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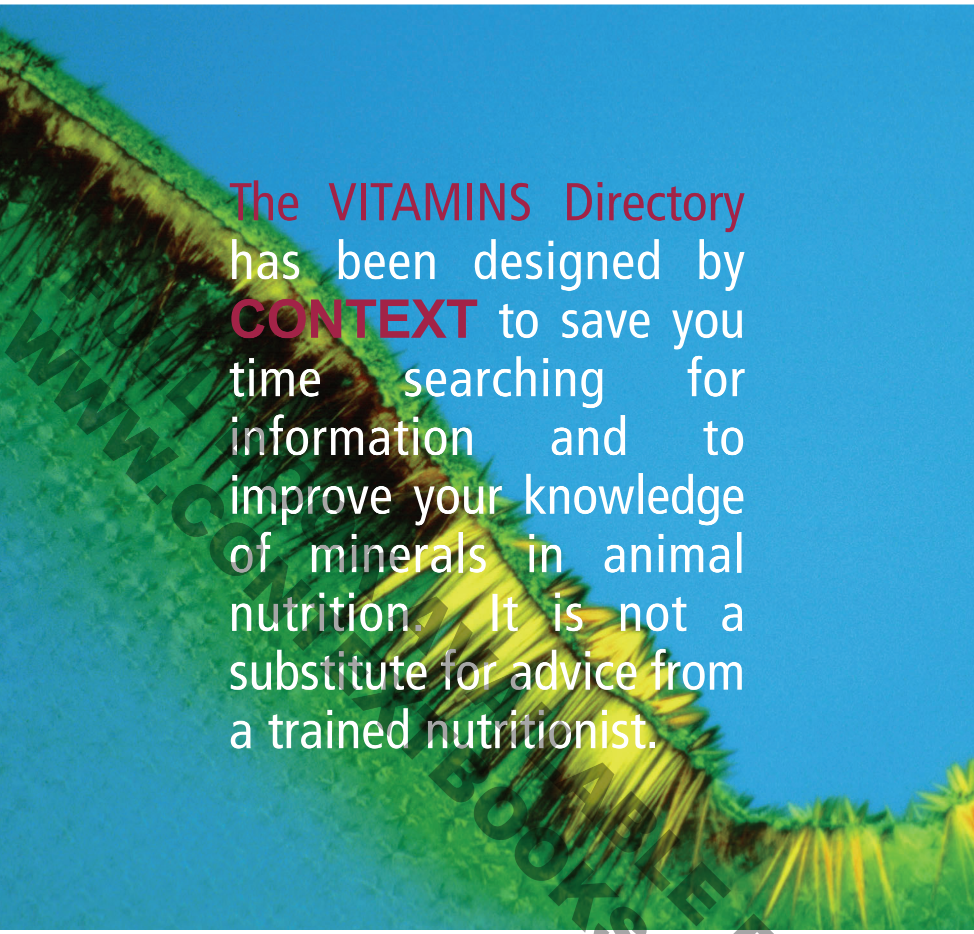

The VITAMINS Directory has been designed by **CONTEXT** to save you time searching for information and to improve your knowledge of minerals in animal nutrition. It is not a substitute for advice from a trained nutritionist.

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After the international success of The FEEDS Directory, by Dr Ewing, it proved the need for further easy to use guides on animal nutrition and especially vitamins. Wesley has both a commercial and technical knowledge of animal nutrition having worked in the industry for 20 years for global leaders such as Cargill and Provimi. He was the General Manager for a UK animal nutrition and health company before establishing Context.

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The VITAMINS Directory

Your simple guide to vitamins in animal nutrition

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This is an early preview copy and some of the figures will change in the first edition.

Information on vitamins is widespread and it has not been possible to review all references. This guide is not intended to replace the many general or more specific nutritional texts currently available. Continual revision and updating is planned as new information becomes available. We would welcome your support on updating this guide. Email wewing@contextproducts.co.uk

Finally this is a colour guide. If you receive a Black and White version please report the copyright theft to us at the above address.

The Vitamins Directory

Contents

Vitamin History

In 1881, in Germany, rats and mice were fed a purified diet of fat, protein, carbohydrate, salts and water. They quickly died. When small quantities of milk were added to the diet, the animals lived longer concluding that milk contained essential active substances. In 1906, in England, 'accessory growth factors' was coined and then in 1912, the 'vitamine' "vital amine" theory was proposed by Funk, a Polish biochemist. This was a result of work on an amine responsible for beri beri. This was the first B vitamin. Initially 'vitamine' was used for a large group of essential organic compounds but later it was found that they did not always contain the amine or nitrogen-containing substances and so 'vitamin' was used thereafter. 1915, USA scientists discovered two essential growth factors, a fat-soluble factor A and a water-soluble factor B. Research during the first half of the 20th century led to the isolation of over a dozen vitamins as pure chemical substances. Vitamin B_{12} was the last vitamin discovered, in 1948. There is the potential that undiscovered vitamins are still to be recognised.

Vitamin	Discovery	Isolation	Structure	Synthesis
Betaine				
Biotin	1931	1935	1942	1943
Carnitine		1905	1932	
Choline	1932	1849		
Coenzyme Q 10				
Folic Acid	1941	1941	1946	1946
Inositol		1850		
Lipoic acid				
Niacin	1936	1935	1937	1949
Orotic acid				
Pangamic acid				
Pantothenic acid	1931	1938	1940	1940
Rutin				
Termitin		1946		
Vitamin A	1909	1931	1931	1947
Beta-carotene		1831	1930	1950
Vitamin B_1	1897	1926	1936	1936
Vitamin B_2	1920	1933	1935	1935
Vitamin B_6	1934	1938	1938	1939
Vitamin B_{12}	1926	1948	1956	1972
Vitamin C	1912	1928	1933	1933
Vitamin D	1918	1932	1936	1959
Vitamin E	1922	1936	1938	1938
Vitamin F	1930			
Vitamin K	1929	1939	1939	1939
Vitamin U				

Abbreviations

Useful Terms and Abbreviations

AF	As fed
BW	Bodyweight
Ca	Calcium
Co	Cobalt
Cu	Copper
DM	Dry matter
DNA	Deoxyribonucleic acid
EFA	Essential fatty acid
Fe	Iron
g/tonne	Grams per tonne (=ppm)
GSH_Px	Glutathione peroxidase
Hb	Haemoglobin
IU	International unit
l	Litre
Mg	Magnesium
Mn	Manganese
MS	Microbial synthesis
mcg	Microgram
MNB	Menadione nicotinamide bisulphite
MPB	Menadione pyrimidinol bisulphite
MR	Milk replacer
MSB	Menadione sodium bisulphite
mEq	Milli equivalents
mg/kg	Milligrams per kilogram (=ppm)
mths	Months
NAD	Nicotinamide Adenine Dinucleotide
NADP	Nicotinamide Adenine Dinucleotide Phosphate
NRC	National research council
ng/g	Nanograms per gram (=ppb)
ng/ml	Nanograms per millilitre
%	Percent
°C	Degrees centigrade
°F	Degrees fahrenheit
P	Phosphorus
ppb	Part per billion
ppm	Parts per million
ppt	Parts per trillion
PTH	Parathyroid hormone
PUFA	Polyunsaturated fatty acid
RNA	Ribonucleic acid
USA	United States of America
µg	Micrograms
µg/g	Micrograms per gram (=ppm)
µg/kg	Micrograms per kilogram
<	Less than
>	Greater than
Zn	Zinc

