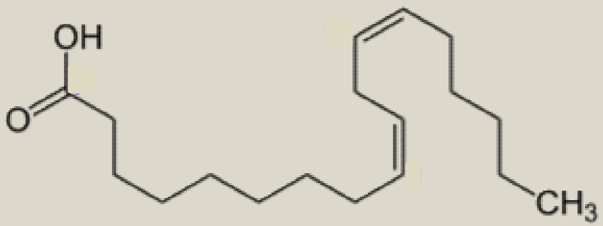
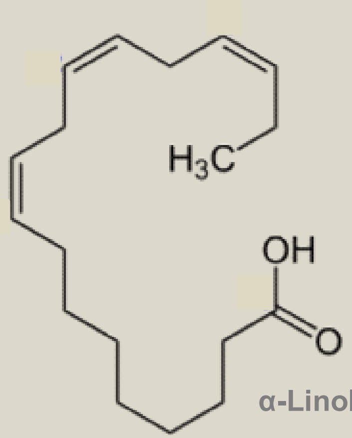
Stiftung Tierärztliche Hochschule Hannover
University of Veterinary Medicine Hannover, Foundation

ω-3 and ω-6 fatty acids in animal nutrition – impact on health and performance –



Linoleic acid (ω-6)

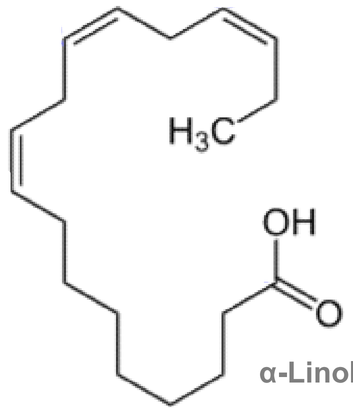


α-Linolenic acid (ω-3)

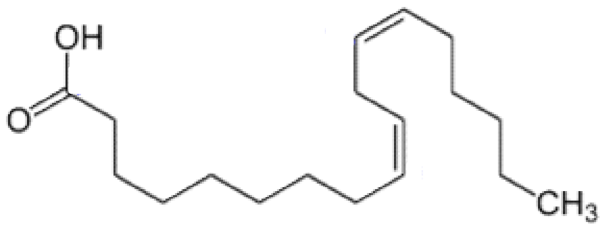
Saara Sander
Institute for Animal Nutrition
University of Veterinary Medicine Hannover, Foundation

Outline

- Background information on the history of essential fatty acids (EFA)
- Metabolism of EFA
- What are EFAs good for?
- Dietary sources and feeding recommendations
- Clinical use and effects on performance
- Summary
- Literature



α-Linolenic acid (ω-3)



Linoleic acid (ω-6)

