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Review Article

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Advances in use of Natural Antioxidants as Food additives for improving the Oxidative Stability of Meat Products

Sajad A Rather, Farooq Ahmad Masoodi*, Rehana Akhter, Jahangir A Rather and **Khurshid A Shiekh**

Department of Food Science and Technology, University of Kashmir, Srinagar-190006, India

Article Info

***Corresponding author:**
Farooq Ahmad Masoodi
Professor
Department of Food Science and Technology
University of Kashmir
Srinagar-190006, India
Tel: +9419135876
E-mail: masoodi_fa@yahoo.co.in

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Abstract

Oxidation is a key problem that reduces the shelf life of fresh and processed meat and meat products. Antioxidants are added to stabilize free radicals there by delaying lipid and protein oxidation, retard development of off-flavors, and improve colour stability. Addition of synthetic antioxidants to combat oxidative damage has the potential to cause adverse health effects and thus remained a challenge to the meat industry. In this regard research studies have directed towards natural antioxidants utilizing fruits, herbs, spices, and vegetable extracts in meat industry for improving the quality of fresh and processed meat and meat products. Due to their high phenolic compound content, fruits and other plant materials provide a good alternative to synthetic antioxidants. This review provides the current overview of the recent advances on plant materials used as natural antioxidants in meat and meat products.

Keywords: Natural antioxidants; Fruits; Herbs; Spices; Lipid oxidation; Meat.

Introduction

Meat as a food has a complex physical structure and chemical composition that is very susceptible to oxidation [68,90]. The oxidative stability of meat depends upon the balance and the interaction between endogenous anti- and pro-oxidant substances and the composition of substrates prone to oxidation including poly unsaturated fatty acids (PUFA), cholesterol, proteins and pigments [12]. The oxidation of lipids in meat products is a key problem that reduces shelf life of frozen meats, fermented processed meat such as dry sausages, and cured raw ham. In meat lipids, the formation of lipid oxidation products from unsaturated fats is initiated by singlet oxygen converted from triplet oxygen or a catalyst and triplet oxygen. Further reactions yield hydro peroxides that act as strong oxidizing agents (ROS — reactive oxygen species) [37]. Metal catalysts such as iron and copper are key elements involved in the breakdown of these compounds. When hydro peroxides are degraded, highly reactive free radicals are generated that in turn react with the double bonds of other unsaturated lipid acids thereby producing more radicals that further propagate the chain reaction of lipid oxidation [37]. In addition lipid oxidation products initiate the oxidation of proteins leading to serious health concerns, and undesirable sensory changes and deterioration of nutritive value [66-67,70]. Lipid oxidation can be reduced or inhibited by the use of antioxidants in meat and meat products and thus the product quality and shelf-life can be improved.

Antioxidants are substances that at low concentrations retard the oxidation of easily Oxidizable bio molecules, such as lipids and proteins in meat products, thus improving shelf life of products by protecting them against deterioration caused by oxidation [39]. Antioxidants can prevent lipid Peroxidation using the following mechanisms: preventing chain inhibition

by scavenging initiating radicals, breaking chain reaction, decomposing peroxides, decreasing localized oxygen concentrations and binding chain initiating catalysts, such as metal ions [19]. There are a huge number of compounds that have been proposed to possess antioxidant activity, but only a few can be used in food products. The use of antioxidants in food products is controlled by regulatory laws of a country or international standards [33]. In the United States the use of antioxidants is subject to regulation under the Federal Food, Drug and Cosmetic Act, Meat Inspection Act, Poultry Inspection Act, and other state laws [46,79]. In the European Union, regulation of antioxidants is stipulated by the European Parliament and Council Directive No. 95/2/EC of 20 February 1995 on food additives other than color or sweeteners. Another organization that regulates the use of antioxidants is the *Codex Alimentarius*, which is a collection of internationally adopted standards. *Codex Alimentarius* permits only the use of those antioxidants which have been evaluated by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and these may be used only in foods standardized by *Codex* [46]. Typical synthetic antioxidants such as propyl gallate, butylated hydroxyanisol (BHA), butylated hydroxytoluene (BHT), tertiary butyl hydroquinone (TBHQ), and nitric oxide from sodium nitrite have been widely used in meat and meat products [87]. Due to the potential toxicological effects of synthetic antioxidants, the demand for natural antioxidants has increased in the recent years [78].

