Use of Natural Antioxidants in Poultry Meat

Tuba Candan[1], Aytunga Bağdatlı[2*]

[1,2] Manisa Celal Bayar University, Faculty of Engineering, Department of Food Engineering, 45140 Yunusemre, Manisa, Turkey, +90 236 201 2266
aytunga.bagdatli@cbu.edu.tr
*Corresponding author

Received: 29th March 2017
Accepted: 25th May 2017
DOI: 10.18466/cbayarfbe.319752

Abstract

Poultry meat is one of the most important protein sources in the world. For this reason, there is a constantly increasing demand by consumers for poultry meat. Lipid oxidation is one of the major factors that determine quality and shelf-life of poultry meat. Lipid oxidation affect the different sensory modalities appearance, aroma/flavor and texture, which can result in colour deteration and the development of off-flavours in poultry. Synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have been effectively being used for the stabilization of poultry meat against lipid oxidation, but safety concerns associated with and their role in causing chronic diseases like cancer have restricted their use in food products. A good alternative for these synthetic antioxidants are natural antioxidants which are safer, economical and capable of preventing oxidative deterioration of food products and alleviating metabolic diseases at the same time. Therefore, there is growing interest in the use of natural antioxidants (rosemary, oregano, green tea, grape seed etc.) by scientists to prevent lipid oxidation in poultry meat. In many research, the use of natural antioxidants in poultry meat has been examined in terms of oxidation mechanism. In this review, it is aimed to transfer the data obtained from current studies in which effects of various natural antioxidants on lipid oxidation in poultry meat are examined.

Keywords—Antioxidant activity, Lipid oxidation, Natural antioxidants, Poultry meat, Synthetic antioxidants

1 Introduction

Poultry meat is a very popular food commodity around the world and its production and consumption of poultry meat have been increasing rapidly in the last few decades. Worldwide poultry meat production was estimated to be around 100 million tons. Poultry meat is preferred by consumers due to low production cost, low fat content and high nutritional value. A range of poultry-based products are currently available on the market, including fresh, frozen and marinated meat as well as a variety of comminuted meat products such as hotdogs, frankfurters, sausages, bologna, nuggets and burgers. Considering the fact that poultry meat belongs to perishable foods, the main concern of industries is the shelf-life extension of the poultry meat. Modern trends to achieve this target include the application of the hurdle technology concept and the use of natural food preservatives so as to sustain minimal processing and also to provide protection from both spoilage and pathogenic microorganisms [1, 2].

Oxidative stability is a central parameter in the estimation of meat quality because of the susceptibility of this food product to oxidative degeneration, which is one of the main causes of spoilage. In meat products oxidative reactions are affected by several factors, among which lipid composition and processing, and could be delayed by endogenous or exogenous antioxidants. Biological antioxidants are molecules which, when present at low concentrations compared to those of an oxidisable substrate, significantly delays or prevent oxidation of that substrate [3].

Lipid oxidation is a major cause of meat quality deterioration, resulting in rancidity and the formation of undesirable odors and flavours, which lowers the functional, sensory and nutritive values of meat products; and therefore, consumer acceptability. Three main factors define the susceptibility of lipids to peroxidation in tissue, that is, the proportion of PUFA in lipid bilayers, the amount of reactive oxygen species produced and the level of endogenous or nutritional antioxidants [4].

Synthetic antioxidants such as butylated hydroxylanisole (BHA), butylated hydroxyltoluene (BHT) and tertiarybutylhydroquinone (THBQ), are generally used to reduce microbial growth and thereby extend the shelf-life of meat and poultry products. But synthetic antioxidants have fallen under scrutiny due to potential toxicological effects [5].

Various synthetic preservatives have been developed, but many of them have specific functions in meat system and they are used either to prevent lipid oxidation or stop microbial growth. But recent reports on health claims of these synthetic chemicals have necessitated research on effective alternatives, particularly from natural sources. The use of natural preservatives to increase the shelf-life of meat products is a promising technology since many herbs, plants, fruits and vegetables extracts or powders have both antioxidant and antimicrobial properties [6].

In the course of consumers' increasing demand on natural foods, through the use of natural antioxidants in poultry meat, various studies are being carried out to reduce lipid oxidation and increase the shelf life of the products. The purpose of this review is to indicate the possibilities of using various natural antioxidants in poultry meat and to transfer the data obtained as a result of the studies.

2 Lipid Oxidation in Poultry Meat

Poultry meat products typically degenerate due to one of the two major causes; chemical deterioration or microbial growth. The most common form of chemical deterioration is oxidative rancidity. Oxidative rancidity in poultry meat can vary greatly, ranging from extensive flavor changes, color losses and structural damage to proteins to a more subtle ‘‘loss of freshness’’ that discourages repeat purchases by consumers. The latter is probably the most important to food processors since it is not apparent, yet results in consumer dissatisfaction [7].