Conversion Factors of Vitamin Forms to Active Substance

Vitamin (active substance)	Unit	Conversion Factors of Vitamin Forms
A (retinol)	1 IU =	0.300 μg vitamin A alcohol (retinol)
	1 IU =	0.344 μg vitamin A (retinyl) acetate
	1 IU =	0.359 μg vitamin A propionate
	1 IU =	0.550 μg vitamin A(retinyl) palmitate
Pro vitamin A	1 IU=	0.6 μg ß- carotene
D_3 (cholecalciferol)	1 IU =	0.025μg vitamin D_3
E (tocopherol)	1 IU =	1 mg dl-α-tocopheryl acetate
Bio-equivalence of tocopherols:		
d-α-tocopherol (RRR)		= 1.49 IU/mg
dl-α-tocopherol (all-rac)		= 1.10 IU/mg
dl-α-tocopheryl acetate (all-rac)		= 1.00 IU/mg
dl-β-tocopherol		= 0.33 IU/mg
dl-δ-tocopherol		= 0.25 IU/mg
dl-γ-tocopherol		= 0.01 IU/mg
K_3 (menadione)	0.51mg =	1 mg MSB
	0.45mg =	1 mg MPB
	0.46mg =	1 mg MNB
B_1 (thiamine)	0.92mg=	1 mg thiamine mononitrate
	0.89mg =	1 mg thiamine hydrochloride
B_6 (pyridoxine)	0.89mg =	1 mg pyridoxine hydrochloride
Niacin	1mg =	1 mg nicotinic acid
	1mg =	1 mg nicotinamide
D-pantothenic acid	0.92mg =	1 mg calcium D-pantothenate
	0.46mg =	1 mg calcium DL-pantothenate
Choline	0.75mg =	1 mg choline chloride (basis choline ion)
	0.87mg =	1mg choline chloride (basis choline hydroxy analogue)
L-ascorbic acid	0.89mg =	1mg sodium ascorbate

Conversions

Metric Weights and Measures to Imperial

	Units From	Conversion Factor	Units To
Length			
	mm	x 0.04	ins
	cm	x 0.4	ins
	mm	x 1.1	yds
	km	x 0.62	miles
Mass and Weight			
	g	x 0.03527	ozs
	g	x 0.002205	lbs
	kg	x 2.2046	lbs
	g	x 0.00422	cups
	kg	x 4.2	cups
	metric ton	x 1.102	short tons
	metric ton	x 0.984	long ton
	metric ton	x 2204.6	lbs
	mg/kg	x 1	ppm
	iu/kg	x 0.454	iu/lb
Volume			
	ml	x 0.0338	fl.oz
	litre	x 33.81	fl.oz
	litre	x 2.1134	pints
	litre dry	x 0.908	quart dry
	litre	x 1.057	quart liquid
	litre	x 0.2642	gallons
	litre	x 4.166	cup
Capacity			
	cm^3	x 0.061	cubic in
	m^3	x 35.315	cubic ft
	m^3	x 1.308	cubic yd
Temperature			
	°C	x (9/5)+32	°F
	°F	-32 x (5/9)	°C
Energy			
	kcal/kg	x 0.454	kcal/lb
	mcal/kg	x 0.454	mcal/lb
	MJ/kg	x 0.24	mcal/kg

Synthetic Vitamins

Feed Additives - Vitamins and Provitamins

Origin

There are three main production processes for vitamins:

- Chemical synthesis
- Fermentation
- Isolation from substances of plant or animal origin

The cost of extraction from plants or animal products tends to exclude these sources from animal nutrition. The other two methods are almost exclusively used as production methods of vitamins for animal nutrition.

Whether vitamins are obtained by fermentation or chemical synthesis, they are identical to those occurring in nature, and therefore produce the same biological effects. Synthetic vitamins are sometimes superior to natural ones, since some, e.g. biotin, niacin and choline are only available naturally to a limited extent because of the nature of their chemical bonds.

Chemical synthesis has been the major source of vitamin production but fermentation methods are becoming more available and preferable. Vitamin B_{12} has a very complicated structure and is therefore almost exclusively obtained by fermentation.

Methods of Vitamin Production

Chemical Synthesis

This is normally based on raw materials such as crude oil or gas. These materials are split into small units, which are subsequently recombined in multi-step processes to form the desired vitamin. The synthesis of vitamin A takes more than 15 process steps.

Fermentation

Identifies and selects suitable micro-organisms capable of producing the desired vitamin. The vitamins are then separated from the fermentation broth and purified. Genetic engineering allows the productivity of the micro-organisms to be increased.

Methods of Producing Commercial Vitamins

Vitamin	Chemical Synthesis	Fermentation Biosynthesis	Plant Extraction
ß-Carotene		+	+
Biotin	+	+	
Choline	+		
Folic acid	+		
Lipoic acid	+		
Niacin	+	+	
Pantothenic acid	+	+	
Vitamin A	+		
Vitamin B_1	+		
Vitamin B_2	+	+	
Vitamin B_6	+		
Vitamin B_{12}		+	
Vitamin C	+	+	
Vitamin D_3	+		+
Vitamin E	+	+	+
Vitamin K	+		

