OPEN ACCESS
Advances in Animal and Veterinary Sciences
Review Article

Using Natural Antioxidants in Meat and Meat Products as Preservatives: A Review

Majid Aminzare[1], Mohammad Hashemi[2], Elham Ansarian[1], Mandana Bimkar[3], Hassan Hassanzad Azar[1], Mohammad Reza Mehrasbi[1], Shahrzad Daneshamooz[4], Mojtaba Raeisi[5], Behrooz Jannat[6], Asma Afshari[2*]

[1]Department of Food Safety and Hygiene, School of Public Health, Zanjan University of Medical Sciences, Zanjan, Iran; [2]Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran; [3]Department of Food Science and Technology, Faculty of Agriculture, University of Zanjan, Zanjan, Iran; [4]Department of Microbiology and Virology, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran; [5]Department of Nutrition, Faculty of Health, Golestan University of Medical Sciences, Gorgan, Iran; [6]Halal Research Center of IRI, FDA, Tehran, Iran.

Abstract | Lipid oxidation is one of the most important problems that decrease the shelf life of meat and meat products. Antioxidants are used to reinstate free radicals thereby retarding lipid oxidation, delay development of unpleasant-flavors, and improve color stability.Application of synthetic antioxidants to mitigate oxidative damage may consider unsafe for consumers. Furthermore, the recent growing in the understanding of the consumers about these hazards resulted in the replacement ofsynthetic antioxidants with natural bioactive compounds. Plant materials are rich sources of bioactive phenolic compounds; hence they can be an effective alternative to synthetic antioxidants. This review presents an overview regarding the new advances in the application of natural antioxidant compounds such as herbs, spices, fruits, plant essential oils and extracts in meat and meat products to improvetheir quality and shelf-life.

Keywords | Meat, Lipid oxidation, Natural antioxidant, Essential oil, Extract

Editor | Kuldeep Dhama, Indian Veterinary Research Institute, Uttar Pradesh, India.
Received | December 03, 2018; **Accepted** | January 23, 2019; **Published** | March 30, 2019
***Correspondence** | Asma Afshari, Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran; [3]Department of Food Science and Technology, Faculty of Agriculture, University of Zanjan, Zanjan, Iran; **Email**: asmafshr@gmail.com
Citation | Aminzare M, Hashemi M, Ansarian E, Bimkar M, Azar HH, Mehrasbi MR, Daneshamooz S, Raeisi M, Jannat B, Afshari A (2019). Using natural antioxidants in meat and meat products as preservatives: a review. Adv. Anim. Vet. Sci. 7(5): 417-426.
DOI | http://dx.doi.org/10.17582/journal.aavs/2019/7.5.417.426
ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331

INTRODUCTION

Meat and meat products are an excellent source of essential nutrients with high-quality proteins, fat and mineral. There are a wide variety of meat products including cured meats, patties, nuggets, meatballs and etc. (Aminzare et al., 2016). Lipid oxidation is a major cause of deterioration in meat and meat products due to their high fat content and low water activity leading to loss of nutritional value, unpleasant flavor and texture, and water holding capacity (García-Lomillo et al., 2017; Ding et al., 2015). Cooking of meat involves the formation of hydro-peroxides that can be easily broken down to various volatile organic compounds such as alkanes, alkenes, aldehydes, ketones, alcohols, esters and acids that are responsible for reducing the sensorial quality and leading to oxidative flavors, loss of pigments and vitamins in meat and meat products (García-Lomillo et al., 2017). Heating process disrupt the muscle cell structure, deactivates anti-oxidative enzymes and produces catalytic iron from myoglobin leading to an intense pro-oxidant environment in which both lipids and proteins can be affected. Grinding can destruct muscle cell membranes so the reaction between unsaturated lipids with pro-oxidant substances such as non-heme iron increases lipid oxidation (Gallego et al., 2015). Furthermore, heme pigments (myoglobin and hemoglobin) are also oxidized in a coupled lipid-pigment reaction, which causes a color change. Antioxidants can be added to meat and meat products during processing to delay lipid oxidation. Plant polyphenols and essential oils (EOs) are considered as major natural source of bioactive compounds to increase the shelf life of meat and meat

products. Different synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butyl hydroquinone (TBHQ), propyl gallate (PG), and nitrite are used in the meat industry. Nowadays, because of the possible health risks and toxicity of these synthetic compounds on human health and increasing tendency to consume natural components, their use has been limited. Several types of research have been conducted to find a new and natural source of antioxidants to replace with synthetic antioxidants (de Florio Almeida et al., 2017; Ehsani et al., 2012).

There are different bioactive compounds in plant sources such as phenolic compounds, carotenoids, tocopherols, and etc. Nowadays EOs are widely used in the food industry because of their ability in retarding the food spoilage, improvement of organoleptic quality, and pathogen growth inhibition (Hashemi et al., 2016). These compounds are classified as "Generally recognized as safe" (GRAS) food additives for human consumption with pharmaceutical, antimicrobial, and antioxidant properties by the Food and Drug Administration (FDA) (Aminzare et al., 2016). Plant polyphenols may be offered as alternatives to EOs. It has been reported that polyphenols have a variety of biological effects such as antioxidant, anti-carcinogenic, anti-inflammatory, and antimicrobial activities (Ehsani et al., 2017). In this review, the potential application of different bioactive compounds derived from plant sourcesin the meat and meat products have been reported. Furthermore, this review aimed to study the effect of replacing natural antioxidants with synthetic components to delay the oxidative reactions in meat and meat products.

