

Natural Antioxidants as Food and Feed Additives to Promote Health and Quality of Meat Product- A Review

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Abstract:

Meat and meat products are good sources of protein, minerals, lipids and small quantity of carbohydrates that are beneficial to the health and also eating satisfaction of the consumers. However, Lipid- protein oxidation has been the major factor that deteriorates the holistic nature of the meat from the point of slaughter to processing and storage. The oxidative effects manifest in the meat in the form of discoloration, off flavor, toxic compound formation, reduced shelf-life and loss of nutrients. Meanwhile, Antioxidants have been effectively used to mitigate these processes that generate chemical hazards in the fresh and processed meats. Recently, natural antioxidants found in herbs, spices, and their extracts such as some plants of the *Lamiaceae* family e.g oregano (*Origanum vulgare* L.) rosemary (*Rosmarinus officinalis* L.) and sage (*Salvia officinalis* L.) etc. are now preferred to synthetic antioxidants in retarding the oxidation of lipid because of the toxicological and carcinogenic effects of the later. Hence, this study reviews oxidative effects in meat and meat products and the effect of using natural antioxidants as food and feed additives to improve the quality of the meat products and health of the consumers.

Keywords:

Natural Antioxidants, Additives, Health, Oxidation, Meat

1. Introduction

Lipid Oxidation plays a pivotal role in the deterioration of the quality attributes of the meat products. Meat as a food has a complex physical structure and chemical composition that is very susceptible to oxidation [1]. In meat, the presence of unsaturated fat in membrane phospholipids causes fat to oxidize during processing and storage. As a result, the quality of meat and meat products deteriorate when fat oxidizes and develops off-flavors. Lipid oxidation increases the conversion rate of oxymyoglobin (bright red color) to metmyoglobin (brown discoloration) and subsequently impacts the physical appearance of meat and meat products [2]. In any

type of meat, oxidative deterioration manifests in form of discoloration, development of off flavor, formation of toxic compounds, poor shelf , nutrient and drip losses respectively [3]. For these reasons, meat products are very susceptible to spoilage and microbial growth during slaughtering and post slaughtering handling [2].

However, various food additives are used by the meat suppliers to extend the shelf life of meat and meat products. These typically include synthetic antioxidants such as BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene), propyl gallate and TBHQ (tertbutylhydroquinone).

Meanwhile, the increasing preference for natural foods has driven the food industry to replace synthetic antioxidants with natural antioxidants in various products to retard oxidative degradation of lipids, improve quality and nutritional value of processed foods [4]. Recently, synthetic antioxidants have been associated with carcinogenicity and have rejected by consumers, [5]. Several types of research have been conducted to find a new and natural source of antioxidants to replace with synthetic antioxidants. Many herbs, spices, and their extracts have been added in a variety of foods to improve their sensory characteristics and extend shelf-life [6]. Significant antioxidant capacity have been reported in herbs of the Lamiaceae family, mainly oregano (*Origanum vulgare* L.), rosemary (*Rosmarinus officinalis* L.), and sage (*Salvia officinalis* L.). Some studies have demonstrated that natural antioxidants added in the pre- slaughter and post-slaughter stages can prolong the meat shelf-life and improve its quality. Some authors have reported the effectiveness of rosemary and oregano extracts to reduce lipid oxidation [7], color loss, and microbial growth in some types of meats. The total antioxidant potential of plant materials such as culinary herbs, spices, vegetables, as well as fruits and oilseed products is related to ascorbic acid (vitamin C), alpha tocopherol (vitamin E), beta-carotene (vitamin A precursor), numerous flavonoids, and other phenolic compounds [1]. Phenolics prevent lipid oxidation by functioning either as free radical scavengers, metal chelators or singlet oxygen quenchers. Thus, natural antioxidants have greater application potential in the meat industry because of the consumers' acceptability over the synthetic antioxidants. It was known that the quality of food was attributed to various factors such as taste, aroma, and appearance. The convenient foods which meet this attributes has led to the rapid growth in ready-to-eat product categories [8]. Fresh and processed meats offer numerous nutritional and health benefits and provide unique eating satisfaction in the lifestyle of the modern society. However, due to the possible health risks associated with cytotoxins that potentially could be generated during meat preparation, consumption of red meat including processed products is subjected to increasing scrutiny. Recent studies evidently suggest free radical pathways as a plausible mechanism for toxin formation, and antioxidants have shown promise to mitigate process-generated chemical hazards [9]. This review discusses the involvements of lipid and protein oxidation in meat quality, nutrition, safety, and organoleptic properties; animal production and meat processing strategies which incorporate natural antioxidants to enhance the nutritional and health benefits of meat; and the application of mixed or purified natural antioxidants to eliminate or minimize the formation of carcinogens for chemical safety of cooked and processed meats [9].