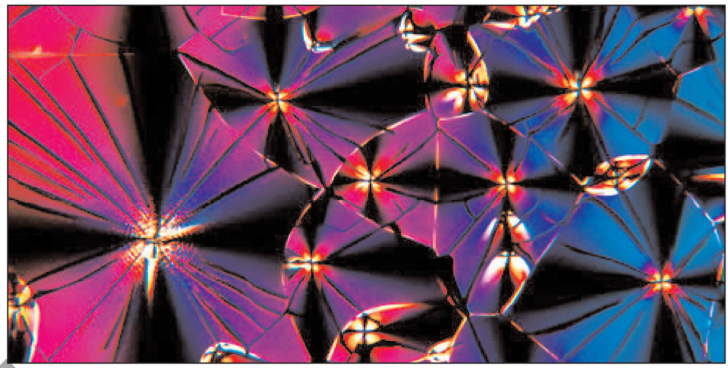
Vitamin Summary

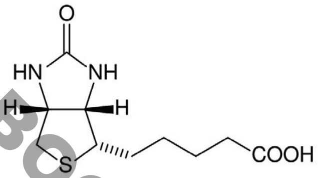
Names and Groups

Vitamin	Synoymn	Group
Betaine	Trimethylglycine	Vitamin like substance
Biotin	Vitamin H	Essential vitamin
Carnitine	Vitamin B_7	Amine
Choline	Gossypine	Essential
Co enzyme Q 10	Vitamin Q Ubiquinone	Vitamin like substance
Folic Acid	Folacin	Essential vitamin
Inositol	Myo-inositol	Vitamin like
Lipoic acid	Thioctic acid	Vitamin like substance
Niacin	Vitamin B_3	Essential vitamin
Orotic acid	Vitamin B_{13}	Vitamin like substance
Pangamic acid	Vitamin B_{15}	Vitamin like substance
Pantothenic acid	Vitamin B_5	Essential vitamin
Rutin	Vitamin P	Bioflavanoid
Termitin	Vitamin T	Vitamin like substance
Vitamin A	Retinol Retinal Retinoic acid	Essential vitamin
Vitamin B_1	Thiamin, Thiamine	Essential vitamin
Vitamin B_2	Riboflavin	Essential vitamin
Vitamin B_6	Pyridoxine	Essential vitamin
Vitamin B_{12}	Cobalamin	Essential vitamin
Vitamin C	Ascorbic acid	Essential vitamin
Vitamin D_3	Ergocalciferol (D_2) Cholecalciferol (D_3)	Essential vitamin
Vitamin E	Toocopherol	Essential vitamin
Vitamin F	Linolenic acid Linoleic acid	Essential fatty acid
Vitamin K_3	Menaqunione (K_1) Phyllaquinone(K_2)	Essential vitamin
Vitamin U	Cabagin	Vitamin like substance

Biotin

Vitamin Like





Chemical Formula

$C_{10}H_{16}N_2O_3S$

Molecular Weight

244.31 g/mol

Alternative Names

- Vitamin H
- Vitamin B_8,
- Co-enzyme R
- Factor W

Target Species

- Milk fed - calf, lamb, kid
- High yielding dairy
- Lactating sheep
- Grower, finishing, breeding
- Broiler, breeder, layer, turkey, geese, pheasant
- Growing
- High performance, stressed
- Trout, carp

Introduction

- A complex sulphur containing organic acid
- Colourless, odourless, crystalline substance
- Involved in energy release, bone development and reproduction
- A key 'skin' vitamin - important in epidermal tissues, production of hair and hoof

Key Natural Sources

- Rich in many feeds of animal and plant origin, in both a free and bound form
- The bound form is practically unavailable to animal species
- Bioavailablity from feeds ranges from 5% (e.g. wheat) to 75%
- Monogastrics are not always able to use much of the biotin in plant feeds
- Biotin can be synthesised by intestinal bacteria (caecum/colon) and micro-organisms in the rumen
- Feed levels vary, influenced by variety, season, yield, storage conditions etc.

Rich sources

- Brewers yeast, distillers feeds, oilseed meals, liver extract, blackstrap molasses, maize gluten feed, alfalfa (lucerne) meal, dried skimmed milk

Medium sources

- Fresh vegetables and some fruits

Poor sources

- Cereals, meat, fish

Biotin

Essential Vitamin

Feed Name	mg/kg DM
Alfalfa dried	0.35
Bakery byproduct	0.07
Barley grain	0.15
Bean field	0.11
Blood meal	0.09
Brewers dried grains	0.65
Buckwheat grain	0.07
Buttermilk dehyd.(cattle)	0.32
Cabbage/brasicas	
Carrots	0.07
Casein dehdy. (cattle)	0.05
Cassava tubers dehy	
Citrus pulp dried	
Copra(coconut) meal (mech ext)	0.11
Cottonseed meal 41 (mech ext)	0.95
Cottonseed meal 41 (solv ext)	0.6
Distillers grains - barley	0.25
Distillers grains - maize	0.5
Distillers grains - wheat	
Fishmeal (white)	0.08
Grass	0.25
Grassmeal	0.2
Groundnut ext. mech	0.35
Hay alfalfa	0.18
Hay grass	0.06
Hominy feed	0.14
Linseed meal (mech ext)	0.37
Lupin seed meal	0.45
Maize (yellow)	0.08
Maize germ ext. sol.	0.26
Maize gluten 20	0.19
Maize gluten 60	0.22
Malt culms	
Meat and bone	0.1
Meat meal	0.05
Milk (cattle-dehyd)	0.38
Milk skimmed	0.32
Millet grain	0.18
Molasses - beet	0.1
Molasses - cane	0.9
Oat grain	0.23
Oat groats	0.22

Feed Name	mg/kg DM
Oat middlings	0.24
Palm kernel ext. solv	
Peas	0.22
Potato dried	0.11
Rape ext (mech)	1
Rice	0.1
Rice bran	0.44
Rye grain	0.07
Safflower ext. solv.	1.5
Sesame ext mech	0.33
Silage grass	
Silage lucerne	
Silage maize	
Sorghum grain	0.26
Soya hipro 48	0.38
Soybean meal	0.35
Straw barley	
Straw oat	
Straw wheat	
Sugar beet pulp (dehyd)	
Sugar beet pulp (mol)	
Sunflower ext. solv.	1.6
Tapioca	0.03
Triticale grain	0.06
Wheat bran	0.3
Wheat feed	0.12
Wheat germ ext. mech.	0.25
Wheat germ feed	5
Wheat grain	0.14
Whey low lactose dried	0.53
Whey (cattle dehyd)	0.35
Yeast (brewers dehyd)	1.2
Yeast (torula dehyd)	1.4
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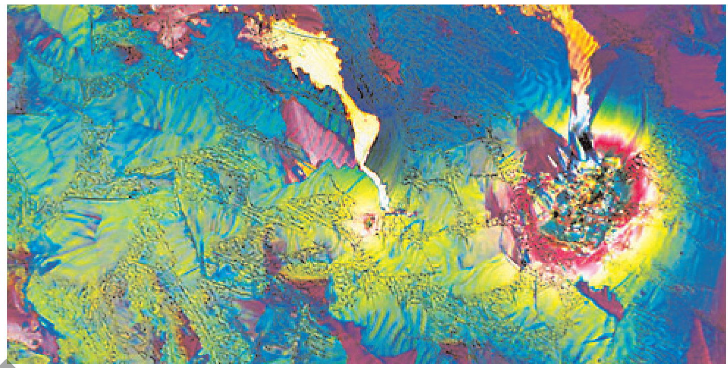
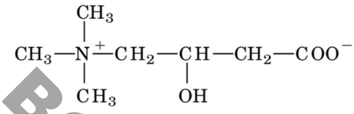
Carnitine

