Dietary antioxidants

Lipids are one of the most important variables in meat quality and are especially vital to meat shelf life. Studies show that the most effective way of prolonging shelf life and maintaining quality is to introduce antioxidant protection through the diet.

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protect meat quality

Lipids are an important component of meat and contribute to several desirable characteristics of meat and meat products. They play important roles in enhancing the flavour and aroma profiles and they increase tenderness and juiciness. However, it is generally accepted that lipid oxidation is the primary process responsible for quality deterioration of meat during storage. The quality characteristics in meat that are affected by lipid oxidation include flavour, colour, texture and nutritional value. The development of rancidity in meat by lipid oxidation begins at slaughter and continues throughout storage. Storing meat at low temperatures and packaging it in oxygen-free containers retards the rapid development of rancidity. However, oxidation of lipids may continue even during frozen storage (Weber, 2001).

All meat and fish products are prone to oxidation. Poultry meat is considered to be more prone to the development of oxidative rancidity than red meat. This is explained by its higher content of phospholipids. Phospholipids are located in the membrane structure and are rich in polyunsaturated fatty acids (PUFA). It has been demonstrated that the oxidation of meat starts with peroxidation of the phospholipid fraction. Due to the high degree of poly-unsaturated lipids, the phospholipids are most prone to oxidation.

Lipid oxidation reduces meat quality in a number of ways, including off-flavour formation, increased drip loss and colour changes. During lipid oxidation, PUFAs are degraded to volatile short-chain oxidation products, which lead to off-odour and off-flavour formation. The oxidation process is strongly enhanced during cooking and storage of the meat. The formation of volatile lipid oxidation products strongly reduces consumer acceptability of the product. Oxidative processes can also affect the ability of the membranes to hold water and may contribute to drip loss (Jensen, 1998; Weber 2001).

Naturally protected

Membrane lipids are protected against oxidative attack by naturally occurring antioxidants such as α-tocopherol. The structure of a membrane and the positioning of α-tocopherol within it is shown in *Figure 1*. It is known that the α-tocopherol level of meat is an important factor in determining its stability. Increasing the content of α, γ- and δ-tocopherol in the feed clearly results in an increase in the blood plasma content of these different tocopherol isomers. However, only α-tocopherol is deposited in skeletal muscle and thigh meat (*Figure 2*) (Jakobsen, 1995). The natural isomer RRR-α-tocopherol has a higher bioavailability compared to racemic mixtures of synthetic all-rac-α-tocopherol (Lauridsen, 2002). The natural content of α-tocopherol present in the feed is not sufficient to protect the meat effectively against oxidative degradation during storage. Application of an additional α-tocopherol source in the feed is beneficial in increasing the oxidative stability of meat (Jensen, 1995).

Generally, α-tocopheryl acetate is added to the feed via the mineral premix (*Figure 3*). In its esterified form, α-tocopheryl acetate has no antioxidant activity, as the active phenol is blocked by esterification. In the gastrointestinal tract, α-tocopheryl acetate is hydrolysed into its active form: α-tocopherol. This liberated α-tocopherol is absorbed in the small intestine; from there it is transported to the liver and then deposited into the membranes of the muscle cells. Positioned between the membrane phospholipids, it protects the poly-unsaturated fatty acids of the phospholipids against oxidation. The chromanol ring of α-tocopherol is located among the polar head group of the phospholipids and the phytol side chain interacts with the unsaturated fatty acid chain towards the interior of the membrane. This specific location of α-tocopherol in the membrane allows it to function very efficiently and protect the unsaturated phospholipids from oxidation, thereby protecting meat quality. ➢