In view of the health effects of synthetic antioxidants consumers demand healthier or "classical" meat products containing natural antioxidants. Recently researchers have focused towards identification of novel antioxidants from plant sources due to their high content of phenolic compounds and provide alternative to currently used conventional antioxidants [33]. Plant extracts are typically obtained by maceration of plant matter with organic solvents or by supercritical CO_2 extraction [93]. These natural antioxidants from plants, in the form of extracts, have been obtained from different sources such as fruits (grapes, pomegranate, date, kinnow), vegetables, (broccoli, potato, drumstick, pumpkin, curry, nettle), herbs and spices (tea, rosemary, oregano, cinnamon, sage, thyme, mint, ginger, clove) and investigated to decrease the lipid oxidation [1,11,13,32,42,44,45,52,74,75,80,88]. In addition to plant extracts direct incorporation of plant materials such as fruit pulp, seed powder have been investigated as potential antioxidants in meat and meat products [33]. The objective of this paper is to review the recent published literature on plant based natural antioxidants used in meat and meat products.

Mechanism of action of natural antioxidants

The concept of natural antioxidant refers to any substance that, when present at a lower concentration compared to that of an oxidizable substrate, is able to either delay or inhibit the oxidation of the substrate [60]. The total antioxidant capacity of plant materials such as culinary herbs, spices, vegetables, as well as fruits and oilseed products reflects concentrations of ascorbic acid (vitamin C), alpha-tocopherol (vitamin E), beta-carotene (vitamin A precursor), various flavonoids, and other phenolic compounds [86,59]. The different factors which initiate lipid and protein oxidation include the presence of oxygen and transition metal ions, moisture, heat and light. To inhibit or retard the rate of oxidation, oxygen and metal catalysts must be removed or sequestered and food prone to oxidation must be stored at low temperatures and shielded from light [20]. The natural antioxidants in plant materials have strong H•-donating activity [48] or have high radical-absorbance capacity or sequestered metal catalysts to render them un reactive [39]. Some natural antioxidants prevent the formation of free radicals and propagation of reactive oxygen species (ROS), while other scavenge free radicals and chelate transition metals (pro oxidants) [56]. The antioxidant potential of these natural substances depends on their pattern of functional groups on this skeleton [89]. For example, the number and position of free hydroxyl (–OH) groups on flavonoid skeleton decide the free radical-scavenging potential [41]. Presence of multiple –OH groups and ortho-3, 4-dihydroxy structures enhance the antioxidant potential of natural phenolics [24,6]. Plant pigments such as anthocyanins and their hydrolyzed products, anthocyanindins also contain –OH groups, which can donate H• and thus have antioxidant potential [39].

Natural antioxidants from fruits and vegetables

The natural antioxidants have been studied in meat from a huge number of plant sources. Some of these natural antioxidants are also available commercially and several studies have been carried out by different researchers applying commercially available natural antioxidants of plant origin to meat (Table 1). The protective effect of fruits has been attributed to phyto chemicals, which are the non-nutrient plant compounds such as the carotenoids, flavonoids, isoflavonoids, and phenolic acids. Phyto chemicals have been found to possess huge functional activities, such as protect against lipid oxidation, inhibit cancer cell proliferation, and regulate inflammatory and immune response [39]. Among the phyto chemicals, phenolic compounds were found to play major role in protection against oxidation. The antioxidant potential of various fruits (plum, grape seed extract, pomegranate, and bearberry) has been conducted in meat products.

Plum

Numerous studies have investigated the antioxidant properties of plums in variety of meat products. Nunez de Gonzalez et al. [53,54] reported the antioxidant activity of plums in precooked pork sausage and roast beef. Raw and cooked pork sausage patties (32% fat) treated with 3% and 6% dried plum puree, 3% and 6% dried plum and apple puree were evaluated for lipid oxidation at 4°C for 28 days or frozen at -20°C for 90 days [53]. Precooked pork sausage patties treated with 3% and 6% dried plum puree, or 3% and 6% dried plum and apple puree showed a reduction ($p<0.05$) in TBARS values compared with the control (untreated) after 28 days of storage at 4°C. Precooked pork sausage patties during frozen storage for 90 days at -20°C treated with 3% and 6% dried plum puree, or 3% and 6% dried plum and apple puree also had a significantly lower TBARS value than the control. In precooked roast beef lipid oxidation was reduced ($p<0.05$) when treated with fresh plum juice concentrate,

dried plum juice concentrate, and spray-dried plum powder [54]. [92] found that plum puree (PP) at different concentrations (5%, 10% and 15%) in low fat (5-6%) beef patties resulted in lower ($p<0.05$) TBARS values than control during frozen storage (45 days of storage at -18°C). Meat products incorporated with different plum products exhibit lower lipid oxidation. However minor flavor differences and some color variations have been observed, but sensory analysis showed no significant differences in color and flavor attributes [33].

