DIETARY ANTIOXIDANTS AND L-CARNITINE – a clever combination to combat oxidative stress in farm animals

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OXIDATIVE STRESS: DEVELOPMENT – DEFINITION – DETRIMENTAL EFFECTS

For the majority of organisms, oxygen is absolutely vital: animals, plants and a number of microorganisms need oxygen to produce energy. Oxygen-dependent redox-reactions, like energy metabolism, result in the formation of reactive oxygen species (ROS). These so-called "free radicals" are very unstable due to their unpaired electrons and are thus highly reactive. If free radicals meet up with proteins, fatty acids, carbohydrates and DNA in the organism, they can react with these and damage them. This damage can lead to the impairment of many processes in the organism, e.g. growth, immune competence and reproduction. Furthermore, the oxidation of membrane-bound polyunsaturated fatty acids (PUFA) influences the composition, structure and properties of membranes, such as fluidity and permeability, as well as the activity of membrane-bound enzymes. The structure of the cell membranes is in turn relevant for the juice-holding capacity of muscle meat and is thus important for meat quality.

During evolution, the organism developed specific protective mechanisms based on antioxidants to protect itself from attacks by free radicals and thus from associated damage to the cell structures. The body´s own radical defence system can be split into three levels. On the first level antioxidative enzyme systems prevent the formation of free radicals. As this cannot occur exhaustively, free radicals which have already been formed are neutralised on the second level, thus preventing and/or limiting a chain reaction and cellular damage. Essential parts of these first two levels are different enzymes, vitamins (vitamin E and C), and trace minerals (Se, Zn, Cu). Vitamins and minerals have direct effects, e.g. vitamin E, as the most important cell protection vitamin, or are important to build up the enzymes, e.g. act as a cofactor. As only a certain amount of the free radicals being formed continually can be bound, it is also necessary to supplement continually the necessary antioxidant vitamins and minerals via feedstuffs. It is still not possible to prevent all molecules from being damaged by radicals. Through the activity of specific enzymes (lipase, protease, DNA repair enzymes), the damaged molecules can be removed or repaired. These repair enzymes form the basis of the third level.

Under ideal conditions a sensitive balance prevails between the quantity of free radicals formed in the body and the antioxidative mechanisms. An excess of free radicals and/or insufficient protection through antioxidants can disturb this balance and cause so-called oxidative stress. Increased respiration with an increased energy metabolism, immune response by the free radicals formed by the scavenger cells and also pro-oxidising inorganic compounds and mycotoxins are described in literature as factors for oxidative stress. A further factor which is directly linked to feeding is the intake of oxidised fatty acids.

Oxidative stress plays an important role in many degenerative illnesses. It is assumed that the majority of illnesses in humans and animals are linked at various stages of their development to the formation and metabolism of free radicals. (Lohmann Information, 01/2005)

INFLUENCE OF DIETARY ANTIOXIDANTS ON MEAT QUALITY

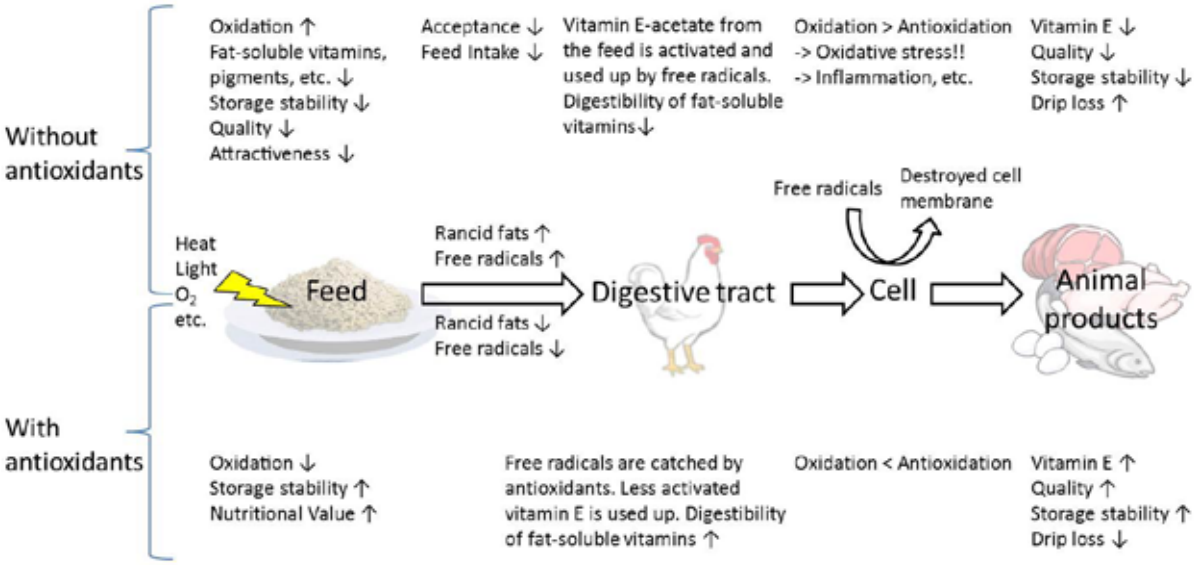
Feeding oxidised feedingstuffs means the animals are exposed to a high number of free radicals, inducing oxidative stress. It also leads to decreased vitamin E content in the tissue which has a negative impact on animal health and the quality of animal products. Vitamin E is certainly the most important fat-soluble antioxidant in the animal organism. Here it ensures the maintenance of cell membranes by preventing stress-related damage through free radicals. Especially in high-performance animals vitamin E is important to maintain good health and quality of muscle and fatty tissue. The content of vitamin E in the tissue is directly linked to the quality and storage stability of meat.

