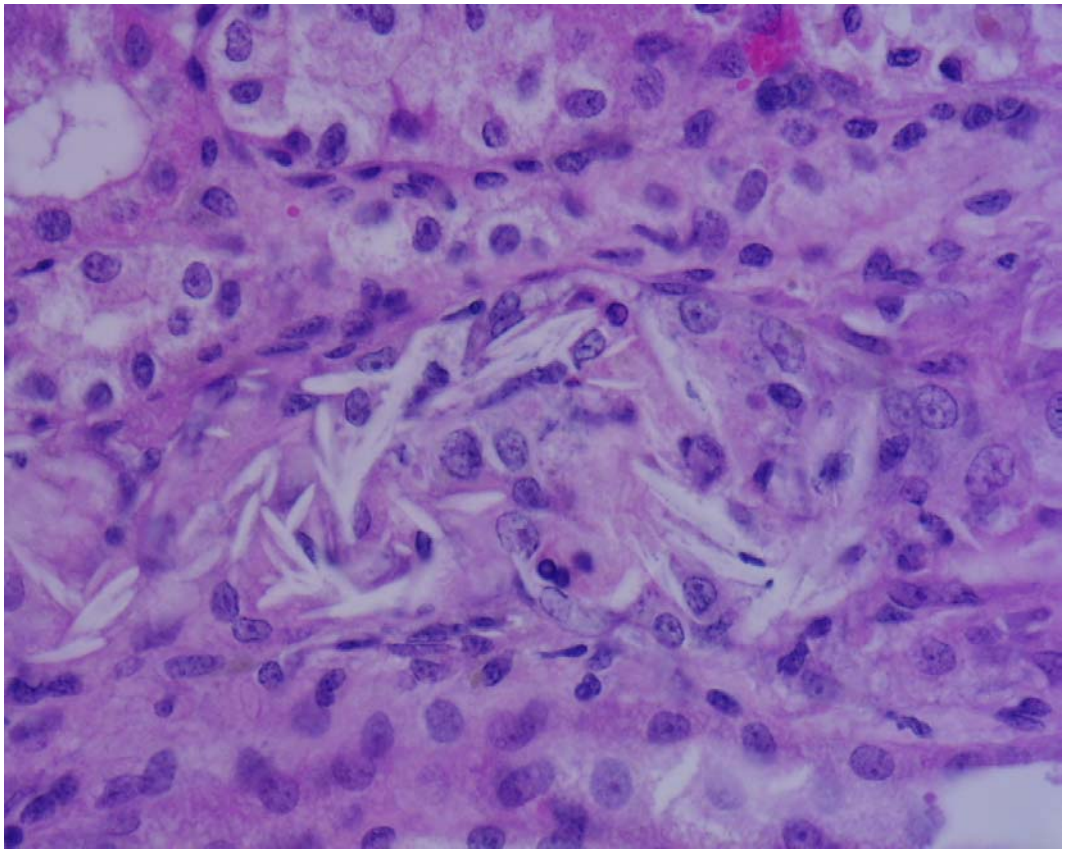
- ± jaundice
- ± swollen yellow-orange liver
- diffuse hepatocellular hydropic degeneration and hyperplasia of smooth endoplasmic reticulum indicative of prolonged cholestasis (Driemeier *et al.* 2002).
- **crystals** in hepatocytes, small bile ducts & Kupffer cells
- ± crystals in renal tubules
- ± crystals in macrophages are reported in intestinal submucosa, liver, spleen, mesenteric and hepatic lymph nodes in cases of weight loss without photosensitisation (Riet-Correa *et al.* 2002).



Steroidal saponin toxicity. Goat liver. Crystal deposit in bile duct. H&E [RAM Image]



Steroidal saponin toxicity. Goat liver. Crystal deposit in bile ductules and hepatocytes. H&E [RAM Image]



Steroidal saponin toxicity. Goat kidney. Crystal deposit in cortical tubule. H&E [RAM Image]

Diagnosis: access + pathology
Therapy: non-specific
Prevention & control:

- graze hazardous pastures with adult animals

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☑ *Tannins (hydrolysable)*

Core data

Common source:
- *Terminalia oblongata* ssp. *oblongata* (yellow-wood)
- *Quercus* spp. (oaks)

Animals affected: cattle
Mode of action: protein binding (astringency); nephrotoxic & hepatotoxic
Poisoning circumstances:
- Oak: acorns or young leaves ingested
- Yellow-wood: large intake from suckers or fallen trees in drought, rarely from fallen leaves (deciduous tree)

Main effects:
- chronic nephrosis (renal fibrosis): → progressive weight loss, polyuria, alimentary erosions/ulcers, yellow-wood → grey-green pigmented kidneys
- additionally, yellow-wood – acute liver damage → jaundice, photosensitisation

Diagnosis: access + pathology
Therapy: nil
Prevention: avoid circumstances promoting excessive intake

Syndrome names:
Yellow wood poisoning (McKenzie River disease)
Oak poisoning (acorn poisoning)

Chemical structure:
Hydrolysable tannins are, in general, the causes of these toxicities.
- gallotannins (oaks)
- ellagitannins e.g. punicalagin (yellow-wood) (Doig *et al.* 1990)

Condensed tannins are common in plants and much less toxic (not being readily metabolised by alimentary tract microbes to release easily absorbed toxic compounds). See the reviews in Brooker (2000).