Vitamin Like





Chemical Formula

$C_7H_{16}NO_3$

Molecular Weight

161.199 g/mol

Alternative Names

- Vitamin B_T
- Vitamin B_7

Target Species

- High NPN diet
- High NPN diet
- Grower
- Working
- Race horses

Introduction

- A protein required for many body functions
- A vital coenzyme in animal tissues
- Occurs in all biological systems
- Under normal conditions, higher animals synthesise their own requirements
- Essential to a few animal species – those unable to synthesise it
- Essential growth factor for some insects, e.g. some beetles and fly
- Essential in diets that are deprived of its precursor amino acids, L-lysine and methionine
- Only the L-form is biologically active
- Name derived from its first isolation from meat (carnus) in 1905

Key Natural Sources

- L-carnitine occurs in mammalian muscle and also in yeast, wheat germ, fish and milk

Function

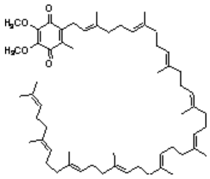
- A cofactor for normal cellular metabolism
- Essential in fat metabolism
- Required for movement of fatty acids within and between cells
- Plays a role in ketone body utilisation
- Plays are role in ammonia detoxification
- Important in regulation of liver and blood acetate levels

Benefits

- Important in production of energy
- Weanling pigs
  - Growth rates improved with lower-energy diets and feed conversion improved with added-fat diets, May have effect on back-fat thickness

Coenzyme Q10

Vitamin Like



Chemical Formula

$C_{59}H_{90}O_4$

Molecular Weight

863.34 g/mol

Alternative Names
- Vitamin Q
- Ubiquinone
- Ubichromenol

Introduction
- Found in most living cells concentrated in the mitochondria
- A lipid-like compound chemically similar to vitamin E
- Synthesised in cells so not considered a true vitamin

Key Natural Sources
- Occurs in aerobic organisms, from bacteria to higher plants and animals

Function
- Involved in production of ATP (cell energy source)
- A coenzyme for several cellular enzymes
- An electron carrier between flavoproteins and cytochromes
- May have a role in antibody production
- Antioxidant

Benefits
- ATP drives muscle contraction, production of protein etc
- May have beneficial effects in some disease states e.g. muscular dystrophy, periodontal disease, congestive heart failure, hypertension
- May enhance immune response mechanisms to disease or parasite challenge
- Possible role in prevention of some of symptoms of vitamin E deficiency

Metabolism
- Plants and micro-organisms can synthesise ubiquinones
- Synthesised in the body from amino acid tyrosine
- Q-10 found in hen eggs
- Q-10 can pass across placenta to foetus

Storage
- Found in liver, kidney and intestinal mucosa cells

Requirement/Allowance
- No dietary requirements established

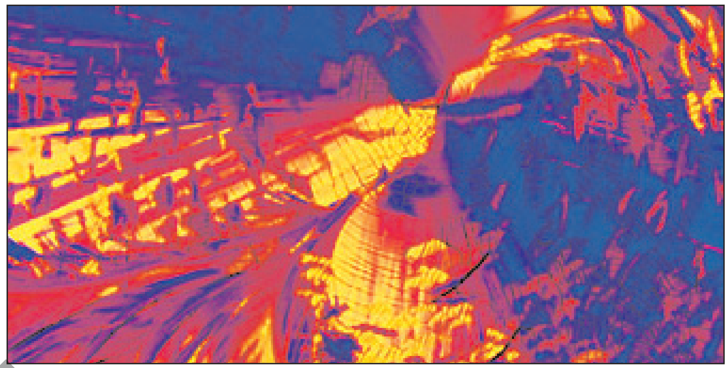
Deficiency
- Non reported

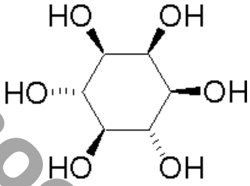
Toxicity
- Non reported

Synergy
- Vitamin A, vitamin E, pantothenic acid

Inositol

Vitamin Like





Chemical Formula

$C_6H_{12}O_6 2H_2O$

Molecular Weight

180.16 g/mol

Alternative Names
- My-inositol
- Anti-mouse alopecia factor

Target Species

Trout, bream, carp, salmon

Introduction
- A growth factor, for certain yeasts, bacteria and species of fish
- Not a true vitamin for most species but often classified with B vitamins
- Commonly called muscle sugar (structure similar to glucose)
- Livestock can usually produce sufficient quantities of inositol (from glucose)
- It is used for the synthesis of phospholipids and lipoproteins

Key Natural Sources
- My-inositol appears in the structure of almost every living plant and animal cell
- It is not often found in its free-state
- In plants, most frequently found as phytic acid
- In animal cells, occurs as a component of phosolipids
- Biotin and pantothenic acid may be required for the biosynthesis of inositol

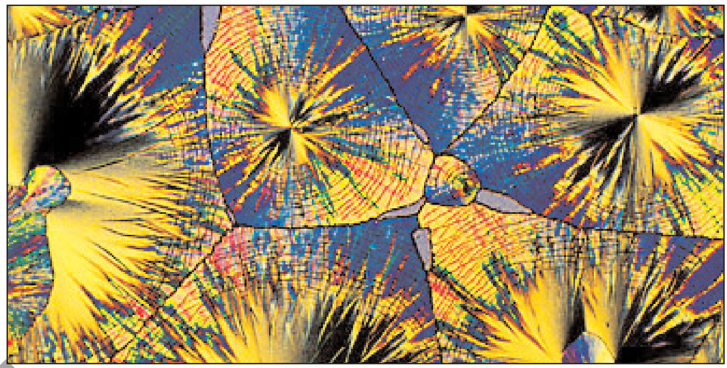
Rich sources
- Legumes, grains, nuts, citrus fruits liver, blackstrap molasses, brewers yeasts, wheatgerm, milk

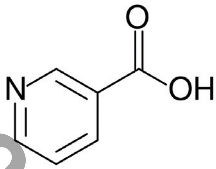
Function
- Physiological effects not completely understood, suggested roles:
  - Aids fat metabolism, has a lipotropic effect (affinity for fat)
  - Prevent hardening of arteries (with choline)
  - Precursor of phosphoinosities, found especially in brain
  - Possibly maintains selective permeability of plasma membranes
  - Possible role in binding of hormones to cell surface and transfer of nervous impulses
  - Maybe involved in production of pancreatic amylase

Benefits
- Reduce blood cholesterol
- Protects heart
- Necessary for normal brain cell function