2. Meat and Meat Products

Meat and meat products are good sources of protein with high biological value, fat-soluble vitamins, minerals, and bioactive compounds [8]. Various methods are employed in the processing of fresh meat to different meat products such as cooked

chicken patties, raw beef patty, raw pork patties, pork sausage etc, with the aim of developing desirable products and reducing perishability during transport and storage.

2.1. Natural Antioxidants Application in Fresh and Processed Meat Products

Antioxidants are compounds or systems that delay autoxidation by inhibiting formation of free radicals or by interrupting propagation of the free radical by one (or more) of several mechanisms: scavenging species that initiate peroxidation, [10], chelating metal ions such that they are unable to generate reactive species or decompose lipid peroxides, quenching O_2^- , so preventing formation of peroxides, breaking the autoxidative chain reaction and/or, reducing localized O_2 concentrations.

An antioxidant, in a biological matrix such as a food, has also been defined as a substance that at low concentration delays, prevents or removes oxidative damage to targeted molecules by scavenging ROS, enhancing the biological antioxidant defenses or inhibiting ROS production. [10] differentiated between primary antioxidants, also known as chain-breaking antioxidants, which break the chain reaction of oxidation mostly by hydrogen (H) or electron donation, and secondary antioxidants, also called preventive inhibitors that slow the oxidation rate by other different mechanisms, especially, by binding metal ions (Fe^{2+} , Fe^{3+} , and Cu^{2+}) able to catalyse oxidative processes, by scavenging oxygen, by absorbing UV radiation, by inhibiting enzymes, or by decomposing hydroperoxides. Antioxidant effectiveness is related to activation energy, rate constants, oxidation-reduction potential, ease with which the antioxidant is lost or destroyed (volatility and heat susceptibility) and antioxidant solubility. The most effective antioxidants are those that interrupt the free radical chain reaction (Tomović et al., 2017). Antioxidants are added to different meat products to prevent lipid oxidation, retard development of off-flavors, and improve colour stability [10].

In food industry, antioxidants are further categorized into natural and synthetic. The synthetic antioxidants include BHA (butylated hydroxyanisole), BHT, PG (propyl gallate) ,and TBHQ (tert- butylhydroquinone); while ingredients obtained from natural sources which exhibit antioxidant potential in a food model system are considered as natural antioxidants [10]. However, some studies had reported that synthetic antioxidants have toxicological and carcinogenic elements. Thus, the food industry now prefers natural products to the synthetic ones. Consequently, the food market is demanding natural antioxidants, free of synthetic additives and still orientated to diminish the oxidation processes in high - fat meat and meat products [10].

It has been discovered in the recent studies that medicinal plants could be potential sources of natural antioxidants for preservation and improvement of nutritional quality of meat products. Most of the plant materials (herbs and spices) possess relatively high chemical nutrients (such as protein, fat, carbohydrate), mineral contents (calcium, potassium, iron, phosphorus) and less anti-nutritional properties. The total antioxidant potential of plant materials such as culinary herbs, spices, vegetables, as well as fruits and oilseed products is related to ascorbic acid (vitamin C), alpha tocopherol (vitamin E), beta-carotene (vitamin A precursor), numerous flavonoids, and other phenolic compounds [1]. The most commonly used naturally sourced antioxidants are phenolic compounds such as phenolic acids, tocopherol, and flavonoids. Phenolics prevent lipid oxidation through different mechanism—by functioning either as free radical scavengers, metal chelators, or singlet oxygen quenchers. The antioxidative potential of phenolics depends on their skeleton

structure. The number and location of functional groups, such as free hydroxyl OH groups, is just one example. For instance, phenolics with a higher number of OH groups and ortho-3,4-dihydroxy structures will have higher antioxidative properties. Moreover, some phenolics, such as carnosic acid from rosemary, and catechin from green tea, not only have OH groups that can donate hydrogen to free radicals, but also contain vicinal -OH groups that can chelate metals.

Consequently, combinations of natural extracts can potentially deliver synergistic effects and improve antioxidant performance in preventing lipid oxidation. Such combinations can also reduce the effective dosage of each extract, thus minimizing impacts on flavor and color.