Lipid oxidation is one of the most important problems encountered in animal products rich in polyunsaturated fatty acids (meat enriched with omega-3 fatty acids). Lipid oxidation is one of the most major factors affecting the quality and shelf life of the poultry meat. Lipid oxidation causes undesirable changes in taste, odor, texture, flavor, and appearance of foods, and also destroys fat-soluble vitamins. Furthermore, the oxidative degradation of lipids can damage biological membranes, enzymes and proteins, which may pose a direct threat to human health [8, 9].

Oxidation of labile double bonds in polyunsaturated fatty acids (PUFA) produces secondary oxidative compounds such as hexanal, pentanal, heptanal and octanal that is responsible for quality deterioration, warmed over flavors (WOF) and health risks. The relatively large proportion of polyunsaturated fatty acids in the composition of poultry meat makes it highly susceptible to lipid oxidation. Lipid oxidation is initiated in the unsaturated fatty acids fraction by the abstraction of a hydrogen atom and propagated as a radical mediated chain reaction. Auto-oxidation proceeds through three steps (initiation, propagation, and termination): during the initiation step, external energy, such as light, acts on unsaturated lipid molecules or fatty acids, in the presence of catalysts such as transition metal, to generate a free radical by losing a hydrogen atom. During the propagation step, the alkyl of the unsaturated lipid reacts very fast with molecular oxygen to form peroxide radicals. At this stage, they form hydro peroxides, which are susceptible to further oxidation and it decomposes to form secondary reaction products such as aldehydes, ketones, acids and alcohols. In many cases, these compounds are responsible for the changes in flavor, aroma, taste, and nutritional value which affects the overall quality. Primary oxidation products and secondary oxidation products, together with free radicals, constitute the basis for measuring the oxidative deterioration of food lipids. In the termination step, the produced radicals from the propagation step can be terminated by self-interactions to form non-radical species, such as oxidized polar/non-polar dimers or trimers of lipids. Oxidized compounds (aldehydes, ketones, acids, alcohols, etc.) formed as a result of the oxidation mechanism are toxic to humans. In humans, cancer can cause serious health problems such as cardiovascular diseases [8]. Fig. 1 showed the stages of the oxidation mechanism respectively [8, 10, 11, 12, 13, 14].

Initiation: $RH + O_2 \longrightarrow R. + .OH$

Propagation: $R. + O_2 \longrightarrow ROO.$

$ROO. + RH \longrightarrow ROOH + R.$

Termination: $R. + R. \longrightarrow RR$

$R. + ROO. \longrightarrow ROOR$

$ROO. + ROO. \longrightarrow ROOR + O_2$

Fig. 1 The stages of the oxidation mechanism [14]

Lipid oxidation is one of the major problems during the process of frying and storage, resulting in the generation of free radicals as well as spoil of food quality and possibly leading to diseases ultimately. In the food industry, antimicrobials, antioxidants and antibrowning agents are among the additives mostly used by the food industry to preserve products for longer periods. In order to retard, reduce or prevent oxidative deterioration in poultry meat, synthetic antioxidants can be added, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG) and tertiarybutyl hydroxyquinone (TBHQ) [15, 16].

Synthetic antioxidants have been successfully used to prevent lipid oxidation in chicken meat. However, increasing concerns over the safety of synthetic food additives have resulted in a trend towards "natural products". Many studies have confirmed that the excessive consumption of synthetic food additives is related with gastrointestinal, respiratory, dermatological, and neurological adverse reactions. While synthetic antioxidants at high dosage application levels can be carcinogenic, there is much less documented evidence indicating adverse effects of natural antioxidants. As a result, the industry faces a challenge to find effective antioxidants from natural sources to prevent deterioration in poultry meat during processing and storage. Among natural antioxidant sources, rosemary (Rosmarinus officinalis L.), has recently been authorized by the European Union under Directive 95/2/EC and assigned E-392 as its E number (European Union Directives 2010/67/EU and 2010/69/EU) for use in meat product preservation [17, 18, 19].

Natural antioxidants of plant origin have been introduced to improve the lipid stability and enhance the sensory properties of poultry meat. The antioxidant properties of natural antioxidants of plant origin are mainly attributed to their phenolic contents, thus, their antioxidant action is similar to synthetic phenolic antioxidants [20].