Niacin

Essential Vitamin





Chemical Formula

$C_6H_5NO_2$

Molecular Weight

123.11 g/mol

Alternative Names

- Vitamin B_3
- Nicotinic acid
- Nicotinamide
- Niacinamide
- Vitamin PP (pellegra preventing)
- Vitamin G

Target Species

Milk fed
- calf, lamb, kid

Grower, finisher, breeding

Broiler, breeder, layer, turkey, geese, pheasant, duck

Maintenance, growth

Growing

Catfish, carp, salmon

Growth

Introduction

- It is the most stable of the B-group vitamins
- Named in 1867, after preparation from nicotine of tobacco
- Biochemical function demonstrated in 1935
- Part of various co-enzyme systems
- Associated with pellagra (pelle-skin, agra-sour) a dermatitis disease dominant on primarily corn based diets.
- Microbial synthesis of niacin occurs in rumen and hind gut fermenters e.g. horse

Key Natural Sources

Two forms of Niacin

Plant form usually nicotinic acid
Animal by-product form is niacinamide/nicotinamide
Both forms have equal vitamin activity

Rich sources

Brewers yeast, bran, legumes, sunflower seeds, peanuts, plant proteins, fishmeal, liver extract, barley, wheat, animal protein

Medium sources

Green forage, soyabean meal, linseed meal

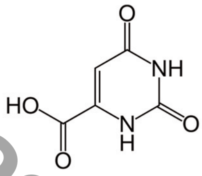
Poor sources

Cassava, rye, oats, maize, milk products, eggs

- Much in plants is in bound form (e.g. cereals – 85-90%, oilseeds – 40%), so low availability particularly for pigs and poultry
- Tryptophan is a precursor of niacin but levels in many feedstuff are low and so contribution to niacin supply is limiting
- Some species (e.g. cat, mink, fish) are unable to convert tryptophan to niacin
- Minor levels produced by microbial synthesis

Orotic Acid

Vitamin Like



Chemical Formula

$C_5H_4N_2O_4$

Molecular Weight

156.098 g/mol

Alternative Names
- Vitamin B_{13}
- Orotidine
- Orotonin
- Whey factor
- Animal galactose factor

Introduction
- Promotes the growth of lactobacilli, streptococci and other microbes
- Can be manufactured by intestinal micro-organisms
- May stimulate volatile fatty acid production
- Plays a central role in the metabolism of folic acid and vitamin B_{12}
- May enhance the transportation of minerals across cell membranes

Key Natural Sources
- Milk products (whey), yeasts, distillers solubles & root crops

Average milk levels (mg/litre)

Cows	5-10	Pigs	1
Sheep	20-30	Mares	1
Goats	2-5	Cow whey	10

Function
- Involved in RNA and DNA synthesis
- Part of at least three enzymes in pyrimidine synthesis principally in mammary tissue
- Pyrimidines also can be derived directly from orotic acid
- Pyrimidine cofactors are essential for the metabolism of carbohydrates
- Involved in folacin metabolism

Benefits
- Appears to aid replacement and restoration of some cells
- May stimulate microbial growth
- May stimulate volatile fatty acid production of bacteria in rumen

Young calves and heifers
- Stimulates growth when combined with methionine

Ruminants
- It may be considered useful with high ammonia diets where it may stimulate the bacterial digestion

Chicks and piglets
- May stimulate growth under certain conditions

Pantothenic Acid

Essential Vitamin

Benefits

- Promotes performance
- Boosts the nervous system
- Necessary for adrenal gland health and function
- Integrity of skin and mucous membranes
- Required for egg production and hatchability (Approximately 80% is stored in the yolk)
- Important in the animals health
- Increased resistance to pathogens

Absorption

- Bound forms digested to release pantothenic acid
- Absorbed primarily in small intestine (jejunum) by specific transport system
- Absorption is saturable and sodium ion dependant

Metabolism

- Transported in the blood plasma to the tissues
- Most used for re-synthesis of CoA
- Some found in cells bound to a protein (acyl carrier protein)
- Adult ruminants, with normal functioning rumen, can produce their own pantothenic acid through microbial synthesis. (High ratio of forage to starchy concentrates reduces level of pantothenic acid)

Storage

- No appreciable stores
- Higher concentration found in liver and kidney

Excretion

- Major route via kidneys
- Urinary excretion is prompt when taken in excess
- Some is oxidised and excreted across the lungs as carbon dioxide

Requirement/Allowance (Pantothenic Acid mg/kg diet DM)

Rums	NRC	Pigs	NRC	Poultry	NRC	Others	NRC
Calf (MR)	13	Creep	11-13.3	Chick	11	Dog[z]	200-400
Dairy	MS	Weaner	10	Broiler	11	Cat	5
Beef	MS	Grower	8.8	Breeder	10	Horse	MS
Heifer	MS	Finisher	7.7	Layer	17.7	Fish	15-30
Sheep	MS	Sow/Boar	13.3	Turkey	10-11	Rabbit	
Rums	**Typical**	**Pigs**	**Typical**	**Poultry**	**Typical**	**Others**	**Typical**
Calf (MR)	20	Creep	23	Chick	16/11	Dog	20
Dairy		Weaner	20	Broiler	12.5	Cat	14
Beef		Grower	20	Breeder	15	Horse	5
Heifer		Finisher	12	Layer	10	Fish	45
Sheep[a]	12.5	Sow/Boar	18	Turkey	12-20	Rabbit	14

Notes

[a] ewe/lamb

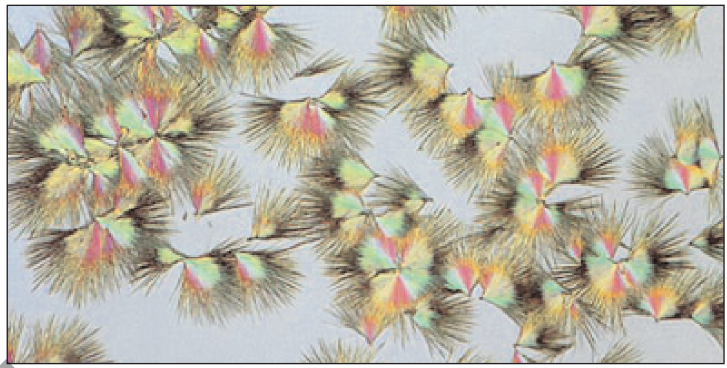
[z] µg/kg BW

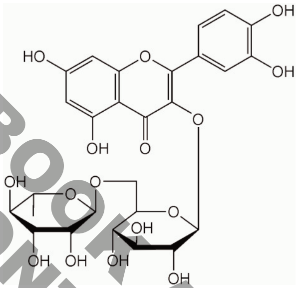
Animal Status:

- Egg contains approximately 800mg/60g egg (90% in yolk)