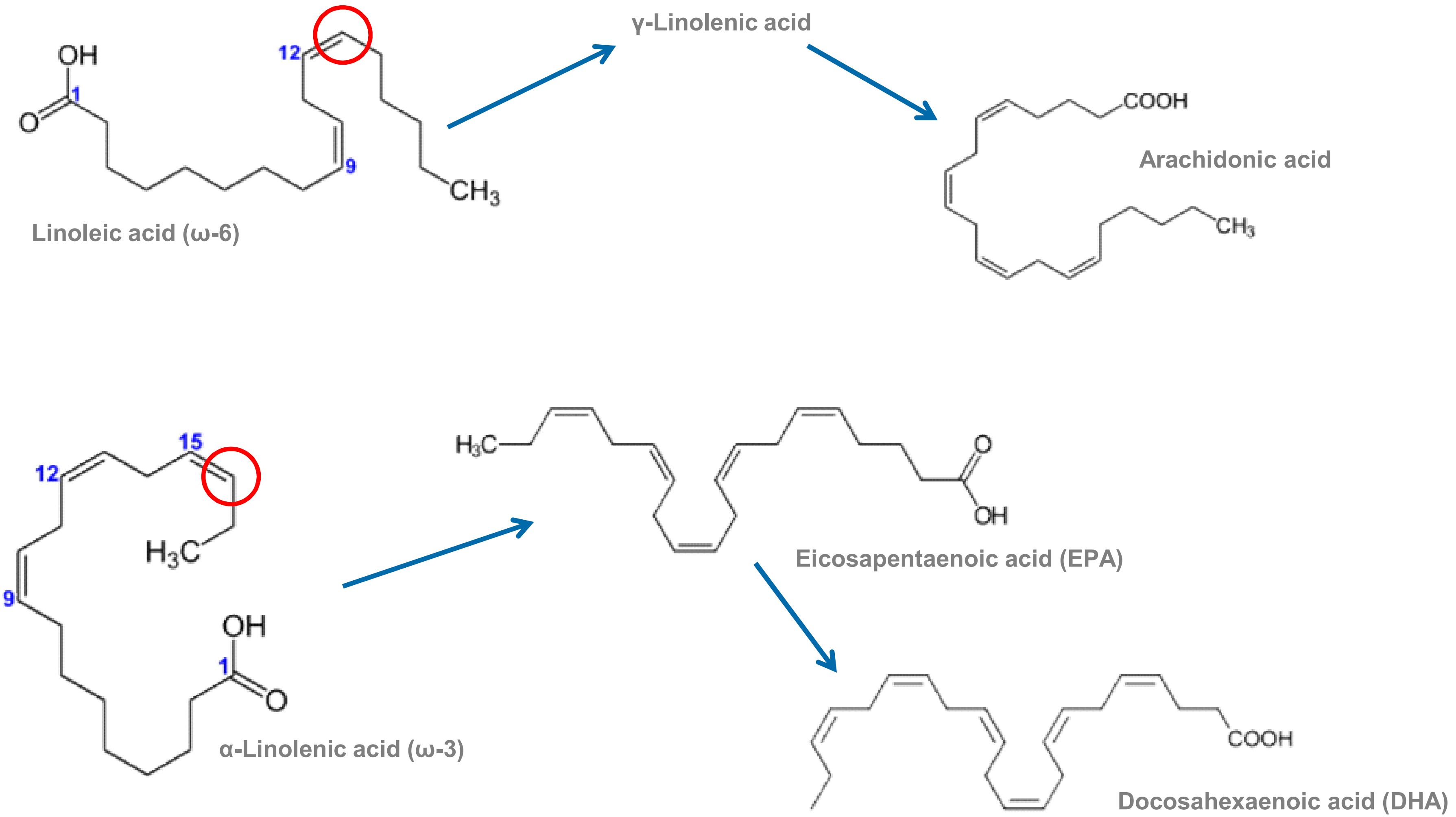
The history of essential fatty acids

- 1926: Burr & Burr proved essentiality of fatty acids
  → skepticism under scientists, but failure to prove them wrong
- 1931: Wesson & Burr stated α-linolenic acid as essential
  → essentiality was under doubt for further 50 years
- 1938 -1942: metabolic pathway linoleic acid → arachidonic acid but elongation and desaturation were not known
- 1953-1960: first insights on elongation and saturation of fatty acids by Jim Mead and co-workers
- 1964: metabolic pathway arachidonic acid → PGE_2
  (by van Dorp and Bergström, independent of each other)
- 1978: studies on the link between ω-3-fatty acids and cardiovascular health by Dyerberg and Bang
  → paradigm-changing discovery

George Oswald Burr (1896-1992)