3 Natural Antioxidants

Synthetic preservatives (antioxidants, chelating agents, antimicrobial compounds etc.) have been used as food additives to extend shelf life of foods, but they are strictly regulated due to toxicological concerns and some health problems. So, it is increasingly attractive to find out effective and non-toxic measures to delay spoilage and to extend the shelf life of poultry meat. Several studies are interested in finding new sources of natural antioxidants could be more efficient than synthetic ones. For instance, it is known that plant extracts are a mixture of different phenolic compounds known for their antioxidant activity. Several plants were therefore tested for this activity and even how do their extract act in poultry meat. Thus, vegetable extracts have been studied in relation to their antioxidant activity [21, 22, 23]

Consumers' demands for safer and more natural products are increasing, mainly in food, cosmetic and medicine industries. One of the most important opportunity to deal with this kind of demands is the use of phytochemicals, which have been demonstrated to be useful as condiments, food, source of colors and flavors, and they have been associated with medicinal properties. It should consider the fact that phytochemical composition of plants could present variations depending of environmental factors, which could interfere with benefits, especially with medicinal properties. Herbs collected from different cultivation regions show variations in the quantity of chemical constituents, and thus exhibit varied therapeutic effects [24, 25].

The use of natural preservatives to increase the shelf life of meat products is a promising technology since many vegetal substances have antioxidant and antimicrobial properties. Functional ingredients in meat products may improve the nutritional and health qualities and prolonging their self-life. Recent investigation has focused towards identification of novel antioxidants from natural sources. Due to their high antioxidant power, the polyphenols are considered among the most interesting and relevant natural compounds to be used as food preservatives and bioactive ingredients. Thus, there have been to date a large number of studies pertaining to the exploitation of polyphenol-bearing medicinal plants [26, 27, 28].

Bioactive molecules represent the pivotal focus of attention, and their plenty in natural matrices clearly determines their preference. In fact, the bioactive potential of plant preparations is directly dependent on the characteristics of the pool of phytochemicals; some of them are biologically active, whereas others need to be metabolized, extracted, or both to exert beneficial effects [29].

The number of publications characterising various plant species has been regularly increasing. Several studies have demonstrated that spices and herbs such as rosemary, sage, oregano with their high content of phenolic compounds serve as strong antioxidants. However, there are still many under investigated species, which may be a promising source of valuable bioactive ingredients. Table 1 summarizes the antioxidant compounds isolated from herbs and spices and their mode of action in inhibiting or slowing down oxidation of fats and oils in foods [30, 31].

Plants are persistently the generous source to supply man with valuable bioactive substances and thus different plant products are being evaluated as natural antioxidants to preserve and improve the overall quality of poultry meat. These natural antioxidants from plants, in the form of extracts, have been obtained from different sources such as fruits (grapes, pomegranate, date, kinnow, citrus peel), vegetables, (broccoli, potato, drumstick, pumpkin, curry, nettle, carob pod), herbs and spices (tea, rosemary, oregano, cinnamon, sage, thyme, mint, ginger, clove) and investigated to decrease the lipid oxidation [32, 33].

An antioxidant significantly delays or inhibits substrate oxidation at low concentrations compared to those of the oxidizable substrate, and may be classified into preventing, scavenging, and repair and de novo antioxidants. Phenolic compounds and aromatic amines act as free radical-scavenging antioxidants, whose principal mechanism of action is remove active species rapidly before they attack biologically essential molecules. These compounds can act in the food matrix, helping to increase its shelf life, avoiding spoilage caused by oxidation of food components. Fig. 2 shows the antioxidant reaction with lipid oxidation at propagation stage to terminate the oxidation cycle [34, 4].

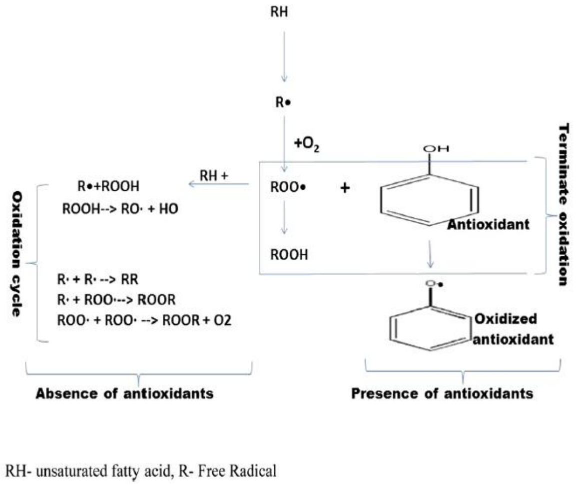

Fig. 2 Antioxidant reaction with lipid oxidation at propagation stage to terminate oxidation cycle [4].

It is well known that antioxidants have protective effects against oxidative stress. Unfortunately, in the presence of transition metals, antioxidants, including polyphenols with potent antioxidant activities, may also exhibit pro-oxidant effects, which may irreversibly damage DNA. Therefore, antioxidants with strong free radical-scavenging abilities and devoid of pro-oxidant effects would be of immense biological importance. If the anti-oxidant network found in the structure is balanced, the pro-oxidant action is inhibited by antioxidants. Thus, the analysis of natural antioxidants for the identification of possible pro-oxidant substances have become topics of increasing interest [35, 36].

