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Role of Vitamin E in Livestock Nutrition

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Abstract: Vitamin E is generally a group of chemically related compounds called tocopherols which plays a critical role in animal nutrition by serving as a potent lipid-soluble antioxidant as well as contributing to anti-inflammation, immune function, and gene expression regulation. As an antioxidant, it protects cell membranes and other lipid-containing structures from oxidative damage caused by free radicals. Due to its antioxidant qualities, vitamin E is a necessary nontoxic fat-soluble micronutrient that has an impact on the health and productivity of livestock. Despite being infrequently required in the diet, it plays a crucial role in livestock production as it enhances the nutritional value, productivity, and overall performance of animals and animal products. Lowering cholesterol levels, enhancing antioxidant capacity, and decreasing lipid oxidation in dairy products, egg, and muscle products all depend on vitamin E supplementation in diet.

Introduction

Throughout the past century, numerous studies and advancements have been made in understanding the crucial role vitamin E plays in livestock production. A deficiency of vitamin E can impair immune responses and increase the susceptibility of animals to infectious diseases. Furthermore, hypovitaminosis E has been linked to reduced reproductive performance in animals, including decreased fertility rates and increased embryonic mortality. For livestock, optimizing vitamin E status is particularly important for animal health and production. In dairy cattle, supplementation with vitamin E has been demonstrated to enhance milk yield and lower the occurrence of mastitis. In poultry, it has been associated with better growth rates, egg production, and hatchability Likewise, in swine, vitamin E supplementation has been proven to enhance meat quality, reduce stress, and increase growth rates

To ensure that animals receive adequate amounts of vitamin E, it is common practice to add this micronutrient as synthetic dl-α-tocopheryl acetate to animal feeds. However, determining the optimal level of vitamin E supplementation can be challenging, as the requirements for this nutrient can vary depending on the species, age, and health status of the animal, as well as other factors

Origin And Structure of Vitamin E

Vitamin E is an efficient nontoxic and widely consumed lipid-soluble vitamin because of its antioxidant capacity and multiple health benefits. It can be found in two forms: natural or synthetic.

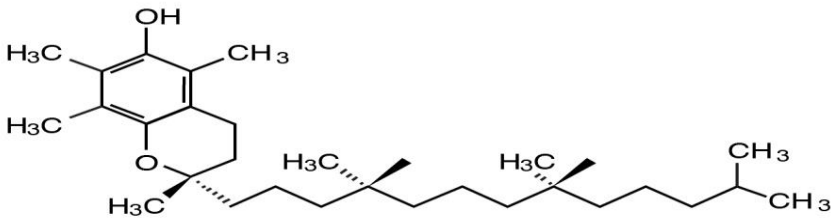
The natural vitamin E was first discovered in 1922 by Herbert Evans and Katherine Bishop when they isolated an uncharacterized lipid soluble compound from green leafy vegetables which is required to prevent a fatal resorption in pregnant rats during reproduction

Vitamin E is a term that is used to describe a group of chemically related compounds called tocopherols and tocotrienols. Among the different isomers, α-tocopherol is the most

active biological form of vitamin E and is the one that is added to animal diets. Other isomers with less biological effects include β-, γ-, δ-tocopherol and α-, β-, γ-, δ tocotrienols. Most commercially available vitamin E is DL-α-tocopheryl acetate.

In nature, vitamin E is mainly synthesized by plants and photosynthetic organisms including algae and some cyanobacteria (Peh et al., 2016; Reboul, 2017).

On the other hand, the synthetic vitamin E (all-rac-a-tocopherol) was first synthesized in 1938 (Karrer, Fritzsche, Ringier, & Salomon, 1938) and consist of four side-chain isomers. According to Fu, Htar, Silva, Tan, and Chuah (2017), it was reported that all rac-a-tocopherol are synthesized from the reaction of 2, 3, 5-trimethylhydroquinone and racemic isophytol under acidic condition.



Vitamin E (α-tocopherol)

Chemical structure of Vitamin E

Natural sources and bioavailability

Vitamin E is a generic term for various compounds based on tocopherol or tocotrienol. It is found in plants and animals. However, it is not the total tocopherol content that is important, but the content of the biologically active d-α-tocopherol.

1) Plant sources:

A. Green plants (Asparagus, Avocado, Nuts such as almonds and hazelnuts Seeds). Spinach and other green leafy vegetables
B. Unheated vegetable oils: cotton seed oil, soybean oil and corn oil are the richest natural source.
C. Wheat germ and Wholegrain foods

2) Animal sources: Liver, egg and milk

Humidity and long storage have an adverse effect on vitamin E stability and content. Conserved green forages and cereals are the types of feed mostly affected.