Rutin

Vitamin Like





Chemical Formula

$C_{27}H_{30}O_{16}$

Molecular Weight

610.52 g/mol

Alternative Names

- Vitamin P
- Quercetin
- Sophorin,
- Hesperidin & Catechol

Introduction

- An organic substance with equal activity to vitamins
- Coloured substances found in higher plants
- More than 3000 different flavonoids have been isolated
- Rutin is a derivative of quercetin and the most active form
- Animals, bacteria or yeast do not appear to synthesise bio-flavanoids

Key Natural Sources

- Found in high quantities in plants with naturally high sugar levels e.g. the fruit of the Fava D'Anta tree (Brazil)

Rich sources

- Fruits, vegetables, (higher levels in coloured exterior tissues, peels, skins etc), black tea, wine

Poor sources

- Roots, seeds

Function

- Prevent capillary breakdown
- Protects adrenaline from oxidation (adrenaline constricts blood vessels)
- Antioxidant effects
- Vasoconstrictor action
- Enhances biological effect of ascorbic acid (vitamin C)

Benefits

- May be helpful when problems of haemorrhage occur
- May have anti-inflammatory, anti-carcinogenic, anti-thrombotic, cytoprotective and vasoprotective activities

Absorption

- Only about 17% of an ingested dose is thought to be absorbed
- Absorption appears to occur mainly from the colon

Vitamin A

Essential Vitamin

Benefits

- Helps maintain normal vision (prevents night blindness)
- Maintains surface skin layers and mucous membranes
- Essential for growth and reproduction
- Essential for optimum immune system
- Helps improve ovulation and implantation of the ovum, embryonic and foetal development and hormone activation for pregnancy

Absorption

- Feeds supply vitamin A, vitamin A esters and carotenes
- Released from protein by pepsin in stomach and enzymes in small intestine
- Bile salts in small intestine (duodenum) break up fatty globules for enzymatic digestion
- Absorption occurs in small intestines (main site is jejunum)
- Absorption affected by bile, dietary fat, protein levels and antioxidants
- Vitamin A absorption 80-90%
- B-Carotene absorption 50-60%
- In pig, goat, sheep, rabbit, buffalo and dog, vitamin A itself is mainly absorbed
- Cattle, horses and carp-carotene can also be absorbed in large amounts

Metabolism

- Conversion of B-carotene to vitamin A occurs in the intestinal wall and also in the liver
- Conversion involves two enzymes for conversion to retinal and then retinol
- Conversion rates and carotene utilisation efficiency varies according to source and species. e.g. Holstein cattle are more efficient converters than Guernsey and Jersey breeds, hence whiter milk and fatty tissues
- Cats are unable to convert carotenoids to retinal because they lack the enzyme
- Fish can convert carotenoids, astaxanthin and cantaxanthin to Vitamin A dependant on vitamin A status
- In the blood, carotenoids are associated with lipid binding protein and vitamin A esters are transported with retinol binding protein (RBP)
- Secretion of RBP from liver is regulated by oestrogen, vitamin A, protein and zinc status
- Metabolism, storage and release of vitamin A by liver are under homeostatic controls
- Transfer across placenta is marginal

Storage

- Occurs mainly as retinyl palmitate, in liver (90%) but also kidneys, body fat and lungs
- Dogs and cats store higher level in kidney as well as liver
- Reserves are easily mobilised and useful during periods of dietary inadequacy
- Infection can deplete stores
- Mammals born with low liver stores
- Retinol readily transferred to eggs

Excretion

- Via faeces

ß-Carotene

Essential Vitamin

Feed Name	mg/kg DM
Alfalfa dried	175
Bakery byproduct	4.9
Barley grain	2.2
Bean field	
Blood meal	
Brewers dried grains	0.5
Buckwheat grain	
Buttermilk dehyd.(cattle)	
Cabbage/brasicas	175
Carrots	750
Casein dehdy. (cattle)	
Cassava tubers dehy	
Citrus pulp dried	10
Copra(coconut) meal (mech ext)	0.5
Cottonseed meal 41 (mech ext)	0.27
Cottonseed meal 41 (solv ext)	
Distillers grains - barley	
Distillers grains - maize	3.0
Distillers grains - wheat	1.1
Fishmeal (white)	
Grass	250
Grassmeal	200
Groundnut ext. mech	0.32
Hay alfalfa	55
Hay grass	22.5
Hominy feed	10
Linseed meal (mech ext)	0.2
Lupin seed meal	
Maize (yellow)	3.2
Maize germ ext. sol.	2.2
Maize gluten 20	3.5
Maize gluten 60	15.5
Malt culms	
Meat and bone	
Meat meal	
Milk (cattle-dehyd)	
Milk skimmed	
Millet grain	0.55
Molasses - beet	<1
Molasses - cane	
Oat grain	2.3
Oat groats	
Oat middlings	
Palm kernel ext. solv	
Peas	1
Potato dried	
Rape ext (mech)	<1
Rice	0.35
Rice bran	
Rye grain	0.11
Safflower ext. solv.	
Sesame ext mech	0.44
Silage grass	100
Silage lucerne	40
Silage maize	20
Sorghum grain	0.9
Soya hipro 48	
Soybean meal	0.22
Straw barley	2.2
Straw oat	4
Straw wheat	2
Sugar beet pulp (dehyd)	0.3
Sugar beet pulp (mol)	0.2
Sunflower ext. solv.	2.5
Tapioca	<1
Triticale grain	<1
Wheat bran	3
Wheat feed	3.5
Wheat germ ext. mech.	3
Wheat germ feed	
Wheat grain	0.3
Whey low lactose dried	
Whey (cattle dehyd)	
Yeast (brewers dehyd)	
Yeast (torula dehyd)	<1
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Vitamin B_1

Essential Vitamin

Deficiency

General
- Nervous disorders
- Cardiovascular disturbances
- Loss of appetite, anorexia
- Poor growth and development
- Muscle weakness and cramp
- Paralysis
- Gastrointestinal problems
- Easily fatigued
- Hyper-irritability

Ruminants
(Rumen not fully developed or from thiaminase activity in the rumen)
- Poor leg coordination
- Inability to stand
- Retraction of head
- Tachycardia
- Anorexia
- Weight loss
- Weakness
- Severe diarrhoea
- Polioencephalomalacia (PEM)
- Cerebrocorticonecrosis, forage poisoning, circling disease)

Pigs
- Anorexia
- Weight loss
- Vomiting
- Diarrhoea
- Haemorrhages
- Hypothermia
- Premature births
- High mortality among young
- Heart failure
- Tachycardia
- Sudden death

Poultry
- Chicks:
  - polyneuritis (retraction of head)
- Appetite loss
- Emaciation
- Impaired digestion
- Weakness
- Stargazing (paralysis of neck muscles)
- Convulsions
- Hypothermia
- Embryo mortality
- Chicks hatch with polyneuritis