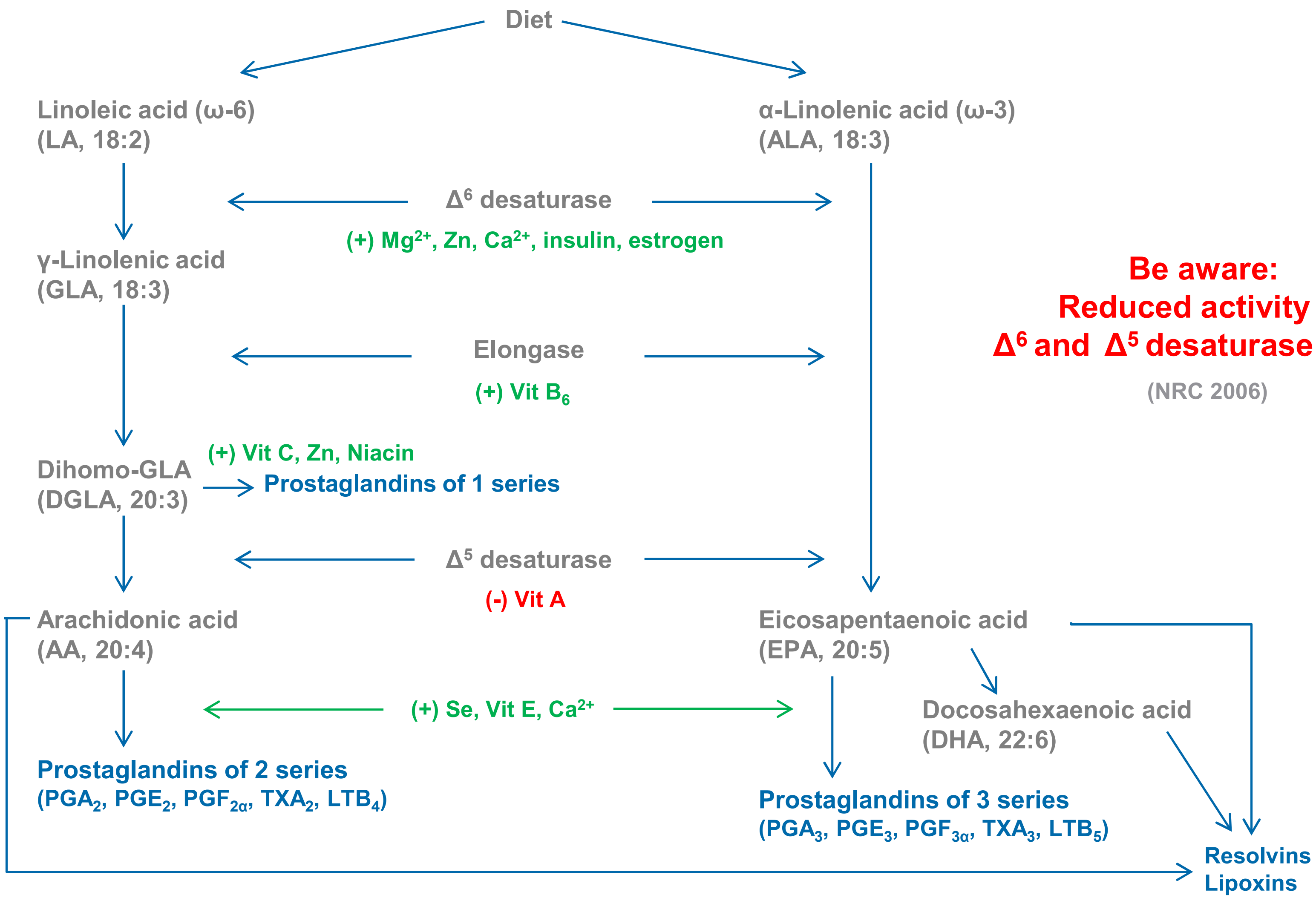
Spector and Kim 2014

Metabolism of essential fatty acids



Metabolism of essential fatty acids

According to Das 2006



Be aware:
Reduced activity of
Δ^6 and Δ^5 desaturase in cats

(NRC 2006)

Metabolism of essential fatty acids (EFA)

- **Conversion ratio of α-Linolenic acid**

  → EPA: 0.2 - 21 %

  → DHA: 0 - 9 %

- **Affected by**
  - intake ratio of ω-6:ω-3
  - competition on Δ^6 desaturase (ω-3 > ω-6 > ω-9)
  - high total PUFA intake → conversion to DHA ↓
  - sex/sex hormones

    (higher in females, especially DHA ↑ during pregnancy and lactation)

Das 2006
Gibson 2013
Abedi & Sahari 2014

Dietary sources of essential fatty acids

Linoleic acid	α-Linolenic acid	EPA/DHA
Cereals	Leafy green vegetables	Marine fish
Eggs	Grass and hay	Milk (human, dog, horse, pig, rabbit)
Poultry	Walnuts	Different bacteria,
Avocado	Linseed	Fungi,
Soybean oil	Linseed oil	Microalgae
Sunflower oil	Canola oil	
Corn oil	Milk (human, dog, horse, pig, rabbit)	
Borage oil		
Black currant oil		
Milk (human, dog, horse, pig, rabbit)		