Cereals and middlings mainly contain β -,γ -, and δ -tocopherols (70–90%) with a biological activity significantly lower than that of α -tocopherol

Table: Biological efficiency of various vitamin E compounds

α -Tocopherol	100%
β –Tocopherol	15–40%
γ -Tocopherol	1–20%
δ -Tocopherol	1%
α- Tocotrienol	15–30%
β –Tocotrienol	1–5%
γ -Tocotrienol	1%
δ -Tocotrienol	1 %

Physiological role

- ✓ Reduces the production of lipid peroxyl radicals from highly unsaturated fatty acids
- ✓ Antitoxic effect in cell metabolism
- ✓ Reduces the incidence of liver necrosis and muscular degeneration

- ✓ Antioxidant effect, i.e. phospholipids in the cell membrane and other substances sensitive to oxidation, e.g. vitamin A, carotenoids and their intermediates, are stabilised. There is a close relationship in the functions of vitamin E and selenium in protecting the cell membrane from oxidation. While vitamin E acts within the cell membrane, the effect of selenium is based on peroxide degradation by glutathione peroxidase in the soluble constituents of the cell. To achieve a sufficient production of selenium containing glutathione peroxidase, a selenium content of 0.2-0.3 mg per kg dry matter in the feed is necessary
- ✓ Controls metabolism of the hormones via the anterior lobe of the hypophysis
- ✓ Maintains membrane stability, especially of the cardiac and skeletal muscles
- ✓ Controls the development and function of the gonads
- ✓ Stimulates antibody production (improved resistance to diseases), phagocytosis and the bactericide effects of phagocytes
- ✓ Preparation for pregnancy and protection against abortion

Antioxidant Mechanism of Vitamin E

The release of free radicals begins with rapid uptake of oxygen during tissue oxidation. Free radicals attack all major components of tissue, especially the unsaturated fatty acids (UFA). The oxidation of UFA is generally destructive because it proceeds as a self-perpetuating chain reaction involving three major stages via initiation, propagation, and termination

The initiation reaction can be catalysed by heat, light, and transition metals to produce alkyl radicals (Chan, 1987). In the propagation step, the alkyl radicals react with singlet oxygen at a very high rate to produce a peroxyl radical. The peroxyl radical can thereafter react with another unsaturated fatty acid to produce a lipid hydro peroxide, and a new alkyl radical which is rapidly converted into another peroxyl radical. In a further reaction, the peroxyl radical meets and combines with another radical to form inactive products to terminate the reaction. In the presence of efficient antioxidant like vitamin E, the lipid peroxyl radicals that have been produced at propagation stage can be intercepted to terminate the lipid peroxidation chain reactions. Strictly, the antioxidant activity of vitamin E is due to its ability to release its hydroxyl groups to combat free radicals and terminate the reaction, while itself is reduced to α-tocopheroxyl radical. The resultant tocopheroxyl radical formed is known to be relatively stable under normal circumstances, but insufficiently reactive to initiate lipid oxidation itself, without a proper regeneration into another α-tocopherol through a redox reaction by other co-antioxidants such as vitamin C and coenzyme Q10 also known as ubiquinol (Cassano, 2012).

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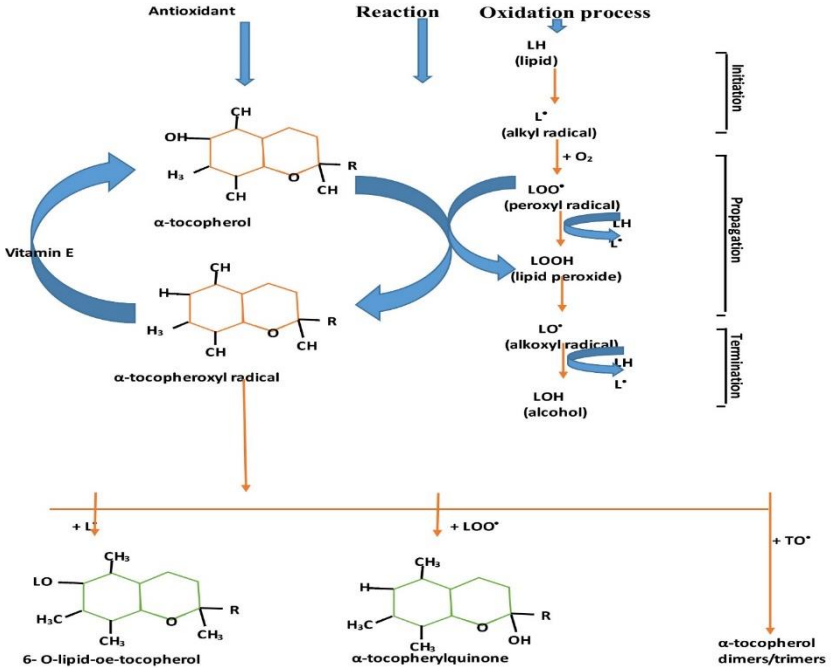

Fig. Showing role of vitamin E as antioxidant by reacting with the free radical generated as a result of oxidation process.