Dogs
- Anorexia
- Weight loss
- Weakness
- Slow pulse
- Cramps
- Gastrointestinal disorders
- Hypothermia

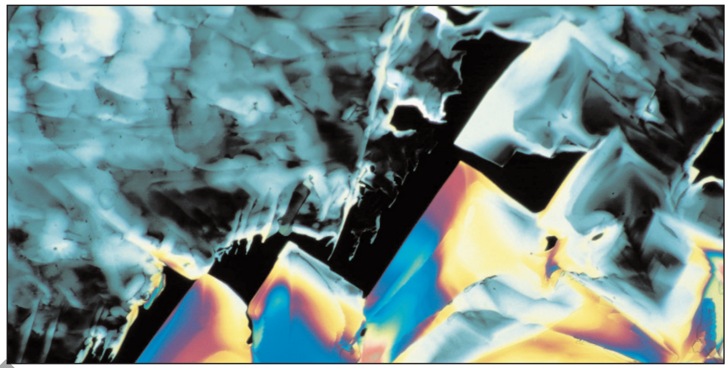
Horses
(Usually from thiaminase-containing plants, e.g. bracken fern)
- Anorexia
- Weight loss
- Lustreless coat
- Heart failure
- Nervousness
- Muscle tremors
- Incoordination
- Diarrhoea
- Constipation
- Reproductive failure

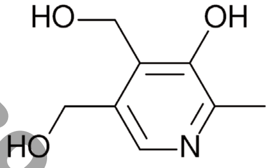
Fish
- Anorexia
- Arrested growth
- Neurological signs

Toxicity
- No known toxic effects
- Safe upper dietary level suggested of 1000 times requirement (NRC 1987)

Vitamin B_6

Essential Vitamin





Chemical Formula

$C_8H_{11}NO_3$

Molecular Weight

169.18 g/mol

Alternative Names
- Pyridoxine (pyridoxol)
- Pyridoxal
- Pyridoxamine (pyridoxamine phosphate, pyridoxal phosphate,PLP)

Target Species
Milk fed
- calf, lamb, kid

Grower, finisher, breeding

Broiler, breeder, layer, turkey, geese, pheasant, duck

Maintenance, growth

Growing

Catfish, carp, trout, salmon

Growth

Introduction
- An essential vitamin involved in many metabolic enzyme systems
- Important in energy production, central nervous system activity, blood and immune systems
- Synthesised in the rumen and intestines by microorganisms
- Large losses occur from feed processing

Key Natural Sources
Dominant forms
- Pyridoxine in plants (level affected by conditions of growth, climate, processing, storage etc)
- Pyridoxal and Pyridoxamine and phosphates in animal products(level dependant on level of nutrition and environment).
  The three chemical forms are readily interconvertable and have equal activity in animals but not micro-organisms

Rich sources
- Brewers yeast, oilseed meals, alfalfa hay/meal, cereals and their products (major proportion is in bran), distillers solubles, fishmeal, fish solubles, hominy, green pasture, potatoes (dehyd), rice bran, wheat germ meal

Poor sources
- Animal products, fruits

Bioavailability
- Typical levels maize 38-45% and soyabean meal 58-65%

Vitamin B_{12}

Essential Vitamin

Requirement/Allowance (µg per kg of diet DM)

Rums	NRC	Pigs	NRC	Poultry	NRC	Others	NRC
Calf (MR)	70	Creep	19.5-22	Chick	11/10	Dog [z]	0.5-1.0
Dairy	MS	Weaner	16.6	Broiler	7.7-11	Cat	20
Beef	MS	Grower	11	Breeder	3.3	Horse	MS
Heifer	MS	Finisher	5.5	Layer	3.3	Fish	10
Sheep	MS	Sow/Boar	16.6	Turkey	3.3	Rabbit	
Rums	**Typical**	**Pigs**	**Typical**	**Poultry**	**Typical**	**Others**	**Typical**
Calf (MR)	35-80	Creep	55	Chick	30	Dog	40
Dairy [a]	15-30	Weaner	45	Broiler	25	Cat	40
Beef		Grower	35	Breeder	35	Horse	15
Heifer		Finisher	20	Layer	23	Fish	45
Sheep	20	Sow/Boar	30	Turkey	30	Rabbit	17.5

Notes

[a] Requirements to meet production levels of high genetic merit animals, particularly in early lactation

[z] µg/kg BW

Requirement Affected by

- Protein
- Choline
- Methionine and folacin levels in diet
- Performance level

Animal Status

- Egg contains approximately 0.5mg/60g egg (95% in yolk)

Deficiency

General

- Loss of appetite
- Growth disorders
- Poor feed conversion
- Anaemia
- Poor coat condition
- Ill thrift and Pine
- Rough skin inflammation
- Nervous disorders e.g. uncoordinated movements

Ruminants

Young ruminants:

- Poor appetite and growth
- Muscular weakness
- Demyelination of nerves
- Poor condition

Adults:

- Reduction in milk and protein yield

Pigs

See general and

- Unco-ordinated hind leg movement
- Increased excitability
- Atrophy of thymus and spleen
- Enlarged liver and tongue
- Litter size and pig survival reduced
- Reproductive failure in sows

Poultry

See general and

- Poor feathering
- Leg weakness
- Gizzard erosion
- Fatty heart, liver and kidneys
- Reduced hatchability and egg size
- Increased embryo and post hatch mortality

Dogs

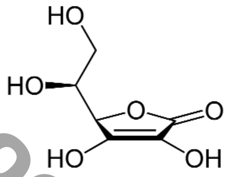
- Reduced growth
- Impaired reproduction
- Some dogs inherit an intestinal vitamin B_{12} malabsorption disorder

Horses

- Not recorded
- Sufficient synthesis in large intestine, where it is absorbed

Vitamin C

Essential Vitamin



Chemical Formula

$C_6H_8O_6$

Molecular Weight

176.13 g/mol

Alternative Names

- Ascorbic acid
- Hexuronic acid
- Antiscorbutic vitamin
- Dehydroascorbic acid (oxidised form)

Target Species

Milk fed
- calf, lamb, kid

Catfish, trout, salmon, tilapia

Introduction

- Known as the anti-scurvy vitamin
- A compound synthesised from glucose and other simple sugars, by plants and most animal species
- Most animals synthesise ascorbic acid from glucose in either the liver or kidney (species dependant)
- Insufficient synthesis at times of stress or high production
- New born animals produce little vitamin C and so benefit from additional supplies
- Dietary intake required by humans, guinea pigs, primates, fruit bats, certain species of fish and certain birds that cannot manufacture it themselves