Mechanisms of Lipid Oxidation

Lipid oxidation is initiated byionized hydrogen (H^+) which is separated from an unsaturated fatty acid and form an alkyl radical (R^o). Lipid radical's formation is thermodynamically undesirable and is usually initiated by the presence of other radical compounds (R^o), single oxygen, and decomposition of hydroperoxides (ROOH) or pigments that act as colorants (Ahna et al. 2007). The alkyl radical (R^o) change the position of the double bond (Cis to trans) and produce a conjugated diene system. The R^o can react with oxygen to form a high-energy peroxyl radical (ROO^o) (Chaijan, 2008). The peroxyl radical can then react with another hydrogen atom (H^+) from another unsaturated fatty acid to form a ROOH and a new R^o. This process propagates to another fatty acid (Falowo et al., 2014).

Consequences of Lipid Oxidation on Meat and Meat Products quality

Severalfactors can affect lipid oxidation in meat and meat products including high ratio of polyunsaturated fatty acids (PUFAs) as components of membrane phospholipids, lack of antioxidants, high concentrations of pro-oxidants and reactive radical species, presence of high amounts of salt (NaCl) and free molecular oxygen that is usually entered into meat mixture during processing. Researchers have proved that salt can reduce the activity of glutathione peroxidase, superoxide dismutase, and catalase (Jiang & Xiong 2016). Oxidative deterioration of meat and meat products results in the development of off-flavor, discoloration, formation of toxic compounds, loss of nutrients, drip losses and thus shorten the shelf life (Contini et al., 2014; Palmieri et al., 2007). Under normal physiologic conditions, the molecular oxygen exposes a series of reactions that causes generation of free radicals. During the metabolic reactions, a small amount of the consumed oxygen is changed to form reactive oxygen species (ROS). Free radicals, especially, ROS and reactive nitrogen species (RNS) which can interact with fatty acids, nucleic acids and proteins, take a part as intermediate agents in several homeostatic processes (Moylan et al., 2014). In general imbalance between the production of ROS and antioxidant leads to oxidative stress, which often causes functional and structural damages to muscle organelles, cells and tissues. Myofibril protein can be affected by ROS during the storagewhich affects meat quality and damage cellular structure. Evidence showed that ROS reduce collagen synthesis in the muscle, which increases meat toughness and decrease solubility of collagen (Falowo et al., 2014; Archile-Contreras and Purslow, 2011).

Oxidation Reaction in Meat Sample

The word 'antioxidant' means any substance that can either delay or prevent the oxidation of an oxidizable substrate. Various factors can promote lipid oxidation including presence of oxygen, metal ions, moisture, heat, and light, therefore to prevent or retard oxidation in susceptible foods, oxygen and metal catalysts should be removed and foods must be kept at low temperatures and be protected from light (Rather et al., 2016).

Antioxidants prevent lipid peroxidation by preventing a chain reaction, scavenging ROSs, breaking the auto-oxidative chain reaction, quenching O2- radicals and preventing peroxides developments, and binding to catalysts such as metal ions. There are large numbers of components that have been proposed to possess antioxidant activity (Shah et al., 2014). Some natural antioxidants inhibit the development of free radicals and promotion of ROS. The antioxidant activity of them is due to their molecular structure, -OH groups and ortho-3, 4-dihydroxy structures which increase the antioxidant activity of natural components. Plant pigments such as anthocyanins have –OH groups, which can donate H· (Rather et al., 2016).

The most important antioxidants are those that interrupt the free radical chain reactions. These compounds usually

contain aromatic or phenolic rings which donate $H^+$to the formed free radicals during oxidation and are converted to radical intermediates. These intermediate radicals are stabilized by the resonance (delocalization) of the electron within the aromatic ring and formation of quinone structures (Maqsood et al., 2014).

Natural Antioxidant in Meat and Meat Products

Plants are potential source of valuable bioactive substances and have been evaluated as natural antioxidants to improve the chemical quality of meat and meat products (Shah et al,. 2014). Nowadays, many studies have been done to use different medicinal plants as potent antioxidant sources for food preservation and improve nutritional quality of meat products. Most of the plants (herbs and spices) have relatively high macronutrients (such as protein, fat, and carbohydrate), micronutrients (minerals and vitamins) and less anti-nutritional properties. Additives with antioxidant properties have been developed to control lipid oxidation and formation of the secondary breakdown products in foods. 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 (Rather et al., 2016).

Spices and herbs are used in foods for their flavor and often contain high concentrations of phenolic components with an extreme H-donating activity.The major anti-oxidative phenolic compounds in plants can be classified into groups including phenolic diterpenes (carnosic acid and-carnosol), flavonoids (quercetin and catechin), phenolic acids (gallic, rosmarinic acids and caffeic acid), and volatile oils (carvacrol, eugenol, thymol, and menthol) (Falowo et al., 2014). The plant extracts obtained from different sources such as fruits, vegetables, herbs, and spices have been proven to possess strong antioxidant activity because of their high content of phenolic compounds. These extracts are prepared from the plant materials by using different solvents and extraction methods. Extraction process should provide the highest yield and quality of target compounds. There are many techniques to obtain antioxidants from plants, such as supercritical fluid extraction (SFE), Soxhlet extraction (SE), ultrasound-assisted extraction (UAE) and subcritical water extraction (SWE) and etc. In general, in solvent extraction process the plant materials are cleaned, washed, dried, and ground into fine powder. There are different solvents for extraction purpose such as acetone, methanol, pure ethanol, 70, 80, 90% ethanol, dimethyl sulfoxide and water (Shah et al., 2014). Recently, green technologies such as SFE or pressurized liquid extraction (PLE) often along with the use of GRAS solvents as water, carbon dioxide (CO_2) or even ethanol have been developed. There are different and controlled combinations of temperature and pressure in PLE method, which can improve extraction efficiency. In fact green extraction techniques are effective assays to extract bioactive compounds from natural sources (Alañón et al., 2017). Plant essential oils are secondary metabolites which are applied as flavoring and preservative agents. Different properties of EOs are due to flavonoids, alkaloids and terpenoids as the most important secondary metabolites in EO (Hashemi et al., 2017). In order to decrease or inhibit oxidative reactions in meat foods, antioxidant components are usually used at an average level. Higher concentration may cause various side effects through pro-oxidative action. (Falowo et al., 2014). Data from scientific reports indicate that most plants contain a wide variety of components with antioxidant activity. Fruits, oilseeds, herbs and spices extracts and essential oils are the most important antioxidant sources used in meat and meat products.