3.1 Rosemary (*Rosmarinus Officinalis L.)*

Rosemary (*Rosmarinus Officinalis L.* (*Labiatae*)) is a Mediterranean herb for both culinary and medicinal purposes. Multiple biological activities of rosemary have been reported. The rosemary extract are used in various industry sectors and are commercialised, since they show a range of properties, for example, they may be antibacterial, antioxidant, antifungal, anti-inflammatory. Antioxidant activity of rosemary verifies its use in abroad range of applications, including food preservation, cosmetics, nutraceuticals and phytomedicines [37, 38, 39].

Various studies have showed that compounds responsible for antioxidant and antimicrobial activity of rosemary are phenolic diterpenes such as carnosol and carnosic acid, royleanonic acid and 7-methoxyrosmanol, rosmadial, rosmanol, epirosmanol and isorosmanol, methyl carnosate, rosmanol-9-ethyl ether. These phenolic compounds can delay or inhibit the oxidation of lipids or other molecules by the following mechanisms: quenching free radicals, acting as reducing agents, and chelating ferrous ions. Due to the strong antioxidant effectiveness, rosemary extracts are commonly used by the food industry to extend the shelf life of various products [40, 41].

3.2 Green Tea (*Camellia sinensis*)

Green tea (Camellia sinensis) is well known for various health benefits associated with risk reduction of a wide range of chronic diseases, such as cancer, diabetes, and cardiovascular diseases. Green tea contains epigallocatechin-3-gallate (EGCG), epigallocatechin (EGC), epicatechin-3-gallate (ECG), epicatechin (EC), and flavonoids including quercetin, kaempferol, and myricitin. These green tea antioxidants, well-studied for biological activities, such as inhibition of oxidative enzymes, inhibition of cancer-related transcriptional factors, reactive oxygen scavenging, and redox active metal chelation. Green tea extract, have been recognized to have diverse health benefits including antioxidant, antimicrobial, anti-inflammatory, and anticarcinogenic properties. For this reason, scientists have widely reported the benefits of consuming green tea extract, in particular, due its high content of antioxidants called catechins [42, 43, 44, 45].

3.3 Grape Seed (*Vitis vinifera*)

Up to now, many bioactive food components like those found in grape have been shown to prevent from a wide array of chronic disorders linked to metabolic syndrome. It is documented that the predominant bioactive phenolic compounds found in grape seed extract are flavonols, flavan-3-ols, anthocyanins, tannins (including ellagitannins and proanthocyanidins), and phenolic acid derivatives [46, 47].

Phenolic compounds in grapes are mainly found in seeds and skins. Proanthocyanidins are present in both tissues, but differences in their composition have been reported as a function of the tissue they are found in. In grape skins both procyanidins and prodelphinidins are present but in seeds only procyanidins have been described. Grape phenolic composition is well known to evolve during ripening, and it is important to take this into account in order to choose the optimum vintage moment. The term "phenolic maturity" was been proposed by to describe the concentration of phenolic compounds in grapes, both skins and seeds, and the ease with which they are released [48].

Proanthocyanidins (PAs) are a class of polyphenols that naturally occur as oligomers or polymers of polyhydroxy flavan-3-ol units, such as (+)-catechin and (−)-epicatechin. They are typically present in red wine, fruits, vegetables, nuts, seeds, and barks. As natural antioxidants, PAs have been reported to exhibit various in vitro and in vivo biological effects. Grape seeds are a particularly rich source of PA, consisting almost solely of the procyanidin type partly esterified by gallic acid. In vitro, GSE, has been shown to be an effective antioxidant in a variety of systems, including raw and cooked meat of different species and in a simulated stomach model system, inhibiting lipid oxidation of meat during a gastric digestion [49, 50].

3.4 Other Antioxidants

Clove oil is a natural preservative and flavoring substance that is not harmful when consumed in food products. There have been a number of reports of clove oil inhibiting growth of bacteria and molds. *Castanea crenata* (Japanese chestnut) belongs to the *Castanea* family and is a woody plant native to Japan and South Korea. Chestnut shells contain an abundance of phenols and hydrolysable tannins. Chestnut (*Castanea sativa*) extracts have been reported to have antimicrobial activity against several species, including *Staphylococcus aureus*, *Bacillus cereus*, and *Salmonella Typhimurium*. Cinnamon is considered a common spice with strong antimicrobial and antioxidant activity. It belongs to the family *Lauraceae* and possesses significant biological activities (antitumor, antifungal, cytotoxic and antimutagenic) attributed to the cinnamaldehyde. The ability of this extract to retard lipid oxidation is attributed to the ability of its phenolic constituents to quench reactive oxygen species [51, 52, 53].