2.2. Natural Antioxidants and Their Sources

Plant foods are rich sources of antioxidants. They are most abundant in fruits and vegetables, as well as other foods including nuts, whole grains and some meats, poultry and fish.

Table 1. Natural antioxidants used to inhibit oxidation in processed meat products.

Antioxidant category	Main active Compound	Example	Mode of action	Treated meat Product	Reference
Spices, herbs, and extracts	Phenolic acids, Terpenoids	Gallic acid, rosmarinic acid, canosic acid, caffeic acid, glabrene	Radical scavenger, metal ion chelator	Breakfast sausage, precooked pork	[11]
Fruits, leaves, and extracts	Flavonoids, water-soluble vitamins	Procyanidins, quercetin, Catechin	Radical scavenger	Cooked burger patties, raw and cooked pork patties	[12]
Nuts, seeds, and extracts	Tocopherols, tocotrienols	α -, β -, γ -, and δ - Tocopherols	Radical scavenger	Restructured steaks, Frankfurters	[12]
Essential oils	Polyphenols, Terpenoids	Eugenol	Radical scavenger	Turkey meat patties, beef Burgers	[13]

2.3. Natural Antioxidants from fruits and Vegetables

Recent studies have shown that excellent natural antioxidants to inhibit the oxidative processes in meat and meat products are obtainable from fruits and vegetables [14]. Pomegranates, strawberry, kinnow, acerola, white grapes, plums, black currant, annatto, bearberries, banana, and sapodilla are some samples that contain relatively high concentrations of antioxidants [14]. Plum (*Prunus* spp. dried, puree and extracts), apple (*Malus pumila*) puree at levels up to 3%–6%, pomegranate (*Punica granatum*) extracts providing c. 10 mg of tannic acid equivalent phenolics per 100 g of meat, bael (*Aegle marmelos*), grape pomace (*Vitis vinifera*), citrus fruits (*Citrus* spp.), noni puree (*Morinda citrifolia*), and kordoi fruit (*Averrhoa carambola*) juice have shown significant antioxidant effects in processed meats with no or slight negative effect on their sensory characteristics [14]. Fruit extract with a high content of phytochemicals such as Acerola (*Malpighia emarginata*), is an excellent food source of vitamin C. In addition, it was discovered that Acerola can improve color and lipid stability and decrease rancid flavor of raw salted beef patties without affecting microbial load [14]. Moreover, several studies have also reported the

antioxidant effects of some vegetables on processed meat, these include Broccoli (*Brassia oleracea*) powder extract, bok choy (*Brassica campestris* subsp. *chinensis*), pumpkin (*Cucurbita moschata*), Korean angelica (*Aralia elata*), stringy stonecrop (*Sedum sarmentosum*), carrot (*Daucus carota* subsp. *sativus*) juice, and borage (*Borago officinalis*) leaf extract [10].

Table 2. Fruit-based natural antioxidants in meat and meat products.

Type of treatment	Meat product	Impact on product	References
Pomegranate juice, pomegranaterind powder extract	Cooked chicken Patties	Protecting against oxidative ran- cidity was better than BHT	
Strawberry fruit Extract	Cooked chicken patties	Strawberry could act as a potential antioxidant source in meatproducts	
Acerola fruit extract	Raw beef patty	Addition of acerola retarded lipidoxidation	[14]
Wine pomace	Raw beef patty	Inhibited lipid oxidation	[15]
grape	Raw beef patty	Inhibited lipid oxidation under modified atmosphere packaging	
Kinnowand pomegranate fruit extracts	Raw chicken patties	Inhibited lipid oxidation	[16]
Grape	Raw pork patties	grape extract showed the most modified atmosphere packaging antioxidant activity compared to synthetic antioxidants	
Black currant	Raw pork patties	Significantly increased lipid andprotein oxidation	[17]

2.4. Oil seed as Antioxidants in Meat and Meat Products

Studies have shown that oilseeds from fruits and vegetables are rich sources of antioxidants. For instance, Grape fruit extract has a proven antioxidant and antimicrobial effects on meat and meat products such as dry-cured sausage “chorizo”. Also, combination of Clove extract oil with different concentrations of Grape seed extracts can be effective against spoilage microorganisms in raw materials, such as buffalo patty.

Table 3. Use of oil seed as antioxidants in meat and meat products.