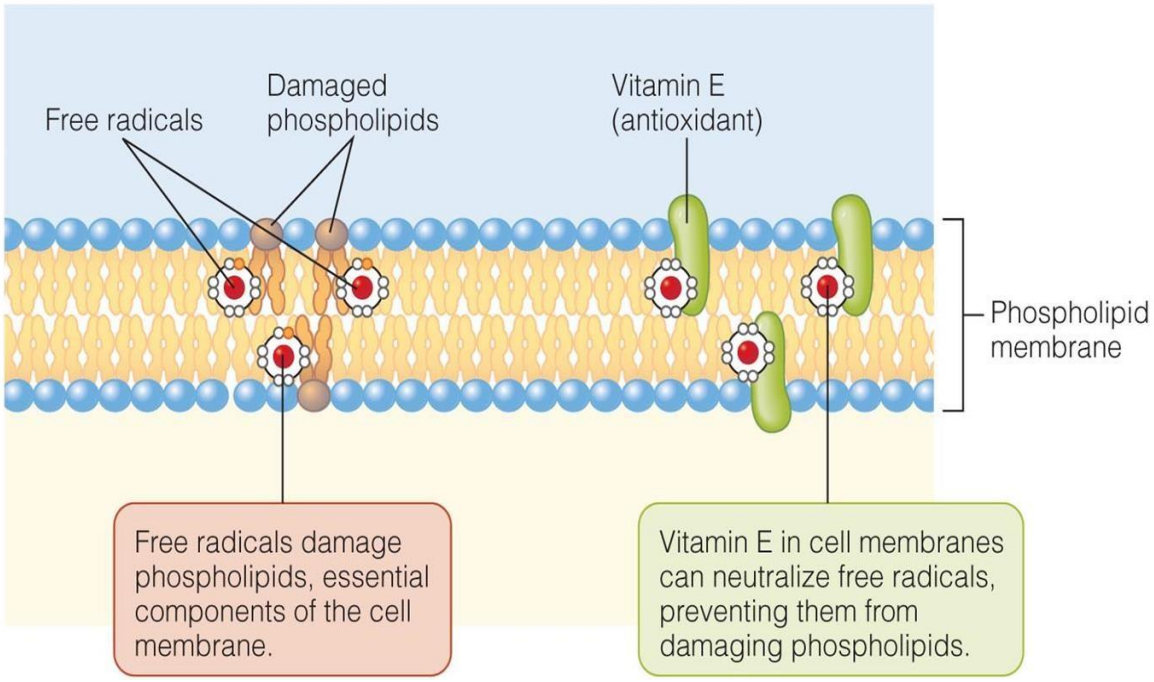

Fig: Showing vitamin E role as antioxidant at cellular level.

