Vitamins and Supplementation Requirements

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Classification

Fat-soluble: vitamins A, D, E, and K

Water-soluble: B complex, vitamin C

Synonyms

Vitamin	Synonym
Fat-soluble	
Vitamin A	Retinol, retinal, retinoic acid
Vitamin D_2	Ergocalciferol
Vitamin D_3	Cholecalciferol
Vitamin E	Tocopherol, tocotrienols
Vitamin K_1 (plants)	Phylloquinone
Vitamin K_2 (bacteria)	Menaquinone
Vitamin K_3 (synthetic)	Menadione
Water-soluble	
Vitamin B_1	Thiamin
Vitamin B_2	Riboflavin
Vitamin B_3, pp	Niacin
Vitamin B_5	Pantothenic acid
Vitamin B_6	Pyridoxal, pyridoxamine
Vitamin B_{12}	Cobalmin
Vitamin C	Ascorbic acid
Vitamin H	Biotin
Vitamin Bc/M	Folacin, folic acid, folate
Choline	Gossypine

Competitive Uptake

Fat-soluble vitamins compete for sites of uptake so an imbalance/excess will impact on other fat-soluble vitamins

Carotenoids (provitamin A): absorption is similar to other fat-soluble vitamins so XS vitamin A can decrease carotenoid uptake.

Ratio Recommendations

A:D:E
100:10:1

However, recommendation of vitamin E 200 mg/kg for animals in captivity

Functions of Vitamin A

Functions vary depending on the form:

- retinol (trans)
- retinal (aldehydes) (dim light vision) component of rhodopsin
- retinoic acid (acid)
  - supports growth and tissue differentiation
  - not vision or reproduction
  - no sperm produced (rats)
  - role in testosterone synthesis

Maintenance of epithelial cells (lung, kidney, GI, reproductive tracts)

Trans form is most active:

- moisture, heat, light and catalysts
- change trans to cis form

Health Implications for Vitamin A

1. Vision: loss of vision due to failure of rhodopsin formation in the retina
2. Growth: defects in bone growth
3. Reproduction:
   - defects in reproduction
   - decline in sexual activity
   - failure of spermatogenesis
4. Epithelial tissues:
   - defects in growth and differentiation of epithelial tissues,
   - frequently result in keratinisation
   - increased susceptibility of affected tissue to infection.

Dietary Recommendations NRC (1994)

Chickens =1,500 IU/kg
Turkey 5,000 IU/kg

So, why are commercial foods so high?

Dietary Sources of Vitamin A

1. Insects: generally low in vitamin A, may be dependant on diet
2. Seeds: low in vitamin A precursors
3. Fruits: can be high in carotenoids (provitamin A)
4. Fish: usually sufficient vitamin A, some XS
5. Whole Prey: high in rodents

Over Supplementation of Vitamin A?

Formulated foods provide vitamin A in form of retinyl palmitates

Plant-based vitamin A: carotenoids

- regulated conversion
- conversion decreases with increased dietary carotenoids
- variation in conversion of carotenoids to vitamin A
- vitamin A can compete with uptake of carotenoids

Hypervitaminosis A

Deficiency in other fat-soluble vitamins

Retinol penetrates lipid of membrane

- and causes it to expand
- protein of membrane is relatively inelastic
  - weakened membrane

Vitamin A Supplementation of Laying Hen

Supplemented with 0-120 µg/g retinol equivalents

- liver: increased vitamin A, decreased vitamin E
- egg yolk: increased vitamin A, decreased vitamin E and carotenoids
- embryonic liver: increased vitamin A, decreased vitamin E, vitamin C and carotenoids
- embryonic/neonatal liver: significantly increased susceptibility to lipid peroxidation

Therefore, excess vitamin A provided to laying hens leads to an adverse effect on vitamin E, carotenoids and ascorbic acid in embryonic/neonatal liver and can compromise the antioxidant status of progeny.

Vitamin E

Tocopherol: (synthesised mainly by green parts of plants)
Tocotrienol derivatives (synthesised mainly in the bran and germ fractions).

Importance:

- against free-radical injury
- enhancing the immune response
- playing a role in the prevention of cancer, heart disease, cataracts, and a number of other diseases.

Vitamin E found in high amounts in sunflower oil, hazelnuts and almonds,

- still below the minimum amount recommended for animals maintained in captivity (200 mg/kg)
- negated by high PUFA content.

Antioxidant Function

Oxygen-free radicals

- form naturally during metabolism and by external factors such as x-rays, ultra-violet radiation and pollution
- antioxidants help to counter the detrimental effects
- implicated in the development of several diseases including
  - cancer, inflammatory conditions and heart disease,
  - highlights need to consider antioxidant levels as part of preventative medicine.

Synthetic vs. Natural

Synthetic occurs as a number of isomers of varying activity

Natural is more potent

Substituting Vitamin E with Selenium

Act synergistically in the glutathione peroxidase system

Higher vitamin E can reduce Se requirement but don't' have same actions

Se toxicity at 5-20 mg/kg:

- decreased hatchability
- deformed embryos
- teratogenesis
- decreased growth
- diminished immune function
- emaciation
- abnormal feather loss
- lesions in liver
- poor reproductive success

Reproduction and vitamin E

Peregrine falcon:

- poor hatchability
- pipping muscle degeneration
- measured vitamin E of wild birds
- captives low in vitamin E
- fed quail high vitamin E diet

Supplementation of Vitamin E to Hens

Control: 147 mg/kg vitamin E, high vitamin E = 365 mg/kg
Chicks from control maternal diet:

- brain more susceptible to both spontaneous and iron –stimulated peroxidation than other tissues

High vitamin E:

- significantly reduced susceptibility to peroxidation
- brain susceptibility decreased to levels of other tissues.