Colored berries, such as blueberry, bilberry, blackcurrant, blackberry, etc., have become particularly popular in recent decades. *Vaccinium uliginosum L.*, also known as bog bilberry or bog blueberry, is a wild, low-growing deciduous shrub classified in the family *Ericaceae*, genus *Vaccinium*, which is known to be rich in anthocyanins and flavonols. A wide variety of health benefits have been associated or claimed for *V. uliginosum* berries, including antioxidative activity, anticancer and anti-vascular disease effects. Tomato is widely cultivated all around the world. The presence high amounts of lycopene in tomato, which is a natural colorant (red) and antioxidant is a functional ingredient that can be used in food products [54, 55].

Pomegranate fruit parts contain a high concentration of antioxidants. The peel and rind are good sources of tannins, anthocyanins, and flavonoids. This antioxidant activity is correlated to the high level of phenolic compounds, including anthocyanins (3-glucosides and 3, 5-diglucosides of delphinidin, cyanidin, and pelargonidin), ellagic acid, punicalin, punicalagin, pedunculagin and various flavanols. Pomegranate anthocyanins are sensitive compounds to oxidation that will be degraded by enormous destructive reactions during storage and processing [56, 57].

Table 1 Antioxidants isolated from herbs and spice [31]

Spice/herb	Antioxidant compounds	Mode of action
Rosemary	Carnosol, carnosic acid, rosmanol, rosmadial, diterpenes (epirosmanol, isorosmanol, rosmaridiphenol, rosmariquinone, rosmarinic acid)	Scavenge superoxide radicals, lipid antioxidant and metal chelator
Sage	Carnosol, carnosic acid, rosmanol, rosmadial, methyl and ethyl esters of carnosol, rosmarinic acid	Free radical scavenger
Oregano	Rosmarinic acid, caffeic acid, protocatechuic acid, 2-caffeoyloxy-3-[2-(4- hydroxybenzyl)-4,5-dihydroxy] phenylpropionic acid; flavonoids – apigen, eriodictyol, dihydroquercetin, dihydrokaempherol; cavacrol, tymol	Free radical scavenger
Thyme	Thymol, cavacrol, ϙ-Cumene-2,3-diol, phenolic acids (gallic acid, caffeic acid, rosmarinic acid), phenolic diterpenes, flavonoids	Free radical scavenger
Ginger	Gingerol, shogaol, zingerone	Free radical scavenger
Turmeric	Curcumins, 4-hydroxycinnamoyl methane	Free radical scavenger
Black pepper	Kaempferol, rhamnetin, quercetin	Free radical scavenger
Chili pepper	Capsaicin, capsaicinol	Free radical scavenger
Clove	Phenolic acids (gallic acid), flavonol glucosides, phenolic volatile oils (eugenol, acetyl eugenol, isoeugenol), tannins	Free radical scavenger, metal chelator
Marjoram	Beta-carotene, beta-sitosterol, caffeic-acid, carvacrol, eugenol, hydroquinone, linalool-acetate plant 3–17,myrcene, rosmarinic-acid, terpinen-4-ol	Free radical scavenger
Cumin	Cuminal, γ-terpinene, pinocarveol, linalool, 1-methyl-2-(1-methylethyl)benzene, carotol	Free radical scavenger, metal chelator

4 Natural Antioxidant Studies in Poultry Meat

Food industry continually seeks to adapt and develop new formulations designed to increase shelf life and to improve quality and food safety. Because of strong antioxidant activity of many plant extract, its use in poultry meat is an important method for prevent to the oxidation mechanism. These alternative methods include use of compounds such as spice extracts, fruit juice, tea extracts, seed extracts and etc. Potential sources that will be used in food

must be selected based on scientific judgements using the following criteria: 1. Natural, possibly of plant or botanic origin and with recognized anti-oxidative properties and antimicrobial activities; 2. Commercially available, accessible through the market of ingredients and additives for the food industry; and 3. Compatible with meat products, which must not adversely influence the technological and sensory properties [58, 59, 60]

There are numerous studies in the literature on the antioxidant effects of different plant extracts on poultry meat. Sampaio et al. [61] evaluated the effect of oregano + sage; oregano + sage + 5%honey and oregano + sage + 10%honey on the lipid oxidation and shelf life of chicken meat held under 48 and 96h of refrigeration at 4 ^{o}C. Lipid oxidation were evaluated a 96h period found that TBARS values were lower in samples treated with oregano+sage+5%honey. In this study, the results confirmed the antioxidative effect of oregano, sage and honey when added prior to processing; these ingredients increased the shelf life of cooked chicken meat after 96h of refrigeration at 4 ^{o}C. Mariutti et al. [62] evaluate that the effects of the addition of sage and garlic in chicken meat on lipid oxidation, having as prooxidant factors the addition of frozen storage, were evaluated. As a result, they reported that although garlic on the other hand did not inhibit oxidation, the addition of sage to chicken meat (0.1g/100g) is a good alternative to prevent and delay the formation of compounds derived from lipid oxidation that are responsible for off flavors and loss of nutritional quality during long-term frozen storage.