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

Plant material/extract	Dosage in meat	Meat product	Effect on oxidation	References
Olive oil waste extract	100, 200 or 400 mg /kg muscle	Lamb patties	SDLP	Muino et al., 2016
Litchi (*Litchi chinensis* Sonn.) pericarp extract	0.5%, 1.0% and 1.5%	Sheep Meat Nuggets	SDL	Das et al., 2016
Mugwort extract and rosemary extract	0.01-0.05% each	Pork patties	SDL	Hwang et al., 2016
Nutmeg (Myristica fragrans) essential oil	10 ppm and 20 ppm	Cooked sausage	SDL	Sojic et al., 2015
Apple pomace powder	1%, 3% and 5%	Goshtaba	SDL	Rather et al., 2015a
Rosa canina L. extract	50 g/kg	Beef Patties	SDP	Utrera et al., 2014
Ginkgo biloba leaf extract	0.05%	Meat ball	SDL	Kobus-Cisowska et al. (2014)
Thuza (*Thuja occidentalis*) cones extract	0.25%	Raw chicken ground meat	SDL	Yogesh and Ali, 2014
Lychee seed extract	0.1%, 0.5% or 1.0%	Raw meat paste	SDL	Qi et al., 2014
lyophilized and powdered *Gentiana lutea* root	2 g/kg	Fresh beef patties	SDL	Azman et al., 2014
Broccoli leaf extract	0.1% and 0.5% w/w	Ground beef patties	SDL	Kim et al., 2013
Butterbur leaf extract	0.1% and 0.5% w/w	Ground beef patties	SDL	Kim et al., 2013; Kim et al., 2013
α-Tocopherol, green tea extract	700 mg/kg and 300 mg/ kg	Cooked cured meat protein extracts	SDLP	Yang et al., 2013
Grape seed extracts	0.1%	Mutton slices	SDL	Reddy et al., 2013
Oregano + sage leaves	0.2% w/w each	Chicken breast and thigh	SDL	Sampaio et al., 2012
Black currant extracts	5, 10 or 20 g/kg	Pork patties	SDLP	Jia et al., 2012.
Rosemary extracts	250, 500, 750 mg/kg	Porcine liver patties	SDL	Doolaege et al., 2012
Curry leaf extracts (Murrayakoenigii L.)	5 mL extract/500 g	Pork meat	SDL	Biswas et al., 2012
Broccoli powder extracts	1.5 and 2%	Goat meat nugget	SDL	Banerjee et al., 2012
Hypericum perforatum L. extract	0.0005% 0.001%	Pork meat	SDL	Sanchez-Muniz et al., 2012
Herbal extracts (Marjoram, rosemary, sage)	0.04% v/w	Ground beef	SDL	Mohameda et al., 2011
Avocado seed extract	50 g extracts/700 g	Porcine patties	SDLP	Rodriguez-Carpena et al., 2011
Rosemary, turmeric, fingerroot, and galangal	0.2%	Fried beef patties	SDL	Puangsombat et al., 2011
lotus rhizome knot (LRK) and lotus leaf (LL) extracts	3% each	Raw and cooked porcine and bovine meat samples	SDL	Huang et al. (2011)
Carrot juice	19.843%	irradiated beef sausage	SDL	Badr and Mahmoud, 2011
Olive leaf extracts	100 and 200 µg/g	Minced v beef patties	SDL	Hayes et al., 2010
Kinnow rind powder, pomegranate rind powder and pomegranate seed powder	-	Cooked goat meat patties	SDL	Devatkal et al., 2010

*SDL: Significantly decreased lipid oxidation; SDP: Significantly decreased lipid oxidation; SDLP: Significantly decreased lipid and protein oxidation.

