



Antinutritional Factors in Animal Feed



ECVCN Residency Class 2018
Münich

Nicole Frost Nyquist

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Content:

- Definition
- Overview antinutrients
- Presence in various plants
- Processing/treatments
- Enzyme inhibitors
- Lectins
- Saponins
- Glucosinolates
- Phytate
- Tannins
- Phytoestrogens
- Glucoalkaloids
- Quinolizidine alkaloids
- Cyanogenic glucosides



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Antinutritional factor (ANF)

Endogenous substances in foods and feedstuffs that produce negative effects on health and nutrient balance when ingested by animals or humans (NRC 2011)

Those substances generated in natural food substances by the normal metabolism of species and by different mechanism which exert effects contrary to optimum nutrition (Prog Drug Res. 2016)

Biologically active secondary plant metabolites –



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Antinutritional factors

May cause:

- Acute signs of poisoning
- Subtle effects by prolonged ingestion – most common under normal feeding conditions

Function in plants:

Protect plant against microorganisms, fungi, insects and herbivorous ingestion

Animal by-products may also contain ANFs if not properly preserved or processed

- Avidin in egg white – binds biotin
- Thiaminase like activity in fresh fish (herring, mackerel, carp)
- Chitin – exoskeleton of crustaceans and insects

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Effect of ANF vary with:

The animal:

- species of animal
- age or stage of development
- size
- sex
- state of health and plane of nutrition
- any stress factors that might be superimposed on these variables

The plant:

- cultivar/variety/breeding
- climate
- location
- growing condition

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Feed

- Factors that determine nutritive value of foods and feedstuffs are complex
- Qualitative and quantitative information
- To much emphasis may be put on analyses of crude protein and fibre as indicator of feed value.
- Anti-nutritional factors may be as important as nutritional content of any edible plant part

- 63% of European protein feedstuffs are imported (Ivarson E. 2018)
- Actions to increase production of protein crop
- Synthetic amino acids and enzymes
- Increased use of soy products, both humans (replace animal meat with soy products) and animals (1995 ban of bone meal)

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Faba bean cultivars

Rich in starch and protein – grows throughout Europe

Antinutritional factors (ANF) such as trypsin inhibitors, lectins, vicine and convicine.

Color-flowered faba bean cultivars contain tannins but yield more, whereas white-flowered faba bean cultivars have a small content (< 1%) of tannins, but yield less.

Faba bean is a viable alternative protein source in well-balanced diets to weaner pigs, with cultivar rather than flower color determining the nutritional value.



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Antinutritional factor	
Proteins	Digestive enzyme inhibitors: Trypsin inhibitors, Amylase inhibitors, Lipase inhibitors Lectins Antigenic properties (food allergens)
Polyphenols	Tannins
Glycosides	Saponins (foam producing steroid glycosides)
Glucosides	Glucosinolates - Goitrogens Cyanogenic glucosides
Alkaloids	Quinolizidine (lupin alkaloids)
Other ANFs	
Phytate	
Gossypol	
Sinapsin	
Flatulence factor	

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Antinutrient	Soyabeans	Peanuts	Sunflower seeds	Lupins (Albus)	Potatoes	Corn	Rye	Bamboo shoots	Rapeseed meal
Proteinase inhibitors	+	+	+	+	+	+	+		+
Amylase inhibitors					+	?	+		
Lipase inhibitor	+		+						
Lectins	+	+	+	+	+	+	+		
Phytic acid / Phytate	+	+	+	+		+	+		
Phytoestrogens	+	+		+					+
Oligosaccharides									
Tannins			+						
Saponins	+			+					+
Sterols									
Choline esterase inhibitors					+				
Cyanogenic glucosides								+	
Gossypol									
Oligosaccharides	+								
Quinolizidine alkaloids									
Glucosinolates-Goitrogens	+								
Allergenes	+	+	+	+	+	+	+		

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Processing/treatments that may reduce impact of antinutrients

Other methods for elimination of antinutrients:

- Fermentation
- Selective breeding
- Gene modification

Antinutrient	Sources	Type of treatment
Proteinase inhibitors	Legumes	Heat, enzyme, fermentation
Amylase inhibitors	Peas	Heat, enzyme
Lipase inhibitor	Beans	Heat, enzyme, gamma-irradiation
Lectins	All plants seeds	Heat, enzyme
Phytic acid	All plants	Enzyme, water-soluble, cook, sprouting
Fibre	All plants	Enzyme, dehulling
Tannins	Rape seed, beans	Dehulling
Saponins	Legumes	Alcohol extraction, sprouting, heat stable
Sterols	Legumes	Alcohol/non-polar extraction
Oestrogens	Beans	Alcohol/non-polar extraction
Gossypol	Cotton seed	Non-polar extraction
Oligosaccharides	Legumes	Aqueous extraction
Quinolizidine alkaloids	Lupins	Aqueous extraction
Goitrogens / Glucosinolates	Rape seed	Aqueous extraction- damaged plant
Cyanogenic glucosides	Bamboo shoot/cassava	Aqueous extraction- crush, slice, peel, shred 1st

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PROTEINASE INHIBITORS (proteins)



Inhibit protein digestion, interfere with lipid digestion
Soybean, beans, sunflower seeds, grains, potato etc.