Vitamin Content of Whole Prey

Vitamin A:

- high in rodents
- increases with age in rodents

Vitamin E:

- deficient in whole prey
- decreases with age in rats
- always low in mice

Vitamin Content of Fish

Vitamin A:

- generally in excess (species dependant)
- no requirement for supplementation
- multi vitamin supplement may decrease vitamin E uptake

Vitamin E:

- deficient in all frozen fish
- PUFA oxidation
- Supplementation required (50 mg/kg as fed)

Thiamine:

- co-enzyme in metabolism of carbohydrates
- absence results in loss of energy
- mild deficiencies are associated with poor appetite, tiredness and irritability.

Thiaminase:

- thiaminase enzymes present in the flesh of fish
- degrade thiamine
- 25 mg/kg lost in 30 minutes
- complete breakdown 90 minutes
- supplement at 25 mg/kg (as fed).

Hyponatremia

A condition suggested to be stress-related

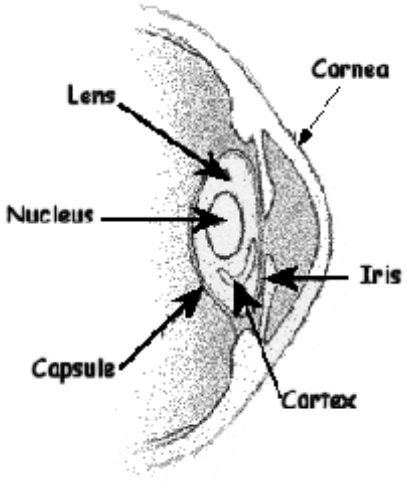
- characterized by a gradual or sudden decrease in plasma sodium
- equivalent decrease in chloride levels
- attributed to a deficiency in dietary vitamin E concentrations
  - resulting in decreased plasma sodium levels

Can be dietary related or behavioural:

- selectively feeding on freshwater fish

Cataracts

There are three types of cataracts with each being described by its location on the lens.



nuclear:

- occurs centre of lens
- most common,
- associated with aging
- particularly sensitive to nutrient deficiencies

cortical:

- cortex of lens
- often associated with diabetes

subcapsular :

- opacity under capsule

Nuclear cataracts:

- Vitamin A may protect against nuclear cataracts
- spinach (also a good source of the carotenoid lutein) may play a role
- high plasma α-tocopherol reduces risk (can be inversely related)

Cortical cataracts:

- middle levels of α-tocopherol associated with a reduced risk of cortical opacity

Vitamin C is a natural anti-inflammatory and helps prevent cataracts. While it is produced by some birds, others have a dysfunction of the enzyme that produces vitamin C and may have higher dietary requirements.

B vitamins and Cataracts

Vitamin B_2 (riboflavin) and B_3 (niacin):

- may protect against nuclear cataracts
- doesn't protect against cortical or capsular

Riboflavin is important in the production of glutathione peroxidase and deficiencies in this enzyme have been correlated with cataracts in animals, with administration of this vitamin clearing the cataracts. Vitamins C and E are also helpful in preserving glutathione levels.

Cataracts in cats have been linked to a B_2 deficiency that may stem from poor nutritional assimilation rather than from a lack of dietary B_2.

Carotenoids and Cataracts:

- not significantly associated with nuclear cataracts
- marginal inverse associations with lutein and cryptoxanthin
- lutein and zeaxanthin (xanthophylls) selectively accumulate in the macula
- quench singlet oxygen produced by UV light exposure

Hyperkeratosis

Epithelial tissue:

- skin and mucous membranes lining respiratory and GITs.
- Necessary for proliferation and differentiation of cells
- Production of mucoproteins
- Mucous secretions maintain integrity of epithelium

- Provide barrier against bacterial invasion

Vitamin A Deficiency:
- failure of differentiation of new epithelial cells beyond squamous
- normal epithelial cells replaced by dysfunction, stratified, keratinised cells
- > lesions in epithelium
- > increased susceptibility to infection

Vitamin E deficiency:
- treatment of rats with oral vitamin A failed to raise serum vitamin A
- may require mix of two vitamins for hyperkeratosis

Zinc Deficiency:
- hyperkeratosis but normal bone development

Biotin Deficiency:
- hyperkeratosis on foot pad and under side of toe
- XS salt can > biotin deficiency of foot pads
- Changes in fat composition of tissues

Hypothyroidism:
- scarlet macaw
- parakeratotic hyperkeratosis of epidermis

Carnivores – model on cats?

Cats lack glucokinase
Elevated need for Taurine, niacin, arachidonic acid
Tryptophan (can't convert from niacin)
Preformed vitamin A (no carotenoid conversion)
Vitamin D
Similarities in carnivorous birds
Should we model them on feline dietary requirements?