Fruits Extracts

In general, fruits and vegetables are excellent sources of antioxidants. Pomegranates, strawberry, kinnow, acerola, white grapes, plums, black currant, annatto, bearberries, banana, and sapodilla are some samplesthat contain relatively high concentrations of antioxidants. These fruits have been well documented for uses in industry considering their antioxidant activity (Table 1). Annatto (*Bixaorellana* L.*)* seeds powder which has been used as a natural coloring agent in food contains bixin and nor-bixin apocarotenoids as antimicrobial and antioxidant agents. Cuong and Chin (2016) showed that this additive can retard lipid and protein oxidation in pork patties. Acerola (*Malpighia emarginata* L.) fruit extract with a high content of phytochemicals is well known as an excellent food source of vitamin C. It was shown that Acerola can improve color and lipid stability and decrease rancid flavor of raw salted beef patties without affecting microbial load (Realini et al., 2015). Grapes are recognized as a power house of antioxidants. Grape by-products such as grape pomace (wine pomace) are a rich source of phenolic compounds with great medicinal properties, but usually is wasted from juice/wine processing industries. García-Lomillo et al. (2017) indicated that beef patties formulated with skin fraction of red wine pomace had the lowest lipid oxidation. Munekata et al. (2015) indicated that application of peanut (*Arachishypogaea* L.) skin extract (PSE) as a natural antioxidant in cooked chicken patties can prevent lipid oxidation during refrigerated storage. The presence of bioactive compounds such as phenolic acids, stilbenes, flavan-3-ols, biflavonoids, isoflavones, flavanols, and flavones in PSE makes it a natural alternative for synthetic antioxidants which reduces the loss of redness and prolonging the shelf life of sheep patties (Munekata et al., 2016).

Table 1: Fruit-based natural antioxidants in meat and meat products

Type of treatment	Meat product	Impact on product	References
Pomegranate juice, pomegranate rind powder extract	Cooked chicken patties	Protecting against oxidative rancidity was better than BHT	(Naveena *et al*,. 2008)
Strawberry fruit extract	Cooked chicken patties	Strawberry could act as a potential antioxidant source in meat products	(Saha *et al*,. 2011)
Acerola fruit extract	Raw beef patty	Addition of acerola retarded lipid oxidation	(Realini *et al*,. 2015)
Wine pomace	Raw beef patty	Inhibited lipid oxidation	(García-Lomillo *et al*,. 2017)
White grape	Raw beef patty	Inhibited lipid oxidation under modified atmosphere packaging	(Jongberg *et al*,. 2011)
Kinnow and pomegranate fruit extracts	Raw chicken patties	Inhibited lipid oxidation	(Devatkal *et al*,. 2011)
Grape	Raw pork patties	grape extract showed the most antioxidant activity compared to synthetic antioxidants	(Lorenzo *et al*,. 2014)
Black currant	Raw pork patties	Significantly increased lipid and protein oxidation	(Jia *et al*,. 2012)
Annatto	Raw pork patties	Samples containing annatto seed indicated lower TBARs and PV values	(Cuong and Chin 2016)
Banana and sapodilla peels extract	Poultry meat	Decreasing of TBARs values vs. control and BHT treatment was observed	(Devatkal *et al*,. 2014)
Peanut skin extract	Cooked chicken patties	Little color change but it can be used as a potent antioxidant	(Munekata *et al*,. 2015)
Peanut skin extract	Raw sheep patty	Peanut skin extract was introduced as an appropriate antioxidant instead of BHT	(Munekata *et al*,. 2016)
Peanut skin extract	Salami	PSE retarded lipid oxidation and preserved sensory properties of salami	(Larrauri *et al*,. 2013)

Table 2: Use of oil seed as antioxidants in meat and meat products

Type of treatment	Meat product	Impact on product	References
Grape seed extract	Cooked pork patties	Grape seed extract had the potential to inhibit oxidative rancidity as well as current synthetic antioxidants	(Sasse *et al*,. 2009)
Adzuki bean extract (AE)	Pork sausage	Results suggested that Adzuki bean extract was a potential antioxidant	(Jayawardana *et al*,. 2011)
Soybean oil	Mortadella-type sausages	Overall properties and oxidative stability were improved	(Morais *et al*,. 2013)
Sunflower oil	Raw pork meat	Decreasing in PV and increasing in TBARs was observed.	(Cardenia *et al*,. 2011)
Sunflower oil	UK-style sausages	Fatty acid composition was improved without adversely affecting the colour or lipid oxidation.	(Asuming-Bediako *et al*,. 2014)
Grape seed extract	Raw and cooked beef patty	Grape seed extract was more powerful to inhibit TBARs formation and protecting a values than BHA and BHT	(Colindres and Brewer 2011)

Grape seed	Dry cured sausage "chorizo" Meat-based ready-to-eat meals	Improved the quality and increased the shelf life of products. The added agents did not change the sensorial properties and were stronger than sodium ascorbate to retard the lipid oxidation	(Lorenzo *et al*,. 2013) (Price *et al*,. 2013)
Olive oil	Dry fermented sausages	Inhibited lipid oxidation and MUFA+ PUFA/SFA ratios in samples was improved	(Ansorena and Astiasaran 2004)
Rapeseed oil	UK-style sausages	No adversely affecting color and shelf life. Reduction in saturated fatty acids profile	(Asuming-Bediako *et al*,. 2014)