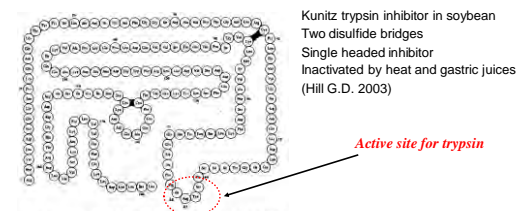
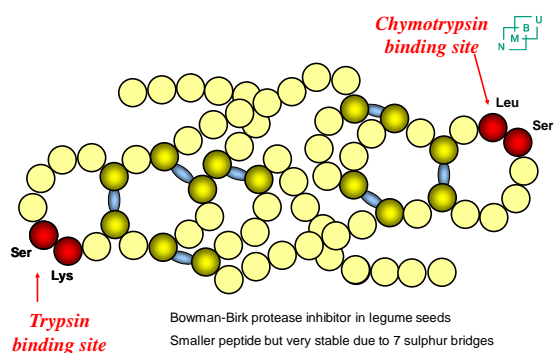


Fig. 1. Atomic ball-and-stick model of the Kunitz trypsin inhibitor from Kunitz et al., 1973, as published with the permission of the European Journal of Biochemistry.

Hill G.D. 2003

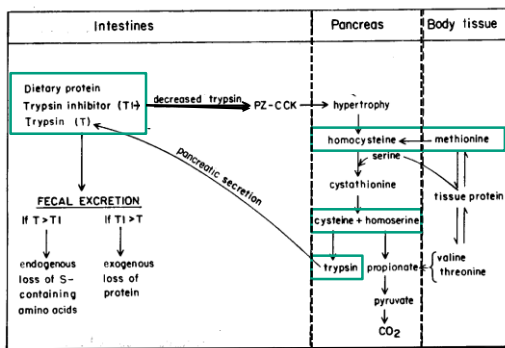
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Effects of trypsin inhibitors on metabolism of sulphur containing amino acids

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(Krogdahl Å. 1994) 17

Soybean meal anti-nutritional factors Effect of Bacillus fermentation

(Zheng L. et al. 2017)



ANF's in soybean meal

Trypsin inhibitors cause:

Inactivity of trypsin and chymotrypsin and impaired protein digestion.
Endogenous sulphur-containing amino acid loss and pancreas swelling.
→ leads to digestive disturbances and slow growth of animals

Glycinin } **Food allergens**, which cause hypersensitivity in animals →
β-conglycinin } abnormal morphology of the small bowel and diarrhea in new-born animals

Effect of fermentation.

Bacillus isolates selected due to their proteolytic activity.
They demonstrated that Bacillus fermentation improved the nutritional quality of soybean meal through degrading ANFs and changing the microstructure of soybean meal protein.

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Lipase and amylase inhibitors - in humans



"Inhibition of α-amylase, enzyme that plays a role in digestion of starch and glycogen, is considered a strategy for the treatment of disorders in carbohydrate uptake, such as **diabetes and obesity**, as well as, **dental caries and periodontal diseases**" (Sales et al. 2012)

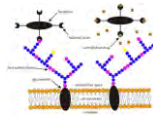
"...inhibitor of gastric, carboxylester and pancreatic lipase and specifically reduces the absorption of dietary fat due to the inhibition of triglyceride hydrolysis. ... **can be used for the treatment of obesity**...One patient dropped out because of faecal incontinence. No effect was seen on vitamin A levels, but vitamin E levels became lower in the ... group" (Drent M. K. 1993)



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Lectins



- Sugar-binding proteins
- Previously called agglutinins or hemagglutinins
- Soluble, heterogeneous (glycol) proteins with one or more sub-units
- Present in most plant feedstuffs: in particular in legumes, cereals
- Binds reversibly to specific mono- or oligosaccharides
- With two or more binding sites => agglutination of cells
- When binding to receptors, the effects depend on receptor function such as regulation of transport, hormone release, cell proliferation, nutrient metabolism etc.
- Some are very toxic (e.g. ricin from castor beans).
- Present in legumes, probably all plant foods.