Das 2006
Abedi & Sahari 2014
Kamphues et al. 2014

Percentage of fatty acids in different oils

Oil	SFA	MFA	PUFA ω-6	PUFA ω-3
Sunflower	12.0	19.0	68.0	1.0
Soybean	15.0	22.5	50.0	7.0
Linseed	9.0	21.0	16.0	53.0
Corn	13.0	28.0	58.0	1.0
Walnut	9.0	22.2	52.0	10.0
Pumpkin seed	9.0	33.5	50.5	7.0
Safflower seed	9.0	13.0	78.0	---
Borage seed	13.9	16.0	60.3	---
Fish (only 14:0-22:6)	23.1	22.5	2.0	27.2

SFA = saturated fatty acids
MFA = mono-unsaturated fatty acids
PUFA = poly-unsaturated fatty acids

Hyvonen et al. 1993
Tvrzicka et al. 2011

Actions of EFAs and their metabolites

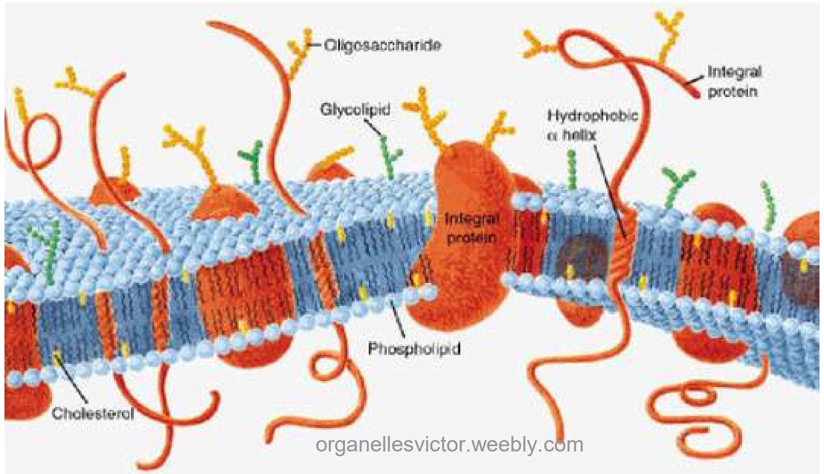
Cell membrane fluidity

Inflammation

Antibiotic-like actions

- Cell membrane fluidity is determined by its phospholipid composition
  - more SFA and cholesterol → more rigid
    more MFA/PUFA → more fluid
  - number and affinity of specific receptors in the cell membrane depend on its fluidity
    → membrane rigidity ↑ → insulin receptors ↓
    → insulin resistance

Das 2006



Actions of EFAs and their metabolites

Cell membrane fluidity

Inflammation

Antibiotic-like actions

- Metabolites of linoleic acid and α-linolenic acid possess **anti-inflammatory action** due to
  - functioning as second messengers that decrease formation of pro-inflammatory eicosanoids and cytokines
  - increasing the production of “beneficial” eicosanoids like PGE1, PGI2, PGI3, endothelial NO, leukotrienes, resolvins
- Chronic inflammation as reason for various diseases in humans
  (e.g. cardiovascular disease, renal diseases, rheumatoid arthritis, atherosclerosis, psoriasis, non-alcoholic fatty liver disease, eventually even obesity)

Das 2006
Abedi & Sahari 2014
Calder 2015

Actions of EFAs and their metabolites

Cell membrane fluidity

Inflammation

Antibiotic-like actions

- Linolenic acid rapidly killed *Staph. aureus* cultures
- Hydrolyzed linseed oil inactivated methicillin-resistant *Staph. aureus*
- α-Linolenic acid promotes adhesion of *Lactobacillus casei* to mucosal surfaces and enhances growth
  → *L. casei* suppresses in turn *Salmonella Thyphimurium*, *Pseudomonas aeroginosa*, *Clostridium difficile*, *E. coli*
- Neutrophils, T-cells and macrophages release PUFAs on stimulation
  → perhaps this is one further defense mechanism of the body to fight infections

Sun et al. 2003
Das 2006

EFA – organs relying on and signs of deficiency

Organs relying on EFA

- Skin (integrity)
- Brain (development and cognitive function)
- Retina
- Liver
- Kidney
- Adrenal glands
- Gonads

Signs of deficiency

- Reduced weight gain/body mass
- Dry or scaly skin, hyperkeratosis
- Increased water losses via skin
  → water intake ↑
- Alopecia
- Renal abnormalities
- Impaired reproductive function
- Impaired immunity

