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THE ROLE OF PLANT BY-PRODUCT ANTIOXIDANTS TO CONTROL LIPID-PROTEIN OXIDATION IN MEAT AND MEAT PRODUCTS

Varun Kumar[1*], Vivek Kumar[1], Muteebullah Rafiqui[2] and Manish Arya[3]

[1*]MVSc scholar, Division of Livestock Products Technology, ICAR- IVRI, Izatnagar, Bareilly (UP)
[1]PhD scholar, Division of Pathology, ICAR-IVRI, Izatnagar, Bareilly (UP)
[2]PhD scholar, Department of Animal Nutrition, ICAR-IVRI, Izatnagar, Bareilly (UP)
[3]PhD scholar, Department of Surgery and Radiology, ICAR-IVRI, Izatnagar, Bareilly (UP)

Corresponding author: vk561997@gmail.com

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ABSTRACT

The global increase in meat consumption, driven by its nutritional benefits, has highlighted the challenge of lipid-protein oxidation during meat processing and storage, adversely affecting quality, safety, and shelf life. This oxidation process leads to detrimental changes in color, texture, nutritional value, and the development of off-flavors, prompting consumer rejection. Traditionally, synthetic antioxidants have been used to mitigate these effects; however, the shift towards health and safety concerns has spurred interest in natural antioxidants, particularly those derived from plant by-products. These include a wide array of bioactive compounds found in leaves, seeds, peels, husks, and roots, which are often discarded despite their potent antioxidant properties. Plant by-products rich in phenolics, tocopherols, carotenoids, and other compounds have been recognized for their ability to scavenge free radicals, thereby protecting against oxidative stress in meat products. Furthermore, encapsulation technology presents a promising approach to enhancing the efficacy of natural antioxidants by improving their stability and controlled release in food matrices. This review underscores the significance of leveraging plant by-products as natural antioxidants in meat preservation, offering a safer, cost-effective, and environmentally friendly alternative to synthetic additives. The adoption of such natural solutions not only aligns with consumer preferences for clean label products but also contributes to the sustainability of the food industry by valorizing waste materials. Further research is encouraged to explore the full potential of these natural antioxidants in meat applications, ensuring food safety, quality, and extending shelf life, thereby benefiting both consumers and the meat industry

Keywords: antioxidants, carotenoids, encapsulation technology, lipid oxidation, protein oxidation, phenolics, tocopherols.

INTRODUCTION

Meat production is increasing globally due to its nutritious and healthy nature. Earlier it was enjoyed only on special occasions in many cultures but now a day, it is being consumed all over the world due to increased health awareness. The meat and meat products are rich in essential nutrients, proteins, vitamins, carbohydrates, minerals, and contains varying proportions of storage (triacylglycerol) and structural lipids (phospholipids) depending on the muscle type (Amoli *et al*., 2021; Redoy *et al*., 2020). The production volume of meat worldwide is about 345 million metric tons in 2022. Only the advanced countries are managed to fulfill the daily protein requirement of the individuals.

Meat and Meat products faces challenges such as lipid oxidation during processing and storage which reduces the quality and produce harmful effects. Lipid oxidation changes color, texture, nutritional value, taste, and aroma leading to rancidity, which is responsible for off-flavors and unacceptable taste, poor shelf life nutrient loss these are the important reasons for consumer rejection **(**Lima *et al*., 2013). Meat industries also faces difficulty to maintain the flavors, color freshness attributes of meat and meat products at very effective cost.

Oxidative rancidity begins at the time of animal slaughter as blood flows is interrupted and the metabolic processes are stopped (Lima *et al*., 2013). in muscle tissue due to high concentrations of unsaturated lipids, heme pigments, metal catalysts oxidizing agents causes meat to oxidative degradation. (Dominguez *et al*., 2019) and more noticeable thing is that cooked meat are more susceptible than raw meat as high temperature causes release of oxygen and heme, iron therefore inducing the production of free radicles.

Meat composed of major part as a muscles which contains high amount of proteins about 17-25 percent. Protein is the essential requirement of the humans. The protein oxidation results in texture impairment, loss of essential nutrients, water holding capacity, color and flavor and formation of toxic substances.