The absorption of vitamin E takes place together with fat in the small intestine and is equally dependent upon the fat content and quality. The uptake of oxidised fatty acids leads to a considerable decrease in the absorption of vitamin E, causing reduced contents of vitamin E in muscle tissue (see Figure 1).

Furthermore, the increased formation of free radicals causes a diminished endogenous antioxidative potential resulting in damaged cell structures. Oxidative stress is thus often considered as the cause of many secondary diseases. Supplementation with high levels of vitamin E leads to higher contents of vitamin E in the organism. However, it cannot prevent the oxidation of the feedstuff. Vitamin E is added to the feed as α-tocopheryl acetate, which obtains its activity following hydrolyses of the acetate groups in the small intestine.

In order to prevent the oxidation of feed fat it is necessary to add effective antioxidants (Figure 1). Both synthetic and naturally-occurring antioxidants can effectively prevent and/or delay oxidative spoilage of the feedstuff during storage as well as during the critical phases of processing and digestion. Supplementing highly-effective dietary antioxidants leads to less oxidised fatty acids and free radicals in the feed. The negative impact for the animal is reduced as the challenge for the endogenous radical defence system (eRDS) in the cells is lower and less vitamin E is used up. Consequently, more vitamin E can be stored in the muscle and fatty tissue which in turn leads to a good quality of animal products.

Figure 1: Overview of the versatile impact of oxidation on feed, the animal and animal products compared to the use of antioxidants



ANTIOXIDANT PROPERTIES OF L-CARNITINE

L-carnitine is an endogenous substance that acts as a carrier for fatty acids across the inner mitochondrial membrane (shuttle function) necessary for subsequent beta-oxidation and ATP production. L-carnitine is also responsible for buffering these fatty acids when they exceed the capacity of the mitochondria to use them (buffer function). The effect of L-carnitine supplementation on energy metabolism has been demonstrated in several species. These benefits include a decreased negative energy balance in the first days of lactation in dairy cows, increased weight at birth and fewer stillbirths in swine, and increased laying persistence and hatchability in poultry production.

L-carnitine also has other functions which go beyond improving the energy metabolism. Several studies have shown the benefits of L-carnitine supplementation in patients with diabetes, Alzheimers, certain heart diseases, liver disease and oxidative stress. The beneficial effects of carnitine appear to arise, at least partially, from its antioxidant properties, which include the upregulation of the level and the elevation of the activities of antioxidant enzymes. L-carnitine prevents free radical formation by both inhibiting enzyme-synthesis and activity and also inducing antioxidant mechanisms. The antioxidant effect of L-carnitine may be partially due to the role of L-carnitine in the chelation of free Fe^{2+} ions, with a subsequent reduction in free radical generation, which improves the overall level and activity of antioxidant enzymes in the cell.

Studies in different species have also shown that L-carnitine affects sperm parameters (sperm count, motility and viability) mainly by increasing the activity of antioxidant enzymes, reflected in increased levels of catalase and superoxide dismutase, reduced glutathione and total antioxidant capacity. These increased levels of antioxidants lead to reduced levels of free radicals available for lipid peroxidation. As a result of the buffer effect and its antioxidant properties (which protect the spermatozoon membranes resulting in an increase in longevity) supplementation increases semen volume and the quality and quantity of the sperm. In a study with boars, L-carnitine supplementation (500mg/day) increased the number of viable sperm and the number of saleable doses. In another study with roosters supplemented with L-carnitine, there was an increase in sperm concentration and a reduction in one of the lipid peroxidation markers, malonaldehyde (MAL), which indicates better semen quality.

Poultry production during summer or in tropical climates struggles to perform with high temperatures and humidity. Birds display signs such as increases in deep body temperature and the biochemical and physiological changes that take place as a result. Supplementation with L-carnitine during heat stress has been shown to be beneficial. During the build-up of heat-stress, feed intake diminishes and the heart rate increases. The cardiac muscle uses fatty acids as its principal source of energy. Taking into account that stress diminishes endogenous production of L-carnitine and that L-carnitine has a buffer effect on fatty acids, supplementation with L-carnitine helps the organism during this challenge. L-carnitine is also crucial to this process due to its antioxidant properties, as shown in an *in vitro* study with endothelial cells. This study shows that L-carnitine increases the gene and protein expression of some of the oxidative stress-related markers that are known to be antioxidant and anti-inflammatory. Some studies have demonstrated the synergistic effect of supplementation with L-carnitine and antioxidants, for example the joint use of L-carnitine and ascorbic acid has been shown to have a positive impact on broilers during rearing in hot conditions.

CONCLUSION

Oxidative stress is a serious problem in livestock management. Dietary antioxidants prevent feed-induced oxidative stress and L-carnitine supports the animal metabolism to strengthen the endogenous radical defence system. This makes dietary antioxidants and L-carnitine the right combination to prevent oxidative stress and its negative effects on farm animals.

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