Type of treatment	Meat product	Impact on product	References
Soy sauce	Raw beef patties	The combined addition of soy sauce and ascorbic acid greatly improved color stability and retarded lipid oxidation.	[18]
Olive and wine extracts	Cooked beef and Pork	Olive extract showed more stronger antioxidant activity than wine extract	
Cloudberry, beetroot or	Pork patties	cloudberry extract was as potent as quercetin	
Willow herb	Liver pâtés	Decreased the amount of sodium	[19]

		nitrite used in pates	
Rosemary extract	Liver pâtés	Rosemary effectively retarded Oxidation	
Green tea, chestnut and grape	Liver pâtés	Green tea (camellia sinensis) and grape extracts weremore effective antioxidants	[20]
Jabuticaba peel Extract	Bologna sausages	Sensory attributes and shelf life were improved	
Strawberry tree and dogrose extract	Frankfurters	Applying of phenolic extracts decreases oxidation reactions without changing their color and texture properties.	
Rosemary extract and whey powder	Wiener sausages	The oxidation was retarded	

2.5. Natural Antioxidants As Feed Additive

The addition of antioxidants as nutritional supplements in animal diets is a common practice to improve animal performance, health, and welfare. For meat animals, natural antioxidants added to feed not only can improve the oxidative stability and organoleptic properties of meat but they also can enhance the nutritional value and the health benefit of meat products [21]. Recently, there has been a growing interest in supplementing animal feeds with plant antioxidant extracts or raw antioxidant plant materials to boost the nutritional value of meat for consumers' health benefits. For example, radical- scavenging rosemary leaves [22], grape seed extract [23], and licorice extract [24] as animal feed additives have been shown to decrease lipid oxidation and improve quality of lamb meat. Lamb fed distilled rosemary or thyme in the diet for several months showed a higher antioxidant stability of the smeat, a higher concentration of polyphenolic antioxidants, and a delayed color deterioration in the meat [25]. α -Tocopherol as the most traditional feed additive up to about 500 mg/kg feed supplementation levels could maintain the redness of fresh beef on retail display, and this protective effect is exerted via the delayed oxidation of oxymyoglobin and the inhibition of PUFA oxidation [26]. Similar findings have been documented for lamb [27] as well as poultry meat [28]. Moreover, there has been a continuing effort to manipulate the fatty acid composition of meat through feed regimens. The goal of the livestock producer is to produce nutritionally balanced or enhanced meat that contains appropriate amounts of n-3 PUFA (from linolenic acid) versus n-6 PUFA formed from linoleic acid (18:2) [29]. n-3 Fatty acids, especially long chain n-3 PUFA, are known to reduce the risk of many diseases, such as arteriosclerosis, coronary heart disease, inflammatory diseases, and possibly behavioral dis-orders [30]. Feeding pigs dried distillers grain with solubles (DDGS) has been shown to increase PUFA iodine value. However, an excessive amount of PUFA deposition could compromise the textural quality of pork belly (softness) intended for bacon. Because of the increased susceptibility to oxidation, PUFA-enriched meat may have a reduced shelf-life, therefore, a high-PUFA diet should include an antioxidant supplement as well. Aromatic herbs and essential oils have been used in animal feed to improve the flavor and palatability of meat. Essential oil plants and essential oils are known for their antioxidant potency which is mainly attributed to phenolic compounds in the oil or in other phytochemical fractions. Some Non-phenolic substances also exhibit antioxidant activity such as, caryophyllene, careen, and terpinene [31]. Such substances contribute to the protection of feed lipids from oxidative damage, since the antioxidant status of the feed can have a profound

impact on the quality and oxidative shelf-life of meat. A dietary supply of thyme oil and thymol to aging rats showed a beneficial effect on the antioxidant enzymes superoxide dismutase and glutathione peroxidase [32]. In chicken, oregano added in doses of 50–100 mg/kg to the broiler diet exerted an antioxidant effect in the muscle tissue [32]. Meat and membrane phospholipids from broilers fed 500 mg/kg rosemary and sage extracts exhibited a significantly lower oxidation rate than those fed 200 mg/kg tocopherol and the control after 9 days of refrigerated storage [33]. Feeding green tea to livestock has mixed results. [34] reported that feeding cattle green tea (0.5 kg/d) reduced the iron content, redness, and intramuscular lipid content of the muscle tissue. While feeding cattle tea catechins and rosemary extract did not improve lipid or color stability, direct addition (1000 mg/kg) can improve color stability of loin slices held in a high O₂ (80%) modified atmosphere under refrigerated storage conditions [35].