Grape Seed Extract

Grape seed extract has antioxidant potential 20 and 50 times higher than vitamin E and vitamin C, respectively and has been reported to be the richest sources of natural poly phenols, comprising flavanols, phenolic acids, catechins, proanthocyanidins and anthocyanins [33,30]. The major poly phenols are catechins and proanthocyanidins representing about 77.6% of total [81]. Earlier researchers compared grape seed extract at different concentrations (100, 300, 500 ppm) with ascorbic acid and propyl gallate (100ppm of fat) in lean beef sausages cooked (70°C) sliced and stored at −18°C for 4 months and observed that samples prepared with the grape seed extract (100, 300 ppm) and propyl gallate retained their freshness, had less rancid odour and had lower thiobarbituric acid reactive substances (TBARS) values compared to controls and ascorbic acid containing samples during the storage period [38]. Özvural and Vural [57] concluded that, frankfurters prepared with addition of different concentrations (0, 0.5, 1, 2, 3, 4, 5%) of grape seed flour, had lower oxidation level and enhanced protein and total dietary fiber content with increasing levels of grape seed flour [57]. Additionally the effect of grape seed extract at different levels (0.01, 0.03, 0.05, 0.1, 0.3 and 0.5%) on the quality properties of frankfurters was evaluated against the control. The results showed that with the increase in level of grape seed extract in frankfurters there was a decrease in the TBARS values of the products [58]. Garrido et al. [23] studied the effect of two different types of red grape pomace extracts (GPI and GPII) at a concentration of 0.06 g/100 g final product, in pork burgers packed under aerobic conditions at 4°C for 6 days. It was observed that GPI showed the highest color stability, lipid oxidation inhibition and the best global acceptability after 6 days of storage. In addition grape seed extract (GSE), oleoresin rosemary (OR), water-soluble oregano extract (WO), propyl gallate (PG), butylated hydroxyanisole (BHA), and butylated hydroxyl toluene (BHT) in cooked, frozen, reheated ground beef patties, overwrapped in commercial PVC film, and stored frozen (−18°C) for 6 months was investigated [9]. It was concluded that PG and GS treated samples showed lower rancid odor scores and TBARS values than controls, after 6 months of storage. BHT treated and control samples did not differ statistically in sensory grassy or rancid odor, indicating that they were the most oxidized.

Pomegranate

Pomegranate fruit parts contain a high concentration of antioxidants and the peel and rind are good sources of tannins, anthocyanins, and flavonoids [50]. Hygreeva et al. and Ganhão et al. [30,21] reported that pomegranate fruit phenolics to meats inhibit lipid and protein oxidation through radical chain inhibition and thus prevent color deterioration in the product. Devatkal et al. [16] investigated the effect of vacuum packaging and pomegranate peel extract on ground goat meat and cooked nuggets during refrigerated storage (4 ± 1°C). Vacuum packaging along with 1% pomegranate peel extract (VP + PPE) showed significantly lower TBARS than atmospheric packaging. In ground meat, VP + PPE reduced

the TBARS by 41% while in nuggets, it was decreased by 40%. Devatkal et al. [14] investigated the use of kinnow rind powder (KRP), pomegranate rind powder (PRP), and pomegranate seed powder (PSP) (10 ml of extract) in raw goat meat, and then prepared cooked goat (80°C) patties. Addition of PRP was effective in reducing TBARS formation up to 67% ($p<0.05$). Additionally in another study, Devatkal and Naveena [14] studied effect of salt, kinnow rind powder (KRP), pomegranate rind powder (PRP), and pomegranate seed powder (PSP) in raw ground goat meat. The addition of fruit powders showed lower ($p<0.05$) TBARS compared with control and salted samples. Pomegranate rind powder (PRP) incorporated patties showed higher reduction in TBARS values (134% and 443%) compared with control and salted samples, respectively. The effect of pomegranate fruit juice phenolics (PFJP) solution on the shelf life of chicken meat held under refrigerated storage at 4°C was evaluated by Vaithiyanathan et al. [86]. TBARS were evaluated in 2 days intervals for 28 days and reported that TBARS values were lower in samples treated with PFJP.

Avocado

Avocado is one of the lesser-studied natural antioxidants. Rodríguez-Carpena et al. [73] investigated the antioxidant activity of peel and seed extracts from two avocado varieties – Hass and Fuerte and observed that during chill storage of raw porcine patties for 15 days the addition of peel and seed extracts resulted in lower TBARS values, and significantly reduced the color loss. In addition Hass avocado extract significantly inhibited the formation of protein carbonyls in the chilled patties. These studies demonstrate that avocado has potential to work as a natural antioxidant in meat.