Figure 1 - Membrane structure and positioning of α-tocopherol in membrane

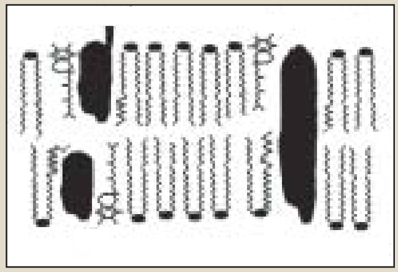


Figure 2 - Chemical structure of α-tocopherol

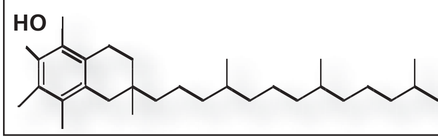


Figure 3 - Chemical structure of α-tocopherol acetate

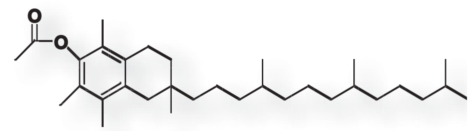
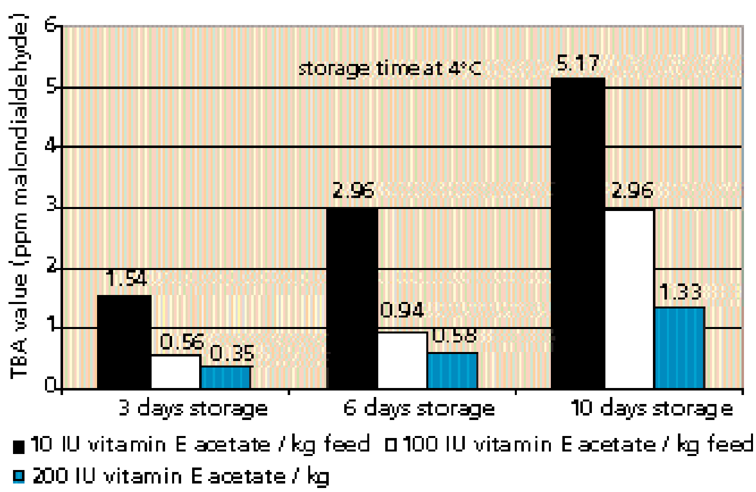


Figure 4 - Concentration of α-tocopherol in pork tissue (µg/g tissue) and muscle (µg/g protein) of pigs fed vitamin E supplemented diets for 14 weeks (Asghar, 1991)



α-tocopherol and meat quality

The development of rancidity in meat can be minimised effectively with the use of dietary antioxidants. Numerous articles have discussed the effects of feeding animals with supplementary vitamin E levels on the deposition of α-tocopherol in the muscle and its subsequent effect on meat quality. Similar observations have been reported in studies in a number of different species such as chickens and turkeys (Bartov, 1983; Bartov, 1991; Sheldon, 1997; Renerre, 1999; Guo, 2001) and pigs (Pfalzgraf, 1995; Onibi, 1998).

Deposition of α-tocopherol in meat

The effect of α-tocopherol acetate supplementation in relation to α-tocopherol deposition in the adipose tissue (back fat) and muscle of pigs is shown in *Figure 4*. Asghar (1991) carried out a trial with 60 pigs fed diets with varying α-tocopherol acetate contents of 10, 100 and 200 IU vitamin E acetate/kg feed. Concentrations of α-tocopherol in both muscle and adipose tissue increased significantly with the level of vitamin E acetate supplementation in the diets. A linear relationship between the α-tocopherol acetate intake and the deposition of α-tocopherol in the muscle is generally observed (Asghar, 1991; Weber, 2001).

Effect on oxidative stability of meat

It has been demonstrated that vitamin E supplementation has a beneficial effect on the oxidative stability and, consequently, on the sensory characteristics of meat. *Figure 5* shows the influence of dietary vitamin E levels on the oxidative stability of pork chops exposed to fluorescent light at 4°C for 10 days (common supermarket refrigerated display conditions). For all treatments the TBA value (a measure of the oxidation products and hence the extent of oxidation) of the meat samples increased as a function of storage time. Pork chops from pigs fed a diet supplemented with vitamin E levels have significantly lower TBA values than those from the control group. During storage of meat the proteins will also oxidise as measured by an increase in the carbonyl value. Protein oxidation is directly linked to lipid oxidation (Renerre, 1999).
Meat obtained from animals given a feed with added α-tocopherol acetate contained significantly less volatile oxidation products compared to meat from the control group (Sheldon, 1997). This also resulted in a beneficial sensory characteristic of the meat as expressed by its tenderness and juiciness (De Winne, 1996; De Winne, 1997).

The inclusion of tocopherols in the membranes is critical in stabilising meat. Dietary inclusion of vitamin E in the feed is considerably more effective than the postmortem addition of tocopherols to the meat (Mitsumoto, 1993).