Table 3: Use of herbs and spices extracts as antioxidant 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.	(Kim *et al*,. 2013)
Olive and wine extracts	Cooked beef and pork	Olive extract showed more stronger antioxidant activity than wine extract	(DeJong and Lanari 2009)
Cloudberry, beetroot or willow herb	Pork patties	cloudberry extract was as potent as quercetin	(Rey *et al*,. 2005)
Rosemary extract	Liver pâtés	Decreased the amount of sodium nitrite used in pates	(Doolaege *et al*,. 2012)
	Liver pâtés	Rosemary effectively retarded oxidation	(Haile 2015)
Green tea, chestnut and grape	Liver pâtés	Green tea (*camellia sinensis*) and grape extracts were more effective antioxidants	(Pateiro *et al*,. 2014)
Jabuticaba peel extract	Bologna sausages	Sensory attributes and shelf life were improved	(de Almeida *et al*.,2015)
Strawberry tree and dog rose extract	Frankfurters	Applying of phenolic extracts decreases oxidation reactions without changing their color and texture properties.	(Armenteros *et al*.,2013)
Rosemary extract and whey powder	Wiener sausages	The oxidation was retarded	(Coronado *et al*,. 2002)
Olive and tea extract	Cooked beef and pork	Tea (*Camellia sinensis*) showed better antioxidant activity than olive extract	(DeJong and Lanari 2009)
Ulam raja leaves extract (UREX), green tea extract (GTE)	Beef patties	UREX showed a strong lipid oxidation inhibitory effect vs. GTE	(Reihani *et al*,. 2014)
Caesalpinia decapetala (CD)	Beef patties	TBARS levels were significantly lower and color stability was higher in the samples containing plant extracts or BHT than the control.	(Gallego *et al*,. 2015)
Curry leaves extract	Chicken patties	Lipid oxidation was reduced in the samples	(Devatkal *et al*,. 2012)
Ganghwayakssuk	Chicken patties	oxidative stress was reduced	(Hwang *et al*,. 2013)
Du-zhong	Pork patties	Du-zhong leaf extract decreased TBARs formation the same as BHT	(Xu *et al*,. 2010)
Sappan wood extract, rehmania or angelica extracts	Meat	TBARs values was decreased of	(Han and Rhee 2005)
Rosemary and oregano extracts	Beef burgers	PUFA and MUFA were decreased while slight increase of SFA content were observed	(Trindade *et al*,. 2010)
Rosemary	Chicken nuggets	Rosemary extracts improved the oxidative stability in frozen chicken nuggets.	(Rocio Teruel *et al*,. 2015)
	Pork sausages	The rosemary extract was more effective for inhibiting increased TBARs values or loss of red color in raw frozen sausage and equally effective as BHA/BHT in lowering lipid oxidation of precooked-frozen sausage	(Sebranek *et al*,. 2005)

Bee pollen extract	Pork sausage	Lyophilized bee pollen was effective in retarding lipid oxidation	(de Florio Almeida *et al*,. 2017)
Tea catechins	Beef and chicken patties	Tea catechins showed more anti-oxidation activity compared to vitamin C under cooking and anaerobic conditions.	(Mitsumoto *et al*,. 2005)
Lutein, sesamol, ellagic acid and olive leaf extract	Pork sausages	Increasing of WHC and reduction of TBARs values was observed under MAP condition	(Hayes *et al*,. 2011)
White peony extract, red peony extract, moutan peony extract	Meat	Oxidation in meat decreased	(Han and Rhee 2005)
Fenugreek leaves extract	Chicken patties	Reduction of TBARs values was more than BHT in the treatments	(Devatkal *et al*,. 2012)
Mate leaves	Fermented sausages	Formulation with 0.4 wt% of mate leaves extract showed the lowest TBARs values compared with the control	(Beal *et al*,. 2011)
Tomato, red grape, olive and pomegranate by-products extract	Raw lamb patties	This study show that the grape and olive pomaces extracts could be an effective additive to replace sodium ascorbate in meat products.	(Andrés *et al*,. 2017)

Table 4: Use of plant essential oils in meat and meat products

Type of treatment	Meat product	Impact on product	References
Cinnamomum zeylanicum essential oil	Cooked sausage	TBARs value decreased and sensory scores didn't show significant differences vs. control samples	(Moarefian *et al*,. 2013)
Mentha piperita essential oil (MPEO)	Cooked sausage	At the end of storage sample with 20 ppm of MPEO samples showed lower TBARs and peroxide values compared to samples with 40 and 60 ppm of MPEO and control	(Moarefian *et al*,. 2012)
Oregano essential oil	Bologna sausages	It can use under vacuum condition to improve the shelf-life of products	(Viuda-Martos *et al*,. 2010b)
Satureja montana L. essential oil (SEO)	Mortadella-type sausages	The use of SEO reduced amounts of sodium nitrite	(Coutinho de Oliveira *et al*,. 2012)
Rosemary or thyme essential oils	Mortadella-type sausages	Reduced residual nitrite levels and improved shelf life of product	(Viuda-Martos *et al*,. 2010a)
Cinnamomum zeylanicum essential oil	Lyoner- type sausage	Improved sensorial properties, did not modify protein, ach and fat content, slowed rates of oxidation	(Aminzare *et al*,. 2015)
Clove essential oil	red meat	This natural additive incorporated in corn starch edible films could improve the stability of raw samples	(Babuskin *et al*,. 2015)
Sage essential oil	liver pâtés	The use of these plants would be an appropriate option as an antioxidant effects in meat and fat products	(Estévez *et al*,. 2004)
Oregano essential oil	Dry fermented sausage *Petrovská klobása*	At the end of the storage, the content of aldehyde was lower treated samples vs. the control.	(Krkić *et al*,. 2013)
Cinnamon essential oil	Red meat	The cinnamon essential oil incorporated in edible films could improve the self-life of raw red meat	(Babuskin *et al*,. 2015)
Rosemary essential oil	Porcine Frankfurters	developed desire aroma properties of frankfurters	(Estévez *et al*,. 2005)
Rosemary essential oil	Liver pâtés	Rosemary essential oil was introduced as a good antioxidant source in liver pâtés	(Estévez *et al*,. 2004)