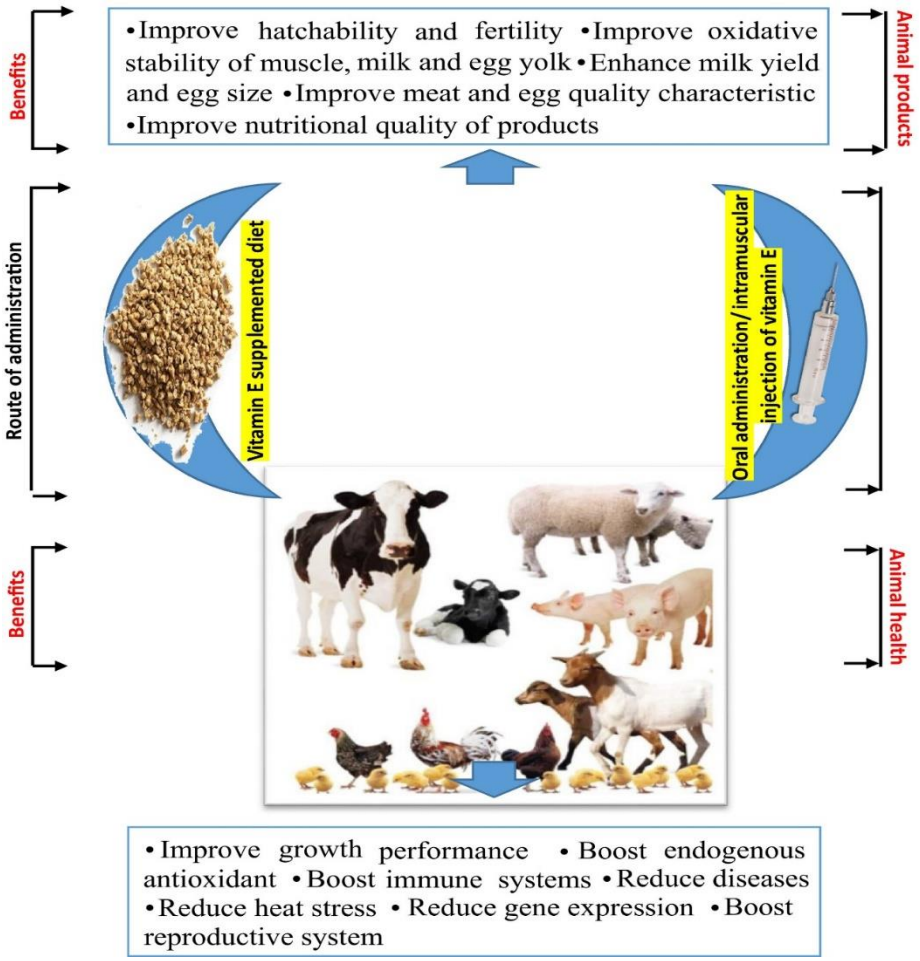

Fig: Multi-nutritional importance of vitamin E in livestock production
(Source: Emrobowansan M. Idamokoro, Andrew B. Falowo, Chika E. Oyeagu Anthony J. Afolayan)

Deficiency symptoms

- Infertility is the classical manifestation of deficiency in female rats while in male rats, deficiency of vitamin E results in immobility of spermatozoa and degeneration of the germinal epithelium.
- Nutritional and muscular dystrophy (Nutritional myopathy) is seen in chicks, pigs and lambs affecting primarily skeletal muscle and occasionally heart muscle. In pigs it is commonly known as mulberry heart disease.
- Stiff lamb disease in suckling lambs and white muscle disease in calves are variable forms of nutritional myopathy. Enzootic disease of sheep and cattle may be due to deficiency of vitamin E or vitamin E and selenium.
- Nutritional Encephalomalacia (cerebellum degenerating disease of chickens) or crazy chick disease: Haemorrhage, oedema and generation of purkinje cells in the cerebellum are seen. The chicks is unable to stand or walk.
- Enlarge hock disorders in turkeys due to niacin and vitamin E deficiency.
- Exudative diathesis (an oedema caused by excessive capillary permeability), a haemorrhage disease in chicks and turkeys.
- Generally, vitamin E appear to be involve in nutritional muscular dystrophy and in exudative diathesis but selenium does not seem to be important in nutritional encephalomalacia.
- Vitamin E deficiency leads to yellow fat disease or pansteatitis in cats. This occurs when high levels of PUFA are fed with low level of vitamin E leading to deposition of caroid pigments in adipose tissue with fat cells necrosis and subsequent inflammation.

Toxicity

Vitamin E is the least toxic of the fat-soluble vitamins and high levels are added in the diets of animals (beef cow, poultry) to enhance food nutritional and aesthetic value and lipid stability.

Functions	Deficiency	Excess
Free radical scavenger	White muscle Disease	Non toxic
Antioxidant function	Crazy chick disease	High level are added in animal diets to enhance lipid stability in omega-3fatty acids rich foods, in red meat, and to reduce heat stress and enhance immune function in poultry.
Affects immune response	Reduction in feed and food liquid quality and rancidity	

Conclusion

The addition of vitamin E to animal diets improves the quality of muscle, egg, and dairy products by retaining their lipid oxidative stability, which in turn improves human health after consumption. Information has demonstrated that animal products enhanced with vitamin E had a bioavailability potentially provide consumers with a priceless nutritional advantage; particularly in resource-poor areas where vitamin E deficiencies may be harmful to certain cellular functions of the human body and health.

Vitamin E being one of the important vitamins of diet is needed for the general good health and healthy reproductive efficiency as vitamin E is known as anti- sterility vitamin. Vitamin E is also detrimental for muscle mass wool quality and fertility of animals. Besides all these functions it performs a major role as antioxidant in body prevent oxidative damage in tissues and cells.

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