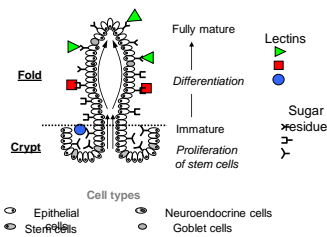
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Lectins: Effects in the gut



- Enterocytes have a wide range of receptors varying in glycation
- Glycation change in one cell type through maturation from crypt to tip
- Variability in glycation patterns helps explain the variability in biological effects of different lectins

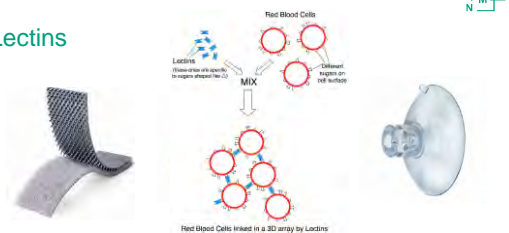


(Bardocz et al. 1995)

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Lectins



Similar to selective Velcro
One sided: just get stuck on tings (germs or our immunesystem)
Two sided: stick cells together like tennis balls stuck my Velcro. The fuzz on tennis balls as the assortment of sugars that line the surface of the cell.
Suction cup: bacteria use lectins to stick to slippery mucus

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FAKE NEWS

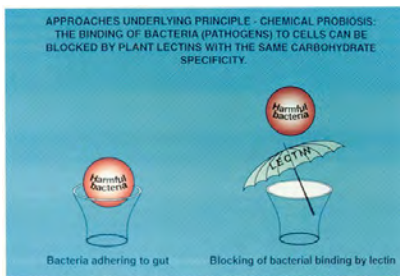


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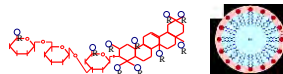
- Lectins in garlic may reduce Salmonella infections (Adebolu.. Et al. 2011)



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SAPONINS



Amphipathic glycosides one or more hydrophilic glycoside moieties combined with a lipophilic triterpene derivative.

Interfere with normal micelle formation, lipid digestion and bile recirculation.
Are integrated into cell membranes forming holes → disrupt cell membranes

Bitter, foaming, bind cholesterol, inhibit protein, and vitamin absorption

Beans, peas, alfalfa, clover (star fish and sea cucumber).

- Legume bloat in ruminants – high amount digestible proteins and saponin (Sucharita S. et al 1998)
- Tannins precipitate proteins and can prevent bloat (merckvetmanual.com)
- Poultry production: Anticoccidia, immunostimulant, antibacterial and antifungal (Elizabeth W et al. . 2017)
- Dissolve in water – toxic to fish
- Affect ammonia emission from animals (Veit M. et al. 2011)



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Saponins pros and cons:



Positive:

Health benefits:

- Hypo-cholesterolemic
- Anti-coagulant
- Anticarcinogenic
- Hepato-protective
- Anti-inflammatory
- Anti-oxidant
- Kill protozoans and molluscs
- Antifungal
- Antiviral
- Influence rumen gas production

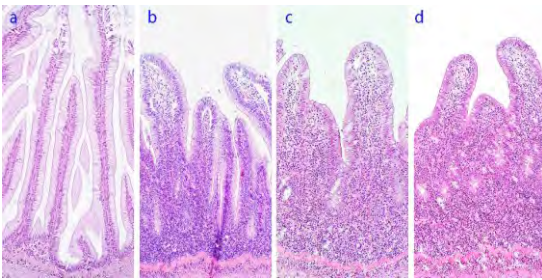
Adverse effects:

- Inhibit protein digestion, vitamin absorption
- Rumen microorganisms
- Rumen fermentation
- Ruminant reproduction
- Growth
- Wool, egg and milk production

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(In Majak W. 1995, NRC 2011, Ponte et al. 2004)

Salmon intestine



Reduced intestinal fold height, fold fusion, increased lamina propria and infiltration of inflammatory cells, loss of vacuolization and function. (Personal communication Prof. Krogdahl Å)

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GLUCOSINOLATES

Goitrogens:



Bitter, hydrolyzed by thioglucosidases (myrosinases) in plant tissue

Interfere with thyreoperoxidase activity → reduced production of thyroid hormone

Present in all cruciferous plants (e.g. rape seeds, mustard seeds, cabbages, camelina).

Reduce feed intake in pigs and poultry (Woyengo et al. 2016)

Glucosinolate reduced conola products

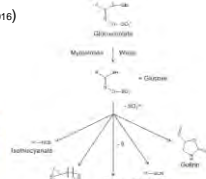


Fig. 2. Isothiocyanate, apothiosulfide, nitrile, thiocyanate, and isoxanth generated from glucosinolates.