Table 1 - Effect of synthetic antioxidant and α-tocopherol combinations on the quality of abdominal fat and the TBA value of thigh muscle in broilers (Bartov, 1981)

FEED		ABDOMINAL FAT		THIGH MUSCLE
Synthetic antioxidant (ppm)	Vitamin E (ppm)	α-tocopherol (ppm)	PV (meq/kg)	TBA
-	-	1.4	27.6	1.58
-	10	3.6	18.4	1.37
125	-	2.8	7.7	1.28
125	10	6.3	0	0.98

Figure 5 - Influence of dietary α-tocopherol acetate supplementation of the oxidative stability of pork chops stored at 4°C expressed by the TBA value (mg malondialdehyde / kg sample) (Asghar, 1991)

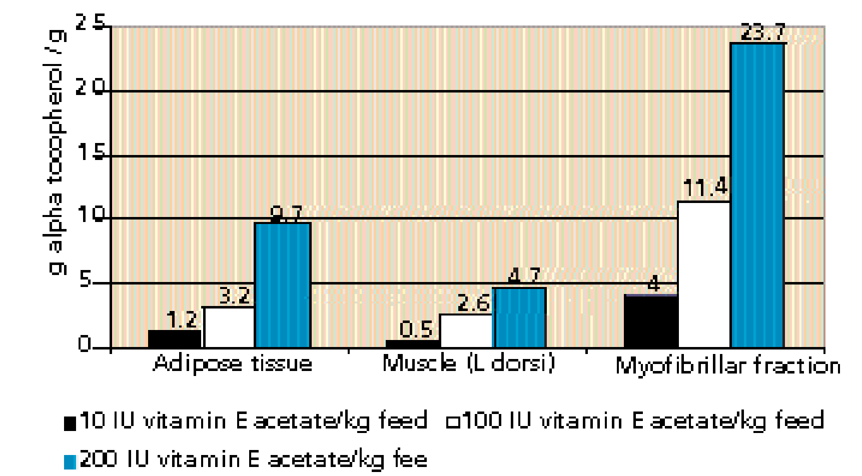
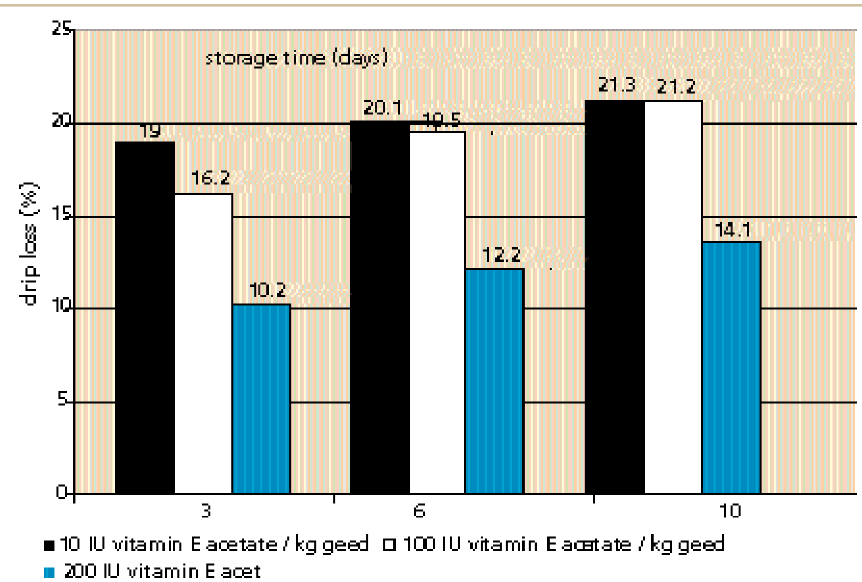


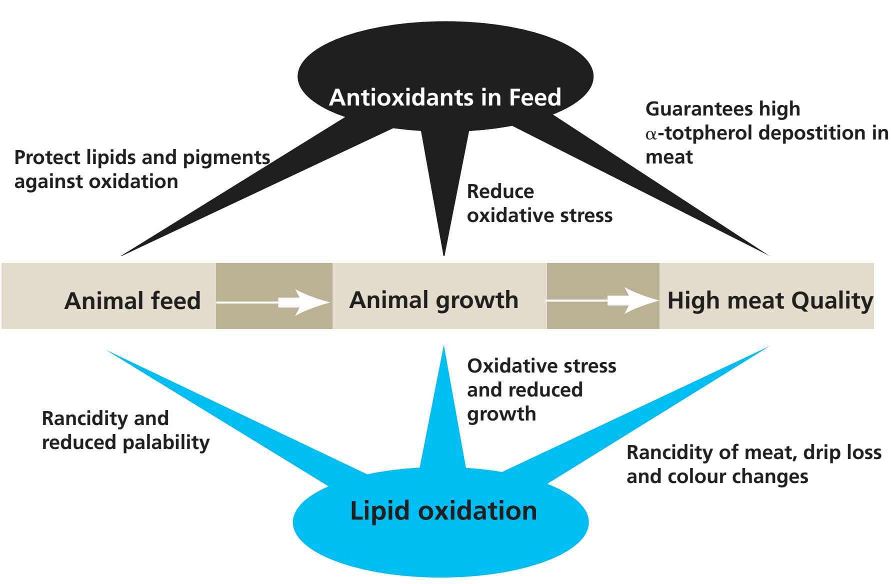
Figure 6. Drip loss (%) from frozen pork chops from pigs fed vitamin E supplemented diets when stored under fluorescent light at 4°C (Asghar, 1991)