Oxygen is a crucial element for life. Oxygen is used by cells to generate energy. Free radicles are created as consequences of metabolic reactions such as reactive oxygen species (ROS) and reactive nitrogen species (RNS). Lower concentration of ROS & RON is having beneficial effect on immune function and cellular responses and in higher amount they cause oxidative stress.

Antioxidant are compounds that inhibits oxidation in biological system and in natural environment as free radical scavengers, reactive oxygen scavengers. These are H atom donors. Mostly synthetic antioxidants are added in meat products so now trend is being changed to use more natural compounds which are getting popular (Lorenzo *et al*., 2018). To overcome these challenges of oxidative instability of lipid and proteins in meat it is better to explore some cost effective and health safe natural antioxidants derived from plant origin (Munekata *et al*., 2020). parts of plant like stem seeds peels leaves husks and roots are some unexploited sources of natural antioxidants. it is interesting to known that non edible parts of plant and fruits are more valuable than non-edible one having more bioactive content. Some of generally recognized as safe food additives are tocopherols carotenoids and phenolic compound having antioxidant antimicrobial property approved by FDA.

Encapsulation technology could be a game-changer in this context. It involves entrapping bioactive within small capsules that can slowly release their contents under specific conditions. This could improve the delivery of these antioxidants into meat products and help to maintain their quality over a longer period

The role of plant by products as natural antioxidants

The modern food industry is now shifting towards natural products as the consumer is now aware of toxic effects and health risk found in synthetic food. Plant by products as natural antioxidant contains the phenolic compounds which is produced through plant metabolism. Plant by products include leaves seeds peels husk stem and roots. These by products are rich in bioactive compounds can inhibit oxidation and enhance the freshness, sensory properties of food and avoid color change during storage. (Tomasevic *et al*.,2021). However only in small percentage antioxidants component are safe(1-100mg/100g) and must meet safety criteria by established by regulatory bodies. Antioxidants have potential to control oxidation in meat and meat products and also enhances the softness of the meat (Pateiro *et al*., 2018).

Mechanism of lipid and protein oxidation in meat and their impact

Lipid and protein oxidation are one of the major causes of meat spoilage. There are various reactions in living tissue that regulates the cellular homeostasis, includes oxidation reduction process. Free radicle can be accumulated in tissue and interacts with fatty acid and protein molecules thus causes the oxidation and contribute to decreased shelf life sensory change and formation of harmful substances. (Manessis *et al*.,2020)

Lipid oxidation

Lipid oxidation is a major cause of the deterioration of fatty tissues in meats. Lipids are one of the most chemically unstable food components that participate in oxidative reactions. Lipid oxidation occurs under conditions where reactive oxygen species (ROS) readily react with vulnerable lipids on cell membranes. Polyunsaturated fatty acids (PUFAs) are highly susceptible to lipid oxidation because of their unstable double bonds. Because the cell membrane is particularly rich in PUFAs.

The reaction between unsaturated fatty acids and oxygen leads to the formation of hydroxyl radicals superoxide anion radicle or hydrogen peroxides and this reaction is catalyzed by ROS, RNS, and metallic ions. For this reaction oxygen needs to be activated, several factors for activation are light and temperature as energy sources, pro-oxidant molecule, transition metal etc.

Lipid oxidation takes place in three steps:
INITIATION- it involve the formation of lipid free radicle through catalyst such as heat, metal ion etc. These free radicles react with oxygen to form peroxy radicle .

PROPAGATION- the peroxy radicle reacting with lipid molecule to form hydroxyperoxides and new free radicle.

TERMINATION- occurs when a buildup of these free radicles formed during propagation interacts with each other and form non radical products.

The reaction of lipid oxidation continuous until depletion of oxygen or when free radical react with stable antioxidant radical or when two unstable radical react (termination).

Protein oxidation

Protein oxidation, defined as a reaction causing the covalent modification of proteins, can cause irreversible damages to protein structure such as amino acid side chain modification, protein backbone cleavage, and protein cross-linkage, thereby resulting in undesirable changes of sensory quality, processing properties, and the nutritional characteristics of muscle foods. Protein oxidation methods include metal catalyzed oxidation, oxidation induced cleavage amino acid oxidation and conjugation of lipid peroxidation products.