(Masahiko I. et al. 2014)



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PHYTIC ACID

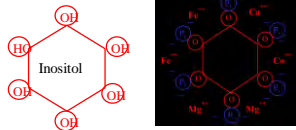


Indigestible, binds divalent ions, inhibits mineral absorption and cause mineral deficiencies, inhibits activity of some digestive enzymes (trypsin)*.

Contains a major share of plant phosphate

Present in all grains, beans and most other plants

Enzyme phytase (ruminant microorganism and added to feed)



Phytate

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(*Madhav Singh AD Krikorian 1982) 25

TANNINS

(water soluble polyphenols)



Bind to proteins reducing protein digestibility, particularly after heat treatment of a plant product, inhibit digestive enzymes, has antioxidative effect.

Present in grain (sorghum, millet), brassica, tea, vine

May affect palatability



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PHYTOESTROGENS

(di-phenolic, ex: lignans, iso-flavonoids)



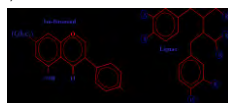
Bind to estrogen receptors, interfere with reproduction, inhibit cholesterol uptake, antioxidant activity

Relief of menopausal symptoms (... Efficacy of phytoestrogens)

Affect processes related to reproduction, bone remodeling, skin, cardiovascular, nervous, immunesystem and metabolism (Alexander V. et al. 2014)

Stimulate mammary development in pigs (Farmer C. 2018)

Present in beans (soy, lupines), grain, linseed and other seeds



Genistein from soya

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Systematically, the group of phytoestrogens includes over 100 molecules, divided according to their chemical structure.

Are metabolized in the digestive tract to even more potent metabolites- para-ethyl-phenol and equol

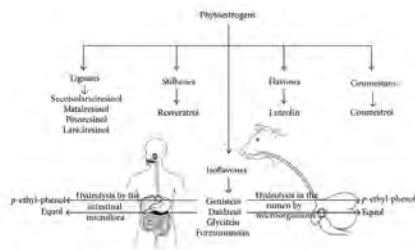


Figure 1: Classification and metabolism of phytoestrogens

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(Wolawek-Potocka et al. 2013) 28

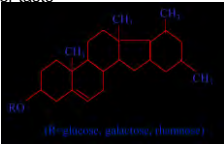


GLYKOALKALOIDS

Acetylcholinesterase inhibitors and can disrupt cell membrane – Neurological symptoms and gastrointestinal irritation.

Toxins can accumulate in case of daily consumption

Solanine in potatoes (production stimulated by UV light)
Bitter taste



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(Mensinga T.T. et al 2005) 29

QUINOLOZIDIN ALKALOIDS

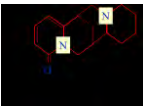
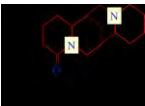
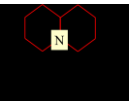
In mammals, quinolizidine alkaloids appear to cause toxicity through neurological effects leading to loss of motor coordination and muscular control.

Exhibit antimuscarinic acetylcholin receptor activity while several also exhibit antinicotinic activity

Bitter, reduce feed intake and growth, cause vomiting in pigs.

Fish seem quite tolerant.

Lupines



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(NRC 2011) 30

Lupins



- Western Australia (WA) accounts for more than 72% of global lupin production.
- Lupin-specific enzymes (polygalacturonase and pectin methyl esterase) These enzymes are not commercially available to date but may be a strategy in the future.
- Young grower pigs (30kg live weight) can effectively handle lupin fibre at 35% dietary inclusion levels (Iverson and Neil 2018)



Narrow leafed lupin, seeds and ground lupin seeds.

www.agric.wa.gov.au

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Food poisoning by alkaloids in fattening pigs



August 2013

Sudden deaths in several integrated fattening farms pertaining to a Spanish company; specifically, six farms on which new feed batches. Pigs: vomiting, watery feces, depression, apathy, death.



Mix of Australian and national (Spanish) lupin.



<https://www.pig333.com/>

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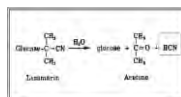
CYANIDE-RELEASING COMPOUNDS



- Liberate hydrogen cyanide (HCN) which inhibits cytochrome c oxidase
- In more than 3000 species of higher plants
- Cassava, linseed, sorghum, peas, maize, barley, wheat, peanut and rapeseed.
- Mental disturbance, breathing difficulties, cyanosis, cramps, death

- Amygdalin in stonefruits
- Linamarin in cassava
- Dhurrin in sorghum
- Taxifyllin i bambu shoots

- Linustatin in linseeds, as well as substances in peas, maize, barley, wheat, peanut and rapeseed



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cyanide detoxification in giant panda

Expression and activity of the enzyme rhodanese is high in liver and kidney of giant panda.



Edible bamboo shoots

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https://en.wikipedia.org/wiki/Bamboo_shoot



e F:

Thank you for your attention!



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