Table 5: Use of dietary fibers in meat and meat products

Type of treatment	Meat product	Impact on product	References
Kinnow rind powder (KRP), pomegranate rind powder (PRP) and seed powder (PSP)	Cooked Goat meat patties	Reduction in TBARs values were lower in PRP, followed by PSP and KRP vs. control	(Devatkal *et al*,. 2010)
Dried Plum	Pork sausage	The addition of 3% dried plum puree limited lipid oxidation, enhanced sweet taste and decreased salt and bitter tastes	(Nunez de Gonzalez *et al*,. 2008)
Litchi flower powder	Pork meatballs	Reduced oxidation and increased sensorial acceptance	(Ding *et al*,. 2015)
Grape seed flour	Frankfurter	protein, oxidative stability, dietary fiber and water holding capacity were improved	(aOzvural and Vural 2011)
Noni puree mixed	Beef patties	This natural ingredient decreased lipid oxidation and improved the shelf life	(Tapp *et al*,. 2012)
Spinach, onion, red pepper, tomato powder	Turkey meat patties	These vegetable powders can be used as a natural antioxidant and cause increasing vegetable intake	(Duthie *et al*,. 2013)
Tomato paste	Mortadella-type sausages	Improved nutritional properties, but did not affect textural and sensory properties	(Domenech-Asensi *et al*,. 2013)
Sage	Chinese-style sausage	Reduced textural deterioration, retarded TBARs and protein carbonyls formation	(Zhang *et al*,. 2013)
Leek and onion	Greek traditional sausages	Sausages with leek, starter culture and ascorbic acid had the best score for odour, taste and overall acceptability.	(Fiesta *et al*,. 2004)
Gentiana lutea root	Beef patties	The addition of *G. lutea* and ascorbic acid showed reduced changes in lipid oxidation	(Azman *et al*,. 2015)
Tomato pulp powder	Pork luncheon roll	Treatments with 50mg nitrite and 1.5% TPP showed similar or better sensory attributes compared to the treatments containing no TPP and a nitrite level of 100mg/kg of product.	(Hayes *et al*,. 2013)
Yellow pea, green pea	Turkey meat patties	Use of chemically complex vegetable powders was offered as an alternative to individual antioxidants for increasing shelf-life	(Duthie *et al*,. 2013)
Leek powder	Fermented sausages	The use of freeze dried leek powder showed a 50% reduction in nitrite addition	(Tsoukalas *et al*,. 2011)
Citrus fiber	Mortadella-type sausages	Enhanced fiber levels	(Viuda-Martos *et al*,. 2010a)
Orange dietary fiber	Bologna sausages	The shelf-life of product under vacuum condition was improve	(Viuda-Martos *et al*,. 2010b)

Oilseeds

Oilseeds are the basis for a wide range of foods, animal feeds and other products. Grape seed, soybeans, Adzuki bean and many vegetable seeds are used as a potential source of seed oils. Grape seed extract) GSE (is a rich antioxidant source. Several studies proved antioxidant and antimicrobial effects of GSE on meat and meat products such as dry-cured sausage "chorizo". It was also shown that combination of Clove EO with different concentrations of GSE can be effective against spoilage microorganisms in raw materials, such as buffalo patty (Tajik et al., 2014). Soybean oil is another vegetable oil extracted from the soybean seeds (Glycine max). Soybean oil contains more than 60% PUFA; however, it has been shown that higher concentrations of soybean oil doesn't affect oxidation rate of mortadella (Morais et al., 2013). Menegas et al. (2013) indicated that the use of standard amounts of corn oil in fermented chicken sausages caused no significant chemical, microbiological, physical, or sensory changes during storage. Table 2 shows some researches about the use of seed oil as antioxidants in meat and meat products.

Herbs and Spices Extracts

Several studies showed that extreme antioxidant activity has been found in herbs, spices, and extracts so they can be used as natural antioxidants in meat and meat products. Soy sauce contains several antioxidants such as melanoidins, phenolic compounds, and free amino acids. The use

of soy sauce in raw beef patties showed decreasing in lipid oxidation of meat products (Kim et al., 2013). Herbal tea prepared from *Camellia sinensis* is a rich source of polyphenolic compounds such as catechin and flavonoid compounds. Itcould be replacedwith synthetic antioxidants in frozen beef patties (Reihani et al., 2014). The antioxidant properties of rosemary extract (RE) are due to the presence of phenolic diterpenes, such as carnosic acid and carnosol. Nitrite concentration decreases dramatically when RE is added to liver pates without a negative effect on color (Doolaege et al., 2012). De Florio Almeida et al. (2017) showed that lyophilized bee pollen (LBP) contains antioxidant compounds such as vitamin Cas well as polyphenols. Hence, The LBP extract presented powerful antioxidant effects in raw and cooked refrigerated pork sausage. The leaves of *caesalpinia decapetala* (CD) contain cassane diterpenoid, caesaldecan, spathulenol, 4,5-epoxy-8(14)-caryophyllene, squalene, lupeol, resveratrol, quercetin, astragalin, and stigmasterol. Beef patties formulated with CD extract showed better color and oxidative stability compared with control patties (Gallego et al., 2015). Table 3 shows some studies about the application ofherbs and spices extracts in meat and meat products.