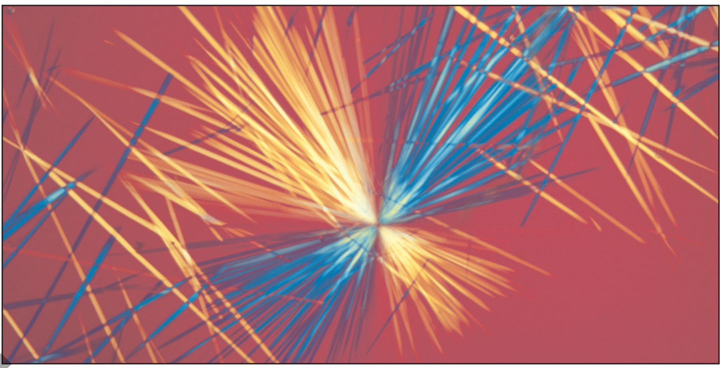
Key Natural Sources

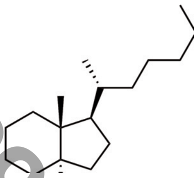
- Present in fresh fruits and vegetables
- Not found in many feedstuff used in animal feeds
- Degrades rapidly during storage and processing
- Bioavailability is limited but 80-90% can be absorbed

Rich sources
- Green forage, citrus fruits, vegetables, potato, tomato, citrus pulp

Vitamin D

Essential Vitamin





Chemical Formula

$C_{27}H_{44}O$

Molecular Weight

384.62 g/mol

Alternative Names

- Ergocalciferol (Vitamin D_2) – predominantly plant origin,
- Cholecalciferol (Vitamin D_3) – animal origin

Target Species

- Milk fed - calf, lamb, kid
- Dairy, heifer, beef
- Sheep
- Grower, finisher, breeding
- Broiler, breeder, layer, turkey, geese, pheasant, duck
- Maintenance, growth
- Growing
- All
- Catfish, trout

Introduction

- A fat soluble vitamin, converted from its chemical forms into Vitamin D by the action of ultra-violet light
- Known as the 'sunshine' vitamin or the 'anti-rickets' vitamin
- Essential in calcium and phosphorous metabolism
- There are about 10 pro-vitamins that can form compounds with anti-rickets activity after irradiation
- The provitamins are precursors of a steroid hormone 1,25 dihydroxy - cholecalciferol [1,25 $(OH)_2$ CC], also known as calcitrol

Vitamin F

Essential Fatty Acid

Absoprtion
- EFA's absorbed in the intestines

Metabolism
Monogastrics
- Fatty acid composition of body fat related to dietary fatty acid composition

Ruminants
- Rumen micro organisms result in more saturated body fat

Requirement/Allowance Linoleic acid (g/kg diet DM)

Rums	NRC	Pigs	NRC	Poultry	NRC	Others	NRC
Calf (MR)		Creep		Chick	11	Dog	11
Dairy		Weaner		Broiler	11	Cat	5.5
Beef		Grower		Breeder	11	Horse	5.5
Heifer		Finisher		Layer	11-15.5	Fish *	11
Sheep		Sow/Boar		Turkey	8.8-11	Rabbit	

Rums	Typical	Pigs	Typical	Poultry	Typical	Others	Typical
Calf (MR)	16.6	Creep	22	Chick	13.8	Dog	11
Dairy		Weaner	16.6	Broiler	5.5-8.8	Cat	11
Beef		Grower	16.6	Breeder	15.5	Horse	5.5
Heifer		Finisher	8.8	Layer	13.3	Fish *	11
Sheep		Sow/Boar	7.7#	Turkey	6.6-13.8	Rabbit	11

Notes
* Also add 10g/kg linolenic acid
# Also add 5.5g/kg arachadonic acid

Requirements Affected by
- Age
- Dietary fat
- Hormone balance
- Growth rate
- Humidity and water balance
- Sex
- Temperature (for fish)

Deficiency
Monogastrics
- Reduced growth rate
- Dermatitis and necrosis of skin
- Loss of hair
- Reduced cell membrane strength
- Cholesterol build-up in cells
- Reduced prostaglandin production
- Fatty livers can develop in poultry
- Disturbed water balance (e.g. increased water intake and retention)
- Impaired reproduction
- Reduced resistance to infection
- Reduced metabolic function and efficiency

Toxicity
- Reduced appetite
- Produce oily carcasses
- Greasy faeces
- Induced vitamin E deficiency (Vitamin E supply must match PUFA supply - 3mg/g PUFA)

Antagonists
- Peroxides, Copper

Synergy
- Selenium, Vitamin E, Vitamin B_6

Feed Additive/Supplement
- Omega-3 essential unsaturated fatty acids
- Omega-6 essential unsaturated fatty acids

Physical Form and Texture
- Colourless oil liquid at room temp
- Linoleic acid - melts at -12°C
- Arachidonic acid - melts at - 49.5°

Storage and Handling
Stable to
- Heat

Vitamin K

Essential Vitamin

Requirements Affected by

- Dietary components
- Age
- Sex
- Strain
- Antagonists
- Disease
- Conditions affecting fat absorption or intestinal flora
- Rate of passage though intestines (diarrhoea)

Animal Status

- Egg contains approximately 0.02mg/60g egg in yolk

Deficiency

General

- Blood coagulation disorders
- Haemorrhages in various tissues and organs
- Prolonged blood clotting time
- Anaemia
- Death in severe cases

Ruminants

- Can occur in presence of metabolic antagonists, e.g. dicoumarol or poisoning

Pigs

- Can occur from poor diet, antagonists, low coprophagy, breed, increased litter size and rate of gain may increase need

Poultry

- Gizard erosion
- Increased bruising
- Embryo mortality
- Poor hatchability
- Egg quality
- Impaired eggshell formation

Dogs

- Rarely seen unless from poisoning

Horses

- Rare when on pasture or good-quality hay

Toxicity

- Natural forms are non toxic
- Synthetic forms have shown toxicity in rats, humans, rabbits, dogs and mice leading to anaemia, renal failure, death
- Safe upper dietary level suggested for Vitamin K3 of 1000 times requirement

Antagonists

- Dicoumarol (produced by moulds from coumarins found naturally in sweet clover)
- Dicourmarol is used commercially in Warfarin, a rodent poison
- Mycotoxin, aflatoxin (toxic substance produced by moulds)
- Certain antibiotics and sulphonamides
- Coccidiosis increases vitamin K requirements
- Excessive vitamin A and calcium

Synergy

- Vitamin K_1 absorption stimulated by oestrogen

Feed Additives/Supplements (Vitamin K_3)

- Menadione sodium bisulphite (MSB) = 50% Menadione
- Menadione dimethylpyrimidinol bisulphite (MPB) = 45.4% Menadione)
- Menadione sodium bisulphite complex (MSBC) = 33% Menadione
- Menadione nicotinamide bisulphite (MNB) = 23% or 43% menadione and 16% or 31% nicotinamide