Phytochemicals and their use in the control of meat oxidation

Toxic molecules called 'free radicals' are short-lived, highly reactive chemicals that can have damaging effects on cells, particularly DNA and cell membranes. They are the natural byproducts of normal physiological functions of living cells.

by Dr Suman Talukder, Dr Arvind Soni & Dr Sagar Chanad, Indian Veterinary Research Institute (IVRI), Izatnagar, Bareilly, Uttar Pradesh, India.

Ultraviolet radiation, smoking, and airborne pollutants etc are environmental factors that can also be the source of free radicals. Antioxidants are our first line of defence against free radical damage to the human body and are critical for maintaining optimum health and well being.

Antioxidants, both naturally occurring in the body and those from food sources, may prevent part of this damage by stabilising the free radical and neutralising the harmful effects.

Food antioxidants like vitamins and minerals can minimise detrimental lipid oxidation by neutralising or scavenging free radicals.

Lipids are one of the major components of meat; it is the structural components of the muscle membranes, as storage droplets of triacylglycerol between muscle fibres and as adipose tissue (marbling fat).

These lipids, or more precisely their fatty acids, contribute to a wide range of quality attributes of meat and its products like colour stability, drip loss etc.

Colour and level of marbling in meat are the two major factors relevant to the selection of meat by the consumer. The contributing factor of 'meat lipid' makes the meat highly vulnerable to oxidative changes, which results in the development of off-flavour and rancidity due to its oxidation.

Peroxidation of lipids becomes apparent to consumers through the development of a rancid odour and warmed-over-flavour in previously cooked meat, due to high storage temperature and/or reheating before serving.

It is a major cause of deterioration of quality and acceptance as it decreases the nutritional impact of foods. It involves the loss of essential fatty acids and vitamins and the generation of potentially toxic reaction products such as manoladehyde (MDA) and cholesterol oxidation products (COPs).

In addition, lipid oxidation affects essential sensory traits of meat products, causing unfavourable changes in flavour, colour and texture. Lipid oxidation is the major factor in reducing the quality and acceptability of meat products.

Other than lipid oxidation of meat proteins, it leads to the loss of functional properties such as gel-formation ability, meat binding ability, emulsification capacity, solubility, viscosity and water holding capacity and results in loss of texture and overall acceptability of processed meat products.

Table 1. Principles of antioxidant defence.

Defence line	Mechanism	Antioxidant
1	Prevention of radical formation	• Superoxide dismutase • Glutathione peroxidase • Metal binding proteins
2	Prevention or restriction of chain reaction once radicals are formed	• Vitamin C, E, A • Carotenoids • Ubiquinols • Polyphenols • Glutathione • Flavonoid compounds
3	Repair or removal of damaged molecules	• Catabolic enzyme systems

Due to the oxidation some undesirable colour changes of cooked meat products during refrigerated storage have been noticed. Several factors have been identified which control these undesirable changes, including the characteristics and amount of fat, the packaging and the presence of antioxidants in meat products.

Numerous studies have indicated that lipid oxidation may be controlled, or at least minimised, through the use of antioxidants.

Studies have shown the potential role of dietary antioxidants in promoting health and reducing the risk of heart disease, cancer, cataracts, and other degenerative diseases related to aging.

In the case of processed meat products the application of exogenous antioxidants can be fruitful to prolong shelf-life and to ensure the better quality of the products. The addition of antioxidants to processed meat is often practiced to reduce the negative effects of processing aids.

Due to the concerns about the toxicological safety of synthetic antioxidants, it is desirable to replace these conventional antioxidants with natural plant based antioxidative substances.

Factors affecting oxidation

Various exogenous factors affecting the oxidative stability of meat and products include the level of processing of products, cooking technique/time employed, pre and post-cooking storage time and temperature, packaging system and materials, and/or the use of antioxidants.

When meat is processed the balance of the system is disrupted. Grinding destroys the integrity and structure of muscle tissue and allows mixing of the cell contents with available oxygen; it also allows pro-oxidants access to the more unsaturated fatty acids in the membrane phospholipids.

Antioxidants in the diet

Dietary antioxidants protect against oxidative damage to DNA, proteins and lipids and have a significant impact on the regulation of gene expression. Intake of dietary antioxidants has been associated

with a low risk of chronic disease. Fruits and vegetables, long associated with reduced risk of chronic diseases, are recognised as rich sources of antioxidants.

Commonly cited dietary antioxidant source vitamins are: vitamins C, E and beta-carotene.

Other than vitamins, several minerals like copper, selenium, iron, manganese and zinc, which are an integral part of various food items, have been referred to as 'antioxidant minerals' because of their presence in enzyme systems which protect against free radicals and oxidant stress.

A number of other dietary antioxidant substances exist beyond the traditional vitamins discussed above. Many plant-derived substances, collectively termed 'phytochemicals', are increasingly known for their healthy antioxidant activity.

Plants can produce a wide range of antioxidant compounds that include carotenoids, flavonoids, cinnamic acids, benzoic acids, folic acid, ascorbic acid, tocopherols and tocotrienols etc to prevent oxidation of the susceptible substrate.