Essential Oils

Many plantessential oils (EOs) are known as rich antioxidant sources (Coutinho de Oliveira et al., 2012; Ehsani et al., 2017; Shah et al., 2014). Cinnamon (*Cinnamomum Zeylanicum*) contains phenolic and polyphenolic compounds and act as a good inhibitor of primary and secondary oxidation products in Lyoner- type sausage (Aminzare et al., 2015). Thymol, *p*-cymene, linalool, and carvacrol available in *Satureja Montana* L. EO could reduce the use of sodium nitrite of mortadella-type sausages (Coutinho de Oliveira et al., 2012). *Petrovskáklobása* is a traditional dry fermented sausage that has been manufactured for over 250 years. It is produced from pork meat, spices and fat. Coating with chitosan incorporated with oregano (*Origanum vulgare*) EO indicated a reduction in lipid oxidation of dry fermented sausages (Krkić et al., 2013). Application of some important essential oils in meat and meat products are listed in Table 4.

Dietary Fiber

The concept of antioxidant dietary fiber (ADF) has been accepted as a natural product with both of the physiological and antioxidants properties. Dried fruit, extracts and/or powders of some plants or their by-products can be good sources of ADF (Eskicioglu et al., 2015).

Ding et al. (2015) indicated that litchi (*Litchi chinensis* Sonn.) is a fiber rich of polyphenols and is considered as an effective natural antioxidant which reduce lipid and protein oxidation of frozen cooked meatballs. Sage (*Salvia officinalis*) contains phenolic compounds, such as carnosol, carnosic acid, and rosmarinic acid. During storage of refrigerated Chinese-style sausage formulated with ground sage, areductionin TBARs values and textural deterioration and no negative effects on the sensory properties were observed (Zhang et al., 2013). Tomato (*Solanum lycopersicum*) pulp powder is rich in carotenoids (particularly lycopene, β-carotene, phytoene, and lutein), flavonoids, vitamins E and C, and fiber. The use of this natural additivecould decrease nitrite supply in pork luncheon roll (Hayes et al., 2013). Table 5 indicates some researches about the use of by-products as antioxidants in meat and meat products.

CONCLUSION

Oxidation is a major problem that decreases the shelf life of meat and meat products. Synthetic compounds are used to delay oxidation reactions. However, because of the increasing consumer's demand to replace synthetic antioxidants with natural bioactive compounds a wide variety of researches have been done to find new and natural sources of antioxidant compounds. There are different chemical compounds derived from plants that can be used in meat and meat products as natural antioxidants which have been isolated from different plant parts like leaves, stems, roots, fruits, bark and seeds. It should be considered that the use of these natural additives is limited by their extreme flavor, which can have adverse sensory effects on meat and meat products. Future studies should be done toward the investigating of new technologies such as high pressure processing, pulsed electric fields and ultrasound combined with natural antioxidant in order to improve the antioxidant properties in meat and meat products.

ACKNOWLEDGEMENTS

The authors would like to thank Mashhad University of Medical Sciences, Mashhad, Iran for their support.

CONFLICT OF INTEREST

None.

AUTHORS CONTRIBUTION

Majid Aminzare designed and monitored the study.Hassan Hassanzad Azar, Mohammad Reza Mehrasbi and Behrooz Jannat searched the database.Elham Ansarian and Shahrzad Daneshamooz drafted the article. Mohammad Hashemi, Mojtaba Raeisi and Mandana Bimkar revised the article. Asma Afshari checked and submitted the article and revised it according to reviewer's comments.