Apple pomace

Apple pomace is the primary by-product of apple juice manufacturing, and approximately 3.0–4.2 9 106 Mton/year are generated annually worldwide. A range of polyphenolic compounds have been isolated from apple pomace, such as epicatechin, caffeic acid, phloridzin, phloretin-20-xyloglucoside, 3-hydroxyphloridzin, avicularin, reynoutrin, hyperin, isoquercitrin and quercitrin [65,70] which have antioxidant property [55,7,28]. Rather et al. [65,70] evaluated apple pomace powder at different levels (1–5 %) in traditional Indian meat product (*Goshtaba*).The addition of apple pomace powder resulted significantly lower TBARS values in uncooked and cooked products and metmyoglobin percent in uncooked meat emulsions than both high fat and low fat samples.

Tomato

Tomato is most cultivated vegetable all around the world. The Presence of high amounts of lycopene in tomato, which is a natural colorant of (red) and antioxidant is a functional ingredient that can be used in meat products [30]. Garcia-Closas et al. [22] reported that tomatoes are a rich source of natural antioxidants such as lycopene (71.6%), vitamin C (12.0%) and β-carotene (17.2%) and vitamin E (6.0%). Doménech-Asensi et al. [17] reported that the addition of 10% tomato paste (TP) during the manufacture of mortadella improved the nutritional status (Lycopene), color stability and decreased lipid oxidation during 2 months storage at 4°C. It has been observed that the MDA content in the regular product (R) increased significantly from initial values of 42.05 to 59.17 mm MDA/100 g while TP incorporated product showed values in the range of 30–40 mm MDA/100 g for the storage period of 2 months. Thus more investigation needs to be conducted for other varieties of meat products with a focus on different storage conditions.

Lotus

Choe et al. [8] evaluated the antioxidant activity of lotus leaf powder, 0.1% (LP_1), 0.5% (LP_2) and barley leaf 0.1% (BP1), 0.5% (BP2) powder in cooked ground pork and reported that addition of LP_2 or BP_2 significantly decreased lipid oxidation and lowered peroxide and conjugated diene values when compared with control samples containing BHT (0.01%) during refrigerated storage for 10 days. There were no significant changes observed in overall acceptability among the treatment groups (LP/BP). Qi and Zhou [63] found that addition of epicarp extract of lotus seed at 6.25, 12.5, 25, 50 and 100 μg mL^{-1} concentrations to pork homogenates retarded TBARS and peroxide values in Chinese Cantonese sausages. Moreover the cytotoxic and anti obesity activity of the extract *in vitro* in 3 T_3-L_1 pre adipocyte cell models depended on the dosage; epicarp extracts of lotus seed are potent antioxidant and anti obesity phyto chemicals with no toxic effects. Huang et al. [27] investigated that extracts from lotus rhizome knot (3% w/w, LRK) and lotus leaf (3% w/w, LL) incorporated in porcine and bovine meat samples stored at 4°C for 10 days increased antioxidant activity of meat samples, but LRK was more effective against lipid oxidation.

Natural antioxidants from herbs and spice extracts

Extracts of herbs and spices have been used as natural antioxidants in meat and meat products by several authors (Table 1). The increasing interest of meat industry in natural antioxidants led to an extensive research on the utilization of spices and herbs lipid oxidation inhibitors. Spices have been shown to have potential antioxidant properties due to the presence of several compounds such as polyphenolics, flavanoids, lignans, and terpenoids [33]. The herb and spice extracts, including rosemary, oregano, clove, and thyme have been studied for their antioxidant potential in cooked, fermented and irradiated meat products [72]. Rosemary and rosemary extracts are the most studied natural antioxidants used in meat and poultry products [74]. Rosemary (Nutrox-30 mg/100gm) and lemon balm (Melinox-30 mg/100g) extracts in cooked pork meat patties packed in modified atmosphere were evaluated by Lara et al. [40]. They observed that natural extracts significantly reduced the TBARS values and hexanal contents in products during 3 days storage under illumination. Trindade et al. [84] evaluated the rosemary (400 mg/kg) and oregano (400 mg/kg) extracts individually or in combination (200 mg rosemary plus 200 mg oregano) and with either BHA/BHT (200 mg/kg) or their blend (100 mg/kg BHA/BHT plus 200 mg/kg rosemary/oregano) in irradiated beef burgers and proved decreased lipid oxidation (TBARS values 2.7 mg/kg