Haskaraca et al. [63] assessed that the effects of green tea extract added into the cover material and microwave-precooking for the mitigation and the formation of antioxidan capacity in chicken drumsticks (CD) and chicken wings (CW) samples produced using a laboratory model. Four groups were formed in the study: T1) CDs-0%GTE, T2) CDs-0.50%GTE, T3) CDs- 1.50%GTE, and T4) CDs-3%GTE; T1) CWs-0%GTE, T2) CWs-0.50%GTE, T3) CWs-1.50%GTE, and T4) CWs-3%GTE. CD and CW samples containing 3% green tea extract were indicated as the result of the study showing the highest antioxidant capacity.

Mielnik et al. [64] investigate that effects of commercial rosemary antioxidants on oxidative stability of mechanically deboned turkey meat (MDTM) compared with Trolox C (vitamin E), ascorbic acid (vitamin C) and control without antioxidant. Rosemary extract was added to mechanically deboned turkey meat at 0.2-0.5-0.8 (g / kg). As a result in the study is reported that low concentrations of antioxidants retarded the oxidation process during the initial 2 months while longer storage required higher level of antioxidants to prevent the development of reaction products from the oxidation process. Can et al. [65] investigated that the effects of rosemary extract addition on sensory, chemical and microbiological properties of chicken meatball. Chicken meatballs were divided as three groups: (group K, B5 and B1) according to added extract amount. Rosemary extract was added to group K, B5 and B1 as 0%, 0.5 and 1%, respectively. In the study, TBA value was found to be lower in chicken meatball samples added with rosemary extract than in other samples. It is thought that the phenolic components of the rosemary essential oil have the antioxidative properties of rosmarinic acid, carnosic acid and carnosine.

Martínez et al. [49] assessed that the effect grape seed extract 0%-5% (GSE) on the antioxidant capacity and lipid oxidation of turkey meat. The Antioxidant capacity (AC: ORACFL) and lipid oxidation (TBARS and lipid peroxides) were measured on control (C) and emulsion added 0.50% GSE before and after "in vitro" gastric digestion. Results showed that gastric digestion increased the AC of meat by 8-11-fold. Based on the data obtained, the incorporation of GSE at 0.50% to meat emulsions has shown to be adequate to prevent lipid oxidation and improve the AC of the emulsions.

Lee and Ahn [66] determined that the effects of adding 1%, 2% and 3% plum extract on the quality characteristics of vacuum-packaged, irradiated ready-to-eat turkey breast rolls. They that reported that plum used at 3% in irradiated (3 kGy) turkey breast rolls reduced lipid oxidation.

Hassan and Fan [67] evaluated that cocoa leaves extracts (CL) (at different concentrations) were tested for their anti-oxidation potential in a model meat system, based on mechanically deboned chicken meat (MDCM). The anti-oxidation characteristics were compared against a 1:1 butylated hydroxyl anisole (BHA)/butylated hydroxyl toluene (BHT) mixture (200 mg/ kg) and green tea extract (GT) (200 mg/kg). The MDCMs containing the various antioxidants were cooked, stored at 4 °C and samples were analysed for their peroxide value, thiobarbituric acid reactive substance and hexanal generation. Although, the best antioxidation characteristics was shown by the BHA/BHT mix, the performance was closely matched by the natural polyphenols from GT and 800 mg/kg CL. At lower concentrations of 200 and 400 mg/kg, the antioxidation potential of CL extracts were about 50–80% of the BHA/BHT.

Brettonnet et al. [68] assessed extracts obtained from canola meal on the TBARS value of pre-cooked beef (66–92%), pork (43–75%) and chicken (36–70%). They reported that the crude polyphenol extract of canola meal inhibited lipid oxidation in cooked ground beef, chicken or pork stored for 6 days at 4 °C. Devatkal et al. [69] evaluated antioxidant properties of banana (*Musa paradisiaca*) and Sapodilla/Chikoo (Manilkara zapota) peel extracts in chicken patties. Four treatments I. Control (meat+2% salt), II. BHT (meat+2% salt+ 0.1% BHT), III. BPE (meat+2% salt+2% banana peel extract) and IV. SPE (meat+2% salt+2% sapodilla/chikoo peel extract) were compared for changes in colour and lipid oxidation during 8 days refrigerated storage (4±°C). Both synthetic antioxidants and natural extracts have been reported significantly decrease the TBARS. Therefore, it was concluded that water extracts obtained from banana and sapodilla peels could be explored as natural antioxidants in poultry meat and meat products. Chan et al. [70] measured stabilizing efficiency of Cinnamon deodorised aqueous extract (CinDAE), for chicken meatballs, against oxidative deterioration as function of storage time under chilled conditions. Oxidative stability, colour and sensory acceptability were measured in the control meatballs (C), and those stabilized with 200 ppm of: CinDAE (T1), ascorbic acid (T2), BHA/BHT (50/50; w/w) (T3). In comparison to "C", induction period (IP) and redness (a* value) of the stabilized samples (T1, T2 and T3) were increased, while TBARS were decreased throughout storage (8±1 °C) significantly.

Vaithiyanathan et al. [71] an experiment conducted to evaluate the effect of dipping in pomegranate fruit juice phenolics (PFJP) solution on the shelf life of chicken meat held under refrigerated storage at 4 °C. Breast muscle obtained from spent hens was dipped (1:2 w/v; muscle: liquid) in sterile water or in sterile water with 0.02% (v/v) PFJP. Thiobarbituric acid reactive substance values were reported lower in samples treated with PFJP. It is concluded that spent hen breast meat samples dipped in 0.02% PFJP reduced protein oxidation and inhibited microbial growth and sensorily acceptable up to 12 days of refrigerated storage at 4 °C. Bazargani-Gilani et al. [57] investigated that the effect of pomegranate juice (PJ) and chitosan (CH) coating enriched with Zataria multiflora essential oil (ZEO) on the shelf-life of chicken breast meat during refrigerated storage. Treatments examined were the following: Control, PJ, PJ–CH, PJ–CH–Z 1%, and PJ–CH–Z 2%. Peroxide value, thiobarbituric acid reactive substance values and protein oxidation significantly were reported lower in all of treatments than control. PJ gave a pleasant effect on sensory attributes and chitosan coating enriched with ZEO significantly improved sensory scores. As a result, it has been suggested that PJ may be recommended to replace synthetic preservatives as well as synthetic flavors in chicken breast meat.

Naveena et al. [56] evaluated the antioxidant potential of pomegranate juice (PJ), rind powder extract (RP) and butylated hydroxyl toluene (BHT) in cooked chicken patties during refrigerated storage. Freshly minced chicken meats were assigned to one of the following four treatments: control (meat treated with no antioxidants); 10 mg equivalent PJ phenolics per 100 g meat; 10 mg equivalent RP phenolics per 100 g meat; 10 mg BHT per 100 g meat. The RP treatment has been reported to inhibit lipid oxidation in cooked chicken patties to a much greater extent than BHT treatment. The PJ or RP at a level of 10 mg equivalent phenolics/100 g meat would be sufficient to protect chicken patties against oxidative rancidity for periods longer than the most commonly used synthetic antioxidant like BHT. Gonzalez et al. [72] observed TBARS values of hams containing plum juice at different concentrations. Five groups was formed in the study: (1) no plum ingredient (control), (2) 2.50% or 5% fresh plum juice concentrate (FP), (3) 2.50% or 5% dried plum juice concentrate (DP), (4) 2.50% or 5% spray dried plum powder (PP) rehydrated in the curing brine. In the study is founded that spray-dried plum powder at 2.50 or 5% and no plum ingredients (control), had similar TBARS values.

Tang et al. [32] appraised the effect tea catechins that included 10%-12%-24%-%40 on susceptibility of cooked chicken, duck and ostrich to lipid oxidation was investigated. TBARS values were reported that its were lower in samples treated with %24 tea catechins. Alves et al. [73] appraised the effects of industrial of 0.1%-0.3% concentrations tomato products on the lipid oxidation of high-pressure processed minced chicken breast meat. The effect of the different tomato products on the further progression of lipid oxidation in high pressure treated chicken meat during chill storage at 5 ◦C for up to 15 days was investigated using TBARS as a measure of the extent of lipid oxidation. It has been reported that 0.30% or 0.10% final tomato paste addition to minced chicken breast meat results in a delay of 6 days for the formation of secondary oxidation products in meat pressured with 600 MPa. Jayawardana et al. [74] evaluated that drumstick (*Moringa oleifera*) leaves for antioxidative capacity and antimicrobial activity when incorporated in chicken sausages. Different concentrations (0.25%, 0.50%, 0.75% and 1%) of M. oleifera leaves (MOL) incorporated sausages and two controls without MOL (one with added artificial antioxidant and other without any antioxidant) were prepared. Sausages with 0.50%, 0.75% and 1% MOL showed significantly lower TBARS value compared to 0.25% MOL and the two control samples. The sensory panel did not detect any difference in any sensory attribute in chicken sausages with 0.25% and 0.50% MOL compared to the controls. The study identifies the significant antioxidant and antimicrobial potential of Drumstick leaves in chicken sausages.