Terminalin (a condensed tannin) isolated from *T. oblongata* ssp. *oblongata* is nephrotoxic in mice when dosed parenterally (Oelrichs *et al.* 1994)

Known *Terminalia oblongata* ssp. *oblongata* toxins:

- Punicalagin, a hepatotoxic hydrolysable ellagitannin
- Terminalin (gallagic acid dilactone, gallagyldilactone), a nephrotoxic condensed tannin

Sources:

Plant sources associated with animal toxicity:

Australia

Terminalia oblongata* ssp. *oblongata (yellow-wood) [DM155] Family Combretaceae

Quercus spp. (oaks, acorns) Family Fagaceae; cultivated in temperate regions

Ventilago viminalis (supplejack, vine tree) (Pryor *et al.* 1972) Family Rhamnaceae

Acacia salicina (black wattle) (McCosker & Hunt 1966) Family Mimosaceae

Europe, Mediterranean region, India, China, southern Africa & North & South America

Quercus spp. (oaks, acorns) Family Fagaceae

South America

Thiloa spp. [*T. glaucocarpa*] Family Combretaceae

Terminalia oblongata ssp. *oblongata* (Yellow-wood). Whole plant. [RAM Photo]

Terminalia oblongata ssp. *oblongata* (Yellow-wood). Twig with flower and unripe fruit. [RAM Photo]

Toxicity:
- **cattle**, sheep, goats
- horses (rare) (Anderson *et al.* 1983)

Mode of action:
- bind to proteins
- in mouth → sensation of astringency
  → ulceration of mucous membranes
- both condensed and hydrolysable tannins are usually not well absorbed from alimentary tract & interfere with protein availability from feeds
- hydrolysable tannins (e.g. tannic acid) undergo microbial and acid hydrolysis releasing simpler phenolics which are absorbed → hepatotoxicity, nephrotoxicity (Murdiati *et al.* 1992)

Conditions of poisoning:
- oak poisoning
  - toxicity: young green leaves & acorns > buds, twigs
  - poisoning when *Quercus* spp. form a large part of the diet
    - seasons producing large acorn crops; cases soon after acorns fall from trees
    - unseasonable weather (heavy snow) denying access to other feed sources (Spier *et al.* 1987)
- yellow-wood poisoning
  - deciduous trees → fallen leaves in late winter/spring → rare toxicity
  - toxicity most likely from **suckers or fallen trees** in **droughts** → large part of diet

Clinical signs:
- oak poisoning
  - anorexia, depression, ruminal atony
  - **weight loss → emaciation**
  - constipation or diarrhoea
  - faeces with mucus and blood / melena
  - dehydration
  - perineal oedema
  - ascites, hydrothorax
  - **polyuria** (glucose, protein, blood)
  - death in 1-4 weeks

- yellow-wood poisoning
- acute toxicity → liver & kidney damage
    - **jaundice**
    - **photosensitisation**
    - abdominal pain
    - dehydration
- chronic toxicity in survivors or in its own right → kidney fibrosis
    - **progressive weight loss**
    - **polyuria**
    - anaemia, ↓ serum protein, submandibular oedema

Pathology:

- oak poisoning
    - serum ↑ urea & creatinine, ↓ protein, Na, Cl & Ca
    - perirenal oedema
    - pale swollen **kidneys** - **tubular necrosis**
    - alimentary mucosal **erosions/ulcers**
    - ± numerous acorns in rumen contents
- yellow-wood poisoning
- acute toxicity
    - multiple erosions of abomasal mucosa
    - swollen greenish-grey kidneys
    - swollen pale to orange liver
- chronic toxicity
    - **fibrotic greenish-grey kidneys** - pigment in nephrotic kidneys
    - distended thickened bladder
    - abomasal ulcers

Diagnosis: access + pathology

Therapy:

- nil
- some cattle recover completely from oak poisoning (Ostrowski *et al.* 1989)

Prevention & control:

- experimental supplementation of a diet containing toxic amounts of oak leaves with calcium hydroxide @ 15% prevented poisoning in calves (Dollahite *et al.* 1966)
- oak leaves have been proposed as livestock feed following detannification (Makkar and Singh 1992)
- rumen floras from indigenous African antelopes and goats can degrade tannin-rich fodders (Odenyo *et al.* 1999) and bacteria capable of degrading tannic acid and hydrolysable tannins have been isolated from goat rumens (Brooker *et al.* 1994, Nelson *et al.* 1995) suggesting possible future prevention of intoxication by transfer of floras between ruminant species or rumen inoculation with specific bacteria.

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