– control, treated samples-below 2.0 mg/kg) in meat samples stored at −20°C for 90 days. Moreover, rosemary alone or in combination with either BHA/BHT or oregano showed the highest inhibitory effect among all the formulations. Boerewors, a South African fresh sausage, was treated with rosemary (260 mg/kg) and compared with 450 mg/kg sulphur dioxide (SO_2). Addition of rosemary showed comparable lipid stability to SO_2. Reduced levels of 100 mg/kg SO_2 showed good color effects in combination with rosemary as antioxidant and improving the sensory properties [43]. Mohameda et al. [47] investigated that addition of herbal extracts of marjoram, rosemary and sage at concentration of 0.04 % (v/w) to ground beef prior to irradiation (2 and 4.5 kGy) significantly reduced the TBARS values. Naveena et al. [51] evaluated the effect of oil soluble and water dispersible carnosic acid (CA) extracted from dried rosemary leaves at two different concentrations (22.5 ppm and 130 ppm) in raw and cooked ground buffalo meat patties. It was observed that CA extracts lowered ($P<0.05$) the TBARS by 39–47% at lower concentration (22.5 ppm) and by 86–96% at higher concentration (130 ppm) in cooked buffalo meat compared to controls. The CA extracts were also effective in inhibiting ($P<0.05$) peroxide value and free fatty acids in cooked buffalo meat patties. Mint leaf extract was evaluated for its antioxidant activity in raw ground pork meat stored at 4 ± 1°C [5]. It was reported that the water extract of mint leaf (WEM) showed a decrease in the Hunter L* and a* values and an increase in b* value during storage. The TBARS values were reduced due to the incorporation of WEM leaf extracts during storage periods. Tajik et al. [83] studied the effect of clove essential oil (0.1%) on lipid oxidation of raw buffalo patties during storage at 8°C for 9 days and observed a lower TBA values in samples 0.1% clove essential oil. Samples with 0.1% clove essential oil had the lowest degrees of lipid oxidation, which was 73% lower than the control. Rababah et al. [64] evaluated the effect of green tea or grape seed extract alone (3000 and 6000 ppm) or combination with TBHQ (200 ppm) on lipid oxidation and the redness of goat meats stored at 5°C for 9 days was evaluated. The antioxidant activity of the plant extracts and the TBHQ ranged from 4.6 to 10.2 h induction time using an oxidative stability instrument. Plant extracts and TBHQ significantly decreased lipid oxidation of the goat meats. Further, higher level addition of antioxidants was more effective in minimizing lipid oxidation. Wojciak et al. [88] investigated the extracts from green tea (catechins, epigallocatechins), rosemary (rosmariquinone, rosmaridiphenol) and red pepper (capsaicinoids) in pork meat products stored for 30 days at refrigerated temperatures. All these plants extracts effectively reduced the lipid oxidation in cooked pork compared to the control. Lipid oxidation was reduced ($P<0.001$) in raw and cooked pork patties stored in aerobic packages and in MAP (80% O2:20% CO_2) treated with sesamol, ellagic acid and olive leaf extract. Addition of lutein, sesamol, ellagic acid and olive leaf extract to pork showed a antioxidant potential and was in the order: sesamol = ellagic acid + olive leaf extract + lutein [25]. Hayes et al. [26] evaluated the lutein (200 µg/g meat), sesamol (250 µg/g meat), ellagic acid (300 µg/g meat) and olive leaf extract (200 µg/g meat) in fresh and cooked pork sausages stored in aerobic or modified atmosphere packages (MAP). Incorporation of sesamol, ellagic acid and olive leaf extract reduced ($P<0.001$) lipid oxidation in all packaged raw and cooked pork sausages.

Conclusion

During recent past there has been an increasing interest in using natural ingredients in meat and meat products. Consumers have increasingly favored meat products which contain natural additives due to concerns over adverse health effects of synthetic substances particularly some synthetic antioxidants. Oxidation has various detrimental effects on quality of meat and meat products such as discoloration, development of rancid flavor and loss of functional properties which renders the products unpalatable and unacceptable. In addition, oxidation of lipids and proteins poses serious health risks besides being a major threat to meat quality. Due to the adverse health effects of synthetic antioxidants; fruits, vegetables, herbs, spices and other plant extracts provide good alternatives to combat such problems in meat products in addition to increasing the health promoting bioactive components. However, since the effect of natural antioxidants on quality of meat and meat products has not been fully investigated, there is a need to explore this area to curb the challenges of quality losses in fresh and processed meat and meat products due to oxidation.

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