Das 2006
NRC 2006
Hand et al. 2010

Feeding recommendations

- **Most species: 1 % linoleic acid (LA) in the diet, based on dry matter**
  (Gurr et al. 2002)

- **Dogs: 1.1 % LA, ≥ 0.04 % ALA (based on dry matter), ratio LA:ALA < 26:1**
  (NRC 2006)

- **Cats: 0.6 % LA, 0.006 % arachidonic acid (based on dry matter)**
  to date, no metabolic requirement for ω-3 fatty acids
  (NRC 2006)

- **Horses: 0.5 % linoleic acid in the diet, based on dry matter**
  (NRC 2007)

- **In the case of inflammatory processes: 50-250 mg/kg body weight**
  (= minimum 0.3 % ω-3 fatty acids in the diet, based on dry matter)
  (Dogs; Hand et al. 2010)

- **Be aware: substantial losses of EFAs during food/feed processing!**

Clinical use in dogs and cats

- **Kidney insufficiency**
  - Supplementation of Ω-3 fatty acids
    → reduces conversion of linoleic acid to arachidonic acid
    → vasodilatation ↑, platelet aggregation ↓
    → reduced blood pressure
    → reduction of platelet induced damage of the glomerulus
- **Inflammatory bowel disease/colitis**
  - Supplementation of Ω-3 fatty acids
    → downregulation of pro-inflammatory mediators
- Support in all cases of **inflammation**
  - **Arthritis** (cartilage health)
  - **Dermatitis**
- In humans: inhibition of **mammary carcinoma** growth
  (Jiang 2012)
- **Supplementation of EPA and DHA more effective than ALA**

NRC 2006, Hand et al. 2010

Clinical use in horses

- Deficiency of essential fatty acids **could not be reproduced** in horses so far
  - Perhaps 7 months were not long enough to deplete body stores in adult ponies
    (Sallmann et al. 1991)
- As an herbivore, the horse is adapted to relatively high proportions of Ω-3 fatty acids in the diet
  - Due to high amounts in hay and pasture, ratios of Ω-6:Ω-3 of 0.3-7.8:1 are normal!
- Clinical studies on effects of Ω-3 fatty acids on
  - **Culicoides hypersensitivity** → conflicting results
    (Friberg et al. 1999, O'Neill et al. 2002)
  - **Osteoarthritis** → no clear beneficial effects
- Supplementation of Ω-3 fatty acids in stallions resulted in **improved sperm motility** after cooling and freezing in stallions producing semen with poor tolerance to cooling
  (Brinsko et al. 2005, Harris et al. 2005)
  No studies in mares so far
- Regularly used in supplements for horses with **low hoof quality**

Warren & Vineyard 2013

Effects in pigs

- Especially **effects on reproductive performance** in sows supplemented with EFA were studied
- Comparing 29 studies, Tanghe and De Smet (2013) did not find **any effects** of linseed oil or fish oil on
  - Litter size, number of piglets born (total/live/stillborn)
  - Piglet birth weight
  - Mortality rate of piglets during suckling period
- **Positive effects** were seen on
  - Piglet vitality after birth (Tanghe and De Smet 2013)
  - Performance in the next reproductive cycle of the sow
    → return to estrus
    → subsequent litter size (Tanghe and De Smet 2013, Rosero et al. 2016)

Effects in dairy cows and calves

- **Biohydrogenation** of PUFAs in the rumen → only negligible amounts of EFA are absorbed
- To counteract this, high conservation rate of EFAs in ruminants

Lourenco et al. 2010
Caldari-Torres et al. 2016

- Despite low EFA plasma levels at birth and low contents in the milk, ruminant offspring scarcely show deficiency signs

Jenkins & Kramer 1986

- **Nevertheless clinical effects of dietary EFA supplementation?**
  - Positive effects on calve growth and health, when cows are fed on a low LA/ALA diet
  - No "on top effect" in calves

Garcia et al. 2014, 2015

  - No effect on ketosis in cows

Drong et al. 2016

Summary

- Deficiency or imbalance of essential fatty acids are associated with a wide variety of diseases, especially in humans
- Signs of deficiency are most obvious in growing animals/humans
- Adequate supply is necessary for various organ systems, during development as well as for the metabolism of mature organs
- An extra supply of Ω-3 fatty acids can be helpful, especially in diseases associated with inflammation
- Effects of “on top” supplementation on performance in healthy animals are rare

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