REFERENCES

- Ahna J, Grun IU, Mustaphab A (2007). Effects of plant extracts on microbial growth, color change, and lipid oxidation in cooked beef. Food Microbiol. 24: 7–14. https://doi.org/10.1016/j.fm.2006.04.006
- Alañón M, Alarcón M, Marchante L, Díaz-Maroto M, Pérez-Coello M (2017). Extraction of natural flavorings with antioxidant capacity from cooperage by-products by green extraction procedure with subcritical fluids. Ind. Crop Prod. 103: 222-232. https://doi.org/10.1016/j.indcrop.2017.03.050
- Aminzare M, Aliakbarlu J, Tajik H (2015). The effect of *Cinnamomum zeylanicum* essential oil on chemical characteristics of Lyoner- type sausage during refrigerated storage. Vet. Res. Forum. 6: 31-39.
- Aminzare M, Hashemi M, Hassanzad Azar H, Hejazi J (2016). The Use of Herbal Extracts and Essential Oils as a Potential Antimicrobial in Meat and Meat Products; A review. J. Human Environ. Health Pro. 1:63-74. https://doi.org/10.29252/jhehp.1.2.63
- Andrés A, Petrón M, Adámez J, López M, Timón M (2017). Food by-products as potential antioxidant and antimicrobial additives in chill stored raw lamb patties. Meat Sci. 129: 62-70. https://doi.org/10.1016/j.meatsci.2017.02.013
- Archile-Contreras AC, Purslow PP (2011). Oxidative stress may affect meat quality by interfering with collagen turnover by muscle fibroblasts. Food Res. Int. 2: 582–588. https://doi.org/10.1016/j.foodres.2010.12.002
- Asuming-Bediako N, Jaspal M, Hallett K, BayntunJ, Baker A, Sheard P (2014). Effects of replacing pork backfat with emulsified vegetable oil on fatty acid composition andquality of UK-style sausages. Meat Sci. 96: 187-194. https://doi.org/10.1016/j.meatsci.2013.06.031
- Azman NA, Gordon MH, Skowyra M, Segovia F, Almajano MP (2015). Use of lyophilised and powdered *Gentiana lutea* root in fresh beef patties stored under different atmospheres. J. Sci. Food Agri. 95: 1804-1811. https://doi.org/10.1002/jsfa.6878
- Chaijan M (2008). Review: Lipid and myoglobin oxidations in muscle foods. Songklanakarin J. Sci. Technol. 30(1): 47–53.
- Contini C, Alvarez R, O'Sullivana M, Dowling DP, Gargan SO, Monahan FJ (2014). Effect of an active packaging with citrus extract on lipid oxidation and sensory quality of cooked turkey meat. Meat Sci. 96: 1171–1176 https://doi.org/10.1016/j.meatsci.2013.11.007
- Coutinho de Oliveira TL, Malfitano de Carvalho S, de Araújo Soares R, Andrade MA, Cardoso MdG, Ramos EM, Piccoli RH (2012). Antioxidant effects of *Satureja montana* L. essential oil on TBARS and color of mortadella-type sausages formulated with different levels of sodium nitrite. LWT - Food Sci. Technol. 45: 204-212.
- Cuong TV, Chin KB (2016). Effects of annatto (*Bixa orellana* L.) seeds powder on physicochemical properties, antioxidant and antimicrobial activities of pork Patties during refrigerated storage. Korean J. Food Sci. Anim. Resour. 36: 476-486. https://doi.org/10.5851/kosfa.2016.36.4.476
- de Almeida PL, de Lima SN, Costa LL, de Oliveira CC, Damasceno KA, dos Santos BA. Campagnol PC (2015). Effect of jabuticaba peel extract on lipid oxidation, microbial stability and sensory properties of Bologna-type sausages during refrigerated storage. Meat Sci. 110: 9-14. https://doi.org/10.1016/j.meatsci.2015.06.012
- de Florio Almeida J, dos Reis AS, Heldt LFS, Pereira D, Bianchin M, de Moura , Plata-Oviedo, MV, Haminiuk CWI, Ribeiro IS, da Luz CF P (2017). Lyophilized bee pollen extract: A natural antioxidant source to prevent lipid oxidation in refrigerated sausages. LWT-Food Sci. Technol. 76: 299-305.
- Ding Y, Wang SY, Yang DJ, Chang MH, Chen YC (2015). Alleviative effects oflitchi (*Litchi chinensis* Sonn.) flower on lipid peroxidation and protein degradation in emulsified pork meatballs. J. Food Drug Anal. 23: 501-508. https://doi.org/10.1016/j.jfda.2015.02.004
- Domenech-Asensi G, Garcia-Alonso FJ, Martinez E, Santaella M, Martin-Pozuelo G, Bravo S. Periago MJ (2013). Effect of the addition of tomato paste on the nutritional and sensory properties of mortadella. Meat Sci. 93: 213-219. https://doi.org/10.1016/j.meatsci.2012.08.021
- Doolaege EH, Vossen E, Raes K, De Meulenaer B, Verhe R, Paelinck H, De Smet S (2012). Effect of rosemary extract dose on lipid oxidation, colour stability and antioxidant concentrations, in reduced nitrite liver pates. Meat Sci. 90: 925-231. https://doi.org/10.1016/j.meatsci.2011.11.034
- Duthie G, Campbell F, Bestwick C, Stephen S, Russell W (2013). Antioxidant effectiveness of vegetable powders on the lipid and protein oxidative stability of cooked turkey meat patties: Implications for health. Nutrients. *5*(4): 1241-1252. https://doi.org/10.3390/nu5041241
- Ehsani A, Alizadeh O, Hashemi M, Afshari A, Aminzare M (2017). Phytochemical, antioxidant and antibacterial properties of Melissa officinalis and *Dracocephalummoldavica* essential oils. Vet. Res. Forum. 8(3): 223-229.
- Ehsani A, Mahmoudi R (2012). Phytochemical properties and hygienic effects of *Allium ascalonicum* and *Pimpinellaanisum* essential oils in Iranian white brined cheese. J Essent Oil Bear Pl. 15(6): 1013-1020. https://doi.org/10.1080/0972060X.2012.10662606
- Eskicioglu V, Kamiloglu S, Nilufer-Erdil D (2015). Antioxidant Dietary Fibres: Potential Functional Food Ingredients from Plant Processing By-Products. Czech J. Food Sci. 33(6): 487–499. https://doi.org/10.17221/42/2015-CJFS
- Falowo AB, Fayemi PO, Muchenje (2014). Natural antioxidants against lipid–protein oxidative deterioration in meat and meat products: A review. Food Res. Int. 64: 171-181. https://doi.org/10.1016/j.foodres.2014.06.022
- Fista GA, Bloukas JG, Siomos AS (2004). Effect of leek and onion on processing and quality characteristics of Greek traditional sausages. Meat Sci. 68(2): 163-172. https://doi.org/10.1016/j.meatsci.2004.02.005
- Gallego MG, Gordon MH, Segovia FJ, Almajano MP (2015). *Caesalpinia decapetala* Extracts as inhibitors of lipid oxidation in beef patties. Molecules. 20: 13913-3926. https://doi.org/10.3390/molecules200813913
- García-Lomillo J, Gonzalez-SanJose ML, Del Pino-García R, Ortega-Heras M, Muñiz-Rodríguez P (2017). Antioxidant effect of seasonings derived from wine pomace on lipid oxidation in refrigerated and frozen beef patties. LWT - Food Sci. Technol. 77: 85-91.
- Hashemi M, Ehsani A, Afshari A, Aminzare M, Raeisi M (2016). Chemical composition and antifungal effect of *echinophora platyloba* essential oil against *Aspergillus flavus*, *Penicillium expansum* and *Fusarium graminearum*. J. Chem. Health Risks. 6: 91-97.
- Hashemi M, Ehsani A, Hassani A, Afshari A, Aminzare M, Sahranavard T, Azimzadeh Z (2017). Phytochemical,

antibacterial, antifungal and antioxidant properties of *Agastache foeniculum*essential oil. J. Chem. Health Risks. 7: 95-104.