Lee et al. [75] examined the potential of the different polyphenolic classes found in cranberries to inhibit lipid oxidation in mechanically separated turkey and cooked ground pork. In the study is reported that mechanically separated turkey treated with cranberry juice powder at 0.32% showed inhibition of lipid oxidation. Hasapidou and Savvaidis [76] reported the effects of modified atmosphere packaging, EDTA and oregano oil on the quality, shelf life and TBARs value of chicken liver meat during stored under refrigeration (4 °C). The following treatments were used in the study: A (control samples, air packaging), AE [(EDTA (20 mM), air packaging)], M (MAP), ME (EDTA, stored under MAP), MER1 [(EDTA, oregano oil (0.1% v/wt), stored under MAP)] and MER2 [(EDTA, oregano oil (0.3% v/wt), stored under MAP)]. The presence of the oregano oil in MER1 and MER2 has been reported to result in a lower production of TBA compared to all other samples. Based on sensory analysis, MER1 and MER2 extended the shelf-life of chicken liver by 14–15 days, while treatments for 7 and 9 days, respectively.

5 Conclusions

Interest in employing antioxidants from natural sources to increase the shelf life of foods is considerably enhanced by consumer preference for natural ingredients and concerns about the toxic effects of synthetic antioxidants. Lipid oxidation begins since the moment of slaughter and continues progressively during processing or storage of poultry meat, which noticeably affects the nutritional and sensorial properties of poultry meat. Besides, products of lipid oxidation may potentially contribute to various disease syndromes. Hence, it is crucial to prevent or delay the process of lipid peroxidation in meat products. Natural sources of antioxidants are considered to be safer than synthetic antioxidants. A good alternative for these synthetic antioxidants are natural antioxidants which are safer, economical and capable of preventing oxidative deterioration of food products and alleviating metabolic diseases at the same time. Hence, there is a need to identify safer and more efficient natural antioxidants for use in the food industry. In conclusion, many studies have investigated the ability of vegetable extracts to prevent lipid oxidation. The production of antioxidant extracts from vegetal material is a research field of increasing importance. The use of vegetable extracts to increase shelf life is a promising new frontier in the prevention of oxidation.

6 References

[1] Khiari, Z.; Pietrasik, Z.; Gaudette, N.J.; Betti, M. Poultry protein isolate prepared using an acid solubilization/precipitation extraction influences the microstructure, the functionality and the consumer acceptability of a processed meat product. Food Structure. 2014; 2, 49-60.

[2] Chouliara, E.; Karatapanis, A.; Savvaidis, I.N.; Kontominas, M.G. Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat stored at 4 ^{0}C. Food Microbiology. 2007; 24, 607–617.

[3] Sacchetti, G.; Martino, G.; Mattia, C.D.; Pittia, P. Application of a radical scavenging activity test to measure the total antioxidant activity of poultry meat. Meat Science. 2008; 80, 1081–1085.

[4] Falowo, A.B.; Fayemi, P.O.; Muchenje, V. Natural antioxidants against lipid–protein oxidative deterioration in meat and meat products: A review. Food Research International. 2014; 64, 171–181.

[5] Zhang, H.; Wu, J.; Guo, X. Effects of antimicrobial and antioxidant activities of spice extracts on rawchicken meat quality. Food Science and Human Wellness. 2016; 5, 39–48.

[6] Khare, A.K.; Biswas, A.K.; Sahoo, J. Comparison study of chitosan, EDTA, eugenol and peppermint oil for antioxidant and antimicrobial potentials in chicken noodles and their effect on colour and oxidative stability at ambient temperature storage. LWT- Food Science and Technology. 2014; 55, 286-293.

[7] Sebranek, J.G.; Sewalt, V.J.H.; Robbins, K.L.; Houser, T.A. Comparison of a natural rosemary extract and BHA/BHT for relative antioxidant effectiveness in pork sausage. Meat Science. 2005; 69, 289–296.

[8] Önenç, S.S.; Açıkgöz, Z. Aromatik Bitkilerin Hayvansal Ürünlerde Antioksidan Etkileri. Hayvansal Üretim. 2005; 46(1), 50-55.

[9] Yang, Y.; Song, X.; Sui, X.; Qi, B.; Wang, Z.; Li, Y.; Jiang, L. Rosemary extract can be used as a synthetic antioxidant to improvevegetable oil oxidative stability. Industrial Crops and Products. 2016; 80, 141–147.

[10] Perumalla, A.V.S.; Hettiarachchy, N.S. Green tea and grape seed extracts— Potential applications in food safety and quality. Food Research International. 2011; 44, 827–839.

[11] Barretto, A.C.S.; