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Lipid oxidation and antioxidant potential in meat

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More and more, consumers are looking for fresh, natural foods of good nutritional quality; to maintain its good place in the human diet, meat must integrate these conditions. In contrast to beef meat, where polyunsaturated fatty acids (PUFAs) are partly biohydrogenated by rumen micro-organisms, in the meat of monogastric animals, such as from poultry and pork, the degree of unsaturation of muscular lipids is a good reflection of lipids found in the animal’s feed (DECKER et al., 2000). In man, the same pattern is observed and it is now well accepted that a food particularly rich in PUFAs, but with a good balance between omega 3 and omega 6 fatty acids, is able to decrease the incidence of cardio-vascular disease or even cancer. Nevertheless, in meat, and more so in dry or cooked-meat products, it is well known that an important lipid unsaturation leads to an easier oxidation and lipid rancidity (and consequently to flavor deterioration), sometimes linked to surface discoloration (myoglobin oxidation) at the origin of poor sales of prepackaged beef (RENERRE, 2000).

When molecular oxygen is present, lipid oxidation is initiated in the unsaturated phospholipidic fraction of membranes. Oxidation is largely dependent on an endogenous mechanism of chain-reactions of radical nature. Free radicals, which in most cases are due to reactive oxygen species (ROS), are superoxide radical anion (O₂⁻), one of the most reactive, peroxyl (ROO⁻) and alcoxyl (RO⁻) radicals and singlet oxygen (¹O₂). Hydrogen peroxide (H₂O₂) produced in the cell is considered as a radical because, in the presence of transition metals such as iron, the formation of the hydroxyl radical (OH⁻) occurs, according to the Fenton and Haber-Weiss reactions (HALLIWELL and GUTTERIDGE, 1989). In meat products, radicals such as nitric oxide (NO⁻) or peroxynitrite anion (ONOO⁻) can be formed and decomposed to give hydroxyl radicals (OH⁻). Free radicals oxidize not only lipids but also proteins, nucleic acids, and other macromolecules leading to cellular death and the destruction of tissues. In meat, myoglobin oxidation is coupled with lipid oxidation and it has been previously described that during oxymyoglobin (Fe^{++}) autoxidation process, mechanism largely responsible for the brown colour of the meat, formation of metmyoglobin (Fe^{+++}) and of O₂⁻ and H₂O₂ radicals occurs. Moreover, H₂O₂ interacts with metmyoglobin to form active species which promote lipid oxidation with the generation of ferryl myoglobin (MbFe(IV)O)

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(RENERRE, 1999). During meat ageing, oxidative processes also concern myofibrillar proteins which favour proteolysis and possibly tenderness.

To prevent or to delay oxidative damage, biological systems have developed a multifunctional defense system. First, antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GSH-Px) have been reported in the skeletal muscle of different species (beef, pork, turkey, chicken) to minimize the production of ROS which are implicated in the formation of the OH° radical. Many micro-nutrients such as Cu, Zn, Mn and Se may be implicated in the regulation of the oxidative processes as components of these different antioxidant enzymes. However, when found in excess, with Cu for example, toxicity can occur. The level of these antioxidant enzymes is dependent on species, breed and muscle type; animal to animal variation in enzyme activity may be improved by genetic selection or changes in feeding mode, for example. Nevertheless, the real importance of antioxidant enzymes during meat storage is always controversial (MORRISSEY et al., 1998) and different treatments such as thermal processing can lead to inactivated forms. Then, many proteins implicated in storage and/or transport (myoglobin, transferrin, ferritin) and also dipeptides such as carnosine and anserine or phytic acid may sequest a large part of transition metals, such as iron which, by the Fenton reaction, is at the origin of the OH° formation. Finally, in the cell there are “chain-breaking antioxidants”, such as vitamin E (or α-tocopherol), which is one of the major lipid-soluble free radical scavenger (PACKER, 1993) with ubiquinon (present in mitochondria) and carotenoids synthesized by plants (such as β-carotene). Vitamin C, numerous flavonoids, folates, thiols (lipoic acid, glutathione), even amines, polyamines (putrescine) or nucleotides (uric acid) act also such as antioxidants (DECKER et al., 2000).

Today, one of the best ways to lower oxidation of meat components is to control the antioxidant concentration in the feeding of animals. When animals are fed PUFAs (soya oil, rapeseed or linseed oil), an important supplementation in vitamin E is also necessary (higher than daily recommended doses) to lower lipid oxidation. Sometimes, a decrease in drip loss is also noted. To achieve this aim, with pork and chicken, a supplementation of 200 ppm α-tocopheryl acetate is necessary during a minimum of 5 weeks. In these conditions (Dietox European project), increases in antioxidant concentration are able to decrease the level of cholesterol in the blood of pig meat consumers. For turkeys, where a low fixation of vitamin E in membranes is observed, feeding ratios of vitamin E must be as high as 400 ppm for 12 weeks. In beef also, and despite the partly biohydrogenation of unsaturated dietary fatty acids by rumen micro-organisms, an important supplementation is necessary with amounts from 500 to 1000 mg vitamin E/day/animal during about 100 days. In these conditions, lipid and myoglobin oxidation are slowed down (RENERRE, 1999) and refrigerated meat shelf-life is increased for many days depending on the studied muscle (linked to the metabolic type). Many recent works have also demonstrated that cattle grazed on good pasture can achieve concentrations of α-tocopherol in muscles as high as those observed by supra-nutritional supplementation of grain-fed cattle with vitamin E; carotenoids and other poly-phenolic antioxidants can be also present in grass. If, in cooked cured-ham, nitrite is useful from a colour, flavour and bacteriological point of vue, it can also react with amines to produce carcinogenic N-nitrosamine. To lower N-nitrosamine formation in turkey hams, it has been shown in the laboratory that nitrite concentration can be reduced to
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50 ppm (instead of 100-150 ppm used currently) provided that high dietary vitamin E supplementation (400 ppm) is used. Conversely, when vitamin E is used in vitro and added to different meat products, generally, lipid oxidation is not decreased despite occasional small improvements.

Many trials were done to study the effect of feeding supplementation with ascorbic acid able to regenerate α-tocopherol, but most of results have shown that oxidative stability is not increased. During meat storage, it has even been shown that free iron was released from ferritin (and from myoglobin following meat cooking) and that ascorbic acid (in low concentration) was the major reducing agent for iron; the reduced iron becomes the initiator of lipid oxidation (HALLIWELL and GUTTERIDGE, 1989). Trials done on turkeys to suppress iron from animal feed have given very contradictory results. Conversely, ascorbate (in high concentration) can inhibit the activity of prooxidative forms of myoglobin, such as the ferryl species. In vitro, the most efficient iron chelators to lower flavor deterioration of cooked meat are always polyphosphates and derived components from citric acid in association, or not, with vitamin E.

Carotenoid components are a very diverse group of antioxidants deposited in the muscle via the diet. Their antioxidant activity is quite controversial and is dependent on numerous physico-chemical factors (oxido-reduction potential, pH, pO2) with non-resolved problems of biodisponibility and stability of these compounds with light and their colour diversity which may be a problem (MORTENSEN and SKIBSTEL, 2000). Moreover, as they reduce iron, they can be pro-oxidants (such as β-carotene) with increasing oxygen tension. Although carotenoid supplementation gives good results in fish feeding (also providing colour to the food), trials are always necessary to be sure of carotenoid efficiency, such as, antioxidants in farm animal feed. But, as with α-tocopherol, carotenoids are not destroyed by heating or cooking of meat. If synthetic phenolic antioxidants such as BHA and BHT are able to lower lipid oxidation, their use in the meat industry, from a nutritional point of view, is more and more controversial. Among the numerous tested polyphenolic compounds, found in crude extracts of fruits, herbs, vegetables and cereals (such as soya phytostereols), green tea catechins (or wine catechins) and added to different meat products, is a very promising potential to slow down lipid and even protein oxidation processes. Experiments are also carried out today to measure catechins efficacy directly in farm animal feed. Other flavonoids (onion quercetin, wine resveratrol, caffeic acid), or carotenoids (such as tomato β-carotene) are also being studied. Many components extracted from aromatic plants (sage, thyme, oregano, cumin, ginseng, mustard, garlic, fenugreek) and also very different products used alone or in mixtures (extracts from lemon skin, sesam seed, cotton seed, olive, paprika, honey) are being studied. Different proteins extracted from whey, soya, maize... or from serum with antioxidant properties are added to different meat products. More particularly, rosemary extracts are used in different products and, with less efficient results, in feeding of animals. Extracts of sage and oregano would be also efficient for antioxidant activity in animal feeding. Different mixtures (tomato-oregano-vitamin C; catechin-rosemary; β-carotene ± catechin-vitamin E) are also tested in different meat products and on membranal model systems. Combinations of feeding supplements of vitamin E and carnosine could be a good solution to slow down lipid oxidation, but costs remain very high. Taurine, to a lesser extent, has also been tested. Glutathione, a natural tripeptide found in the
muscle, would help the glutathion peroxidase to eliminate lipid peroxides and help regeneration of vitamins E and C. Selenium, as part of the glutathion peroxidase, is an essential element fighting against oxidation. Selenium content of the muscle is dependent of the nature of the soil and in great quantity, it can help to save vitamin E concentration. Trials of vitamin E and selenium addition in animal feeds give good results.

To slow down the occurrence of oxidative processes, it is well known in our laboratory (RENERRE, 2000) how to control the percentage of residual oxygen in trays by using adequate packaging modes (under vacuum or with modified atmosphere packaging). With the use of oxygen scavengers (pO2 <0.1% in the package), meat storage is possible for several months (T°:0-2°C).

To conclude, many hopes are permitted with the use of flavonoids (and/or carotenoids), with or without vitamin E, but more experiments should be designed to explore their real actions and interactions with many other antioxidants present in meat (DECKER et al., 2000). With the use of natural oils rich in PUFA's in animal diets, the supplementation of dietary antioxidants like dietary vitamin E is necessary, and can offer the consumer a better meat from a flavour and nutritional perspective.

REFERENCES