Free radicle can remove hydrogen atom from protein forms protein radicle which further reacts with oxygen to form analkyl proxyl radical thus in turn react with water molecule to alkoxyl proxyl radicals, oxygen and more water or react with another protein to give alkoxyl radical ultimately transformed into hydroxyl derivative that cause protein carboxylation. (Guyon *et al*., 2016).

Controlling protein lipid oxidation in meat and meat products

Lipid and protein oxidation affects the various meat properties and make it harmful for the health. Antioxidants are the effective way as they neutralize free radicle and reactive oxygen species that causes oxidation**.** (Das *et al*., 2020; Vel´azquez *et al*., 2021)**.** Antioxidants reacts with the free radicle making more stable product by donating H atoms and results in slowing down the oxidation.

There is some other strategy that we can follow that to add antioxidants in meat or by feeding the animal with antioxidant rich diet can prevents the oxidation.

The action of mechanism of natural antioxidants like polyphenols they have higher free radicle absorbance and stronger H atom donating capacity examples are flavonoids, phenolic acids ,and essential ions. They function as controlling the creation of free radical and propagation of reactive oxygen species also they chelate the metal ions such as Fe^{2+}, Fe^{3+}, Zn^{2+} and Cu^{2+}.

There are some methods for determining the antioxidant capacity, that prevents lipid oxidation

Sr no.	**Test name**	**Result**
1	Thiobarbituric Acid Reactive Substances (TBARS)	measures the interaction between malondialdehyde (MDA) and thiobarbituric acid (TBA), which results in pink-colored products indicative of lipid oxidation.
2	DPPH assay	involves the reduction of a stable, purple-hued radical (DPPH) by antioxidant compounds, leading to a color change observed through absorbance.

3	Ferric Reducing Antioxidant Power (FRAP)	measures the ability of antioxidant compounds to reduce an iron complex, resulting in a blue-colored compound whose intensity indicates antioxidant capacity.
4	ABTS Test	measures the antioxidant capacity to neutralize the ABTS•+ radical cation
5	Oxygen Radical Absorption Capacity (ORAC)	measures the ability of antioxidants to inhibit oxidation of the peroxyl radical, which predominates in lipid oxidation in biological systems.

Methods to Detect Protein Oxidation:

- DTNB (5,5′ -dithiobis(2-nitrobenzoate) is used to measure the thiol group losses
- DNPH(2,4-dinitrophenylhidrazine) measure the carbonyl compound produced
- Both processes can be monitored by spectrometry.

Some of natural plant based antioxidant are

Plant by product	**Major compound**	**Meat product**
Wild thyme by product extract	Carvacrol, thymol and α-terpineol	Ground pork patties
Rice bran extract	*p*-coumaric acid ferulic acid, γ-oryzanol	Pork burgers
Blueberry pomace	Phenolic acids, flavonoids, and anthocyanins	Pork burgers
Olive waste extract	Tyrosol and hydroxytyrosol	Lamb burger
mix extract of green tea stinging olive nettle leaves	Catechin, epigallocatechin, and epigallocatechin gallate	Frankfurter type sausage
Olive tree vegetation water extract and rosemary extract	Hydroxytyrosol	Lamb burger
Sweet basil essential oil	Estragole, 1, 6-octadien-3-ol, 3,7- dimethyl, and α-bergamotene	Minced beef

Encapsulation technology

Encapsulation is a method that enhances the stability and function of meat products by preserving natural antioxidants and preventing direct contact with food components. Several bioactive compounds isolated from botanical sources can't be used directly due to their low water solubility, chemical instability, or limited biological activity so they need to be encapsulated. Encapsulated plant extracts have been used as functional ingredients in food matrices, edible films, active packaging materials, and food coatings Studies have shown that powdered extracts from grape waste and Laurus nobilis leaf extract have antioxidant capabilities that can protect meat products from oxidation and microbial activity. The encapsulation of these extracts further improved their effectiveness (Garcia *et al*., 2017).

CONCLUSION

Protein-lipid oxidation reactions are major factors in quality deterioration in meat and meat products. By the use of antioxidants, we can prevent the oxidation of the foods during storage and extend the shelf life of meat that will be beneficial for both consumer and marketer. Natural plant based antioxidants can be a useful substitute to artificial one in terms of health safety and economics. Encapsulation method is also useful for compounds having low stability or limited biological activity. Further research will be very beneficial to scope of natural antioxidant derived from plant by products in meat industry.

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