- Hayes JE, Canonico I, Allen P (2013). Effects of organic tomato pulp powder and nitrite level on the physicochemical, textural and sensory properties of pork luncheon roll. Meat Sci. 95: 755-762. https://doi.org/10.1016/j.meatsci.2013.04.049
- Jiang J, Xiong YL (2016). Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: A review. Meat Sci. 120: 107-117. https://doi.org/10.1016/j.meatsci.2016.04.005
- Kim HW, Choi YS, Choi JH, Kim HY, Hwang KE, Song DH, Lee SY, Lee MA, Kim CJ. (2013). Antioxidant effects of soy sauceon color stability and lipid oxidation of raw beef patties during cold storage. Meat Sci. 95: 641-646. https://doi.org/10.1016/j.meatsci.2013.06.006
- Krkić N, Šojić B, Lazić V, Petrović L, Mandić A, Sedej I, Tomović V (2013). Lipid oxidative changes in chitosan-oregano coated traditional dry fermented sausage Petrovská klobása. Meat Sci. 93: 767-770. https://doi.org/10.1016/j.meatsci.2012.11.043
- Lorenzo JM, González-Rodríguez RM, Sánchez M, Amado IR, Franco D (2013). Effects of natural (grape seed and chestnut extract) and synthetic antioxidants (buthylatedhydroxytoluene, BHT) on the physical, chemical, microbiological and sensory characteristics of dry cured sausage "chorizo". Food Res. Int. 54: 611-620. https://doi.org/10.1016/j.foodres.2013.07.064
- Maqsood S, Benjakul S, Abushelaibi A, Alam A (2014). Phenolic compounds and plant phenolic extracts as natural antioxidants in prevention of lipid oxidation in seafood: A detailed review. Compr. Rev. Food Sci. Food Safety.13: 1125-1140. https://doi.org/10.1111/1541-4337.12106
- Menegas LZ, Pimentel TC, Garcia S, Prudencio SH (2013). Dry-fermented chicken sausage produced with inulin and corn oil: Physicochemical, microbiological, and textural characteristics and acceptability during storage. Meat Sci. 93: 501-506. https://doi.org/10.1016/j.meatsci.2012.11.003
- Moarefian M, Barzegar M, Sattari M, Naghdi Badi H (2012). Production of functional cooked sausage by *Mentha piperita* essential oil as a natural antioxidant and antimicrobial material. J. Med. Plant. 1: 46-57.
- Morais CS, Morais Junior NN, Vicente-Neto J, Ramos EM, Almeida J, Roseiro C, Santos C, Gama LT, Bressan MC (2013). Mortadella sausage manufactured with *Caiman yacare* (*Caiman crocodilus yacare*) meat, pork backfat, and soybean oil. Meat Sci. 95: 403-411. https://doi.org/10.1016/j.meatsci.2013.04.017
- Moylan S, Michael B, Dean OM, Samuni Y, Williams L, O'Neil A, et al. (2014). Oxidative and nitrosative stress in depression: Why so much stress? Neurosci. Biobehav. Rev. http://dx.doi.org/10.1016/j.neubiorev
- Munekata PE, Calomeni AV, Rodrigues CE, Favaro-Trindade CS,Alencar SM, Trindade MA (2015). Peanut skin extract reduces lipid oxidation in cooked chicken patties. Poult. Sci. 94: 442-446. https://doi.org/10.3382/ps/pev005
- Munekata PES, Paseto Fernandes RdP, de Melo MP, Trindade MA, Lorenzo JM (2016). Influence of peanut skin extract on shelf-life of sheep patties. Asian Pac. J. Trop. Biomed. 6: 586-596. https://doi.org/10.1016/j.apjtb.2016.05.002
- Palmieri B, Sblendorio V (2007). Oxidative stress tests: Overview on reliability and use Part II. Euro. Rev. Med. Pharmacol. Sci. 11: 383–399.
- Pateiro M, Lorenzo J M, Amado IR, Franco D (2014). Effect of addition of green tea, chestnut and grape extract on the shelf-life of pig liver pâté. Food Chem. 147: 386-394 https://doi.org/10.1016/j.foodchem.2013.09.153
- Rather SA, Masoodi F, Akhter R, Rather JA, Shiekh KA (2016). Advances in use of natural antioxidants as food additives for improving the oxidative stability of meat products. Madridge J. Food Technol. 1: 10-17. https://doi.org/10.18689/mjft-1000102
- Realini CE, Guardia MD, Diaz I, Garcia-Regueiro JA, Arnau J (2015). Effects of acerola fruit extract on sensory and shelf-life of salted beef patties from grinds differing in fatty acid composition. Meat Sci. 99: 18-24. https://doi.org/10.1016/j.meatsci.2014.08.008
- Reihani SF, Tan TC, Huda N, Easa AM (2014). Frozenstorage stability of beef patties incorporated with extracts from ulam raja leaves (*Cosmos caudatus*). Food Chem. 155: 17-23. https://doi.org/10.1016/j.foodchem.2014.01.027
- Shah MA, Bosco SJ, Mir SA (2014). Plant extracts as natural antioxidants in meat and meat products. Meat Sci. 98: 21-33. https://doi.org/10.1016/j.meatsci.2014.03.020
- Tajik H, Farhangfar A, Moradi M, Razavi Rohani S.M (2014). Effectiveness of clove essential oil and grape seed extract combination on microbial and lipid oxidation characteristics of raw buffalo patty during storage at abuse refrigeration temperature. J. Food Process Preserv. 38(1): 31-38. https://doi.org/10.1111/j.1745-4549.2012.00736.x
- Teruel MR, Garrido MD, Espinosa MC, Linares MB (2015). Effect of different format-solvent rosemary extracts (Rosmarinus officinalis) on frozen chicken nuggets quality. Food Chem.172: 40-46. https://doi.org/10.1016/j.foodchem.2014.09.018
- Zhang L, Lin YH, Leng XJ, Huang M, Zhou GH (2013). Effect of sage (*Salvia officinalis*) on the oxidative stability of Chinese-style sausage during refrigerated storage. Meat Sci. 95: 145-150. https://doi.org/10.1016/j.meatsci.2013.05.005