Whenever these natural compounds are consumed along with plant based food they start acting as free radical scavengers inside the body tissue. The advantages of natural antioxidants in foods are high consumer acceptance and their safe use. Phenolic compounds such as flavonoids are ubiquitous within the plant kingdom and known for their antioxidant activity.

They serve as protectors against a wide variety of environmental stresses in humans and appear to function as 'biological response modifiers'. The broad therapeutic effects of flavonoids can be largely attributed to their antioxidant properties.

Endogenous antioxidants

Along with extraneous dietary antioxidants, the body depends upon several endogenous resistance mechanisms to help protect against free radical related tissue damage. Increasing the levels of endogenous antioxidants in muscle tissue via dietary supplementation has shown strong promise for increasing the oxidative stability of muscle foods.

There are several endogenous compounds which have antioxidant like free radical scavenging activity inside the body, but their function depends upon some micronutrient cofactors such as selenium, iron, copper, zinc, and manganese for optimum catalytic activity. It has been shown that an inadequate dietary intake of these trace mineral cofactors may compromise the effectiveness of these antioxidant defence mechanisms.

Glutathione

Glutathione is a water soluble antioxidant, cysteine in nature, containing tripeptide (glutamine, cysteine, glycine) found in mammalian cells. It plays an important role in detoxification and catalyses reactions for the antioxidation of reactive oxygen species (ROS) and free radicals. Research suggests that glutathione and vitamin C work interactively to quench free radicals. It is believed that GSH acts to stabilise free radicals.

Carnosine

Carnosine is one of the major dipeptides in the skeletal muscle tissue of most vertebrates; it is a natural dipeptide (alanine and histidine). It is a potential dietary antioxidant and has been found to be capable of inhibiting lipid oxidation due to iron, haemoglobin, lipoxidase and singlet oxygen in vitro. Carnosine can reduce oxidative rancidity; which is why it could be used as a natural antioxidant in muscle foods for extending the shelf life of products. Vitamin E influences the antioxidant effect of carnosine.

Lipoxygenase

Lipoxygenase is the major enzyme initiator of lipid oxidation in fish tissues, but it is also found in various mammalian tissues.

Lipoxygenase is capable of direct oxygenation of PUFAs, even in phospholipids (PLs) bound to membranes to generate lipid hydroperoxides.

Lipoic acid

Lipoic acid is another important endogenous antioxidant, categorised as a 'thiol' or 'biothiol'. It is a sulphur-containing molecule that is known for its involvement in the reaction that catalyses oxidative decarboxylation. It is capable of quenching free radicals in both lipid and aqueous domains and, as such, has been called a 'universal antioxidant'. Lipoic acid may also exert its antioxidant effect by chelating with pro-oxidant metals. Research further suggests that lipoic acid has a sparing effect on other antioxidants too.

Conjugated linoleic acid

Conjugated linoleic acid (CLA), a derivative of a fatty acid linoleic acid (LA), has been reported to be present in food from animal sources such as dairy foods and has been demonstrated to exert antioxidant-like activity in vitro and in vivo. In some cases CLA reduces the development of early aortic atherosclerosis, possibly by decreasing LDL susceptibility to oxidation.

Table 2. Conjugated linoleic acid content of various meat sources.

Food	Mg/g fat
Fresh ground beef	4.3
Veal	2.7
Lamb	5.8
Pork	0.6
Chicken	0.9
Fresh ground turkey	2.6
Salmon	0.3
Egg yolk	0.6

Selenium

Selenium is an antioxidant which regulates important enzymes that protect against oxidised molecules, such as low density lipoproteins (LDL). It is a mineral which functions through selenoproteins, several of which are oxidant defence enzymes, viz., selenium is a constituent of the enzyme glutathione peroxidase which protects cellular membranes from oxidative damage. A deficiency of selenium and vitamin E increases the degradation of compounds susceptible to oxidation.

Vitamin E

Vitamin E supplementation through feed to meat animals like beef cattle, pigs, lambs and veal calves can increase the meat quality in terms of its colour, lipid stability of fresh meat and overall acceptability. Meat from animals supplemented with vitamin E shows an improved oxidative stability and enhanced colour retention and increased retail shelf life may offer an opportunity for 'value addition'.

Conclusion

The importance of fat in the form of fatty acids in meat and meat products is well recognised and the acceptability and character of products depends upon its nature. Well processed meat products are susceptible to oxidation during processing and storage. This common phenomenon leads to the rancidity and deterioration of the quality and acceptability of the products, which indicates that lipid peroxidation is a major problem in meat.

The control of the catalyst of the peroxidation reaction is very important because the catalyst can be rapidly amplified by free radical chain reactions and quality deterioration.

The use of dietary and extraneous antioxidants as feed supplements during the rearing of meat animals and the processing of meat products respectively may reduce the chances of deterioration of raw and processed meat quality.

There is an increase in the shelf life of the products which leads to economic gain. The utilisation of natural antioxidants is more acceptable due to their safe aspect as food ingredients in comparison to synthetic counterparts. Packaging of cooked meat with oxygen scavengers and metal chelators immediately after cooking is very effective in the prevention of lipid oxidation by reducing oxygen contact with meat. ■

References are available from the authors on request