Effect on drip loss

The deposition of α-tocopherol in the muscle has several beneficial effects on meat quality, reducing drip loss and increasing the oxidative stability of the meat. Frozen pork chops from pigs given different dietary levels of α-tocopherol acetate exhibited significantly different rates of

Figure 7 - Schematic overview of interaction between meat quality, lipid oxidation and antioxidants in animal diets



drip loss on thawing during storage at 4°C for 10 days. Pork chops obtained from animals fed 200 IU vitamin E acetate/ kg feed had less drip loss compared to the other treatments (*Figure 6*). These data suggest that a higher α-tocopherol content in the meat has a positive effect on minimising the drip loss from frozen meat upon thawing. Although the exact nature of these observations is not fully understood, there are several possible explanations. Alpha-tocopherol may protect the integrity of cell membranes and protect them from freeze injury. Alpha-tocopherol has also been shown to protect the membranes from the action of the enzyme phospholipase. The phospholipase enzyme hydrolyses a fatty acid chain from the phospholipids, reducing their fluidity, which may increase the drip loss.

Feed quality affects meat quality

The oxidative status of the feed given to animals has a significant influence on the final meat quality. Meat obtained from animals grown on oxidised feed has a significantly lower oxidative status compared to animals fed a feed with good oxidative status. Feeding animals oxidised feed clearly results in a lower α-tocopherol content in the meat. The α-tocopheryl acetate supplemented in the feed does not function as an antioxidant until it is hydrolysed in the small intestine into free α-tocopherol.

Meat obtained from animals grown on oxidised feed has a significantly lower oxidative status compared to animals fed a feed with good oxidative status.

However, once liberated in the small intestine, α-tocopherol regains its antioxidant activity. Free radicals, peroxides and other reactive oxygen species present in the feed will thus be neutralised by α-tocopherol, leading to a reduction of the α-tocopherol content deposited in the muscle (Buckley, 1995; Tesoriere, 2002).

To achieve the highest meat quality, stabilisation of the feed ingredients is crucial. An adequate stabilisation of the feed protects it against oxidative degradation during storage. Meat quality not only depends on the Vitamin E content in the feed: it is also directly linked to global feed quality. Optimal feed quality can be obtained by stabilisation of the feed with synthetic antioxidants. Synthetic antioxidants added to the feed clearly have a sparing effect on the α-tocopherol acetate level. Chickens given feed stabilised with synthetic antioxidants have a significantly higher α-tocopherol content in the plasma compared to animals fed a feed not stabilised with synthetic antioxidants. Lauridsen (1994) even suggests that synthetic antioxidants present in the feed are still active in the gastro-intestinal tract, protecting α-tocopherol from oxidative deterioration.

The effect of stabilising feed with synthetic antioxidants on the α-tocopherol deposition and meat quality characteristics is shown in *Table 1*. Animals fed a diet stabilised with antioxidants have a twofold higher α-tocopherol deposition compared to the control group fed α-tocopherol. Synthetic antioxidants have the beneficial effect of lowering the oxidative status of the meat. These data indicate a lower oxidation of vitamin E in a feed well stabilised with synthetic antioxidants.

Conclusion

The interaction between meat quality and animal feed stabilised with antioxidants is shown in *Figure 7*. The α-tocopherol content of the meat is an important factor in determining meat quality. However, meat quality not only depends on vitamin E supplementation of the feed but also on the general oxidative status of the feed. These observations demonstrate the importance of an adequate stabilisation of the feed with antioxidants in order to achieve optimal meat quality. ●

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