2.6. Health Benefits of Natural Antioxidants on Meat Products

Apart from improving shelf-life and organoleptic qualities, the use of plant-derived nutraceuticals rich in antioxidant flavonoids and phenolics may allow meat processors to develop novel products with enhanced nutritional and health benefits. For example, incorporation of vegetable food ingredients, such as rice bran and walnut extract that are rich in vitamin E, vitamin B, and polyphenols, into vegetable oil-substituted sausage, restructured beef, and other processed meats improved the oxidative stability, textural properties, and nutritional value of the products [36]. Improvement in color, texture, and vitamin A content of beef patties by the addition of cooked carrot and sweet potato has been reported [37]. Likewise [38] developed a variety of meat products with added lutein to enrich with pro-vitamin A thereby promoting the eye health. Similarly, Apple pomace as a polyphenol-rich by-product of apple juice production can be a valuable source of nutraceuticals with antioxidants for processed meats [39]. The presence of dietary fibers in fruit and vegetable ingredients impart additional benefits to meat products.

When incorporated into meat processing, many of the antioxidant compounds present in plant extracts are also of therapeutic functions and their diverse roles in promoting human health and inhibiting various physiological disorders and pathological conditions have been well documented. Consumption of meat products rich in natural antioxidants has been shown to reinforce the endogenous antioxidant efficacy against oxidative stress and ROS-induced tissue damage and degenerative diseases [40]. While natural phenolic antioxidants as food ingredients are of general effectiveness in promoting the overall health, the protection of the gastrointestinal tract health seems to be most obvious because absorption is not required [41]. Unlike most non-protein antioxidants that have the exclusive role of stabilizing free radicals and inhibiting radical propagation, antioxidant peptides may exert other biological functionalities, for example, antihypertensive, anticancer, anti-microbial, immunomodulatory, and opioid activities [42]. Thus, naturally occurring antioxidant peptides and those derived from protein hydrolysis are now considered as novel and potential food ingredients to promote human health. Antioxidants can protect against the cell damage that free radicals cause, known as oxidative stress.[43] Activities and processes that can lead to oxidative stress include: mitochondrial activity, excessive exercise, tissue trauma, due to inflammation and injury, ischemia and reperfusion damage, consumption of certain foods, especially refined and processed foods, trans fats, artificial sweeteners, and certain dyes and additives, smoking,

environmental pollution, radiation, exposure to chemicals, such as pesticides and drugs, including chemotherapy, and industrial solvents. Such activities and exposures can result in cell damage. This in turn may lead to an excessive release of free iron or copper ions, an activation of phagocytes, a type of white blood cell with a role in fighting infection, an increase in enzymes that generate free radicals, a disruption of electron transport chains. All these can result in oxidative stress. [44]. The damage caused by oxidative stress has been linked to cancer, atherosclerosis, and vision loss. It is thought that the free radicals cause changes in the cells that lead to these and possibly other conditions. An intake of antioxidants is believed to reduce these risks. (Lobo, and Patil 2010). According to [45] “Antioxidants act as radical scavenger, hydrogen donor, electron donor, peroxide decomposer, enzyme inhibitor, synergy, and metalchelating agents”. Other research demonstrated the antioxidant supplements role in reducing vision loss due to age-related macular degeneration in older people.

3. Conclusions

Meat and Meat Products are essential sources of quality nutrients with high protein value that is required in human diet to carry out functional activities. The challenges of meat start from the point of slaughter to processing and eventual packaging into final products. These meat products are more susceptible to oxidation and microbial activities, due the fact that they are highly rich in protein and fat. These are responsible to the physical and chemical changes in the meat products in terms of the nutritional and organoleptic properties such as colour, odor, texture and general safety of the meat. Several synthetic antioxidants have been used to combat oxidation in meat products. However, it has been discovered that synthetic antioxidants are carcinogenic and pose threat to the health of consumers; therefore natural antioxidants are preferred because they proffer similar protective effect against oxidation in meat and meat products. Apart from the ability to fight Lipid-protein Oxidation, natural antioxidants also exhibit antimicrobial properties that retard the growth and activities of spoilage micro-organisms in post- slaughter carcass, thus help to retain and improve their nutritional and organoleptic properties. Also, they are discovered to be free – radical scavengers, therefore help to promote the health of consumers. In the same vein, plant antioxidant extracts are used as supplement in animal feeds to enhance the nutritional value of meat for consumers.

In spite of the fact that natural extracts are safe on meat and meat products, some still require further studies on their anti- nutritional and toxicological effects. Also little has been done on recommended dosage of the extracts that should be introduced into the meat products that will prevent oxidation and as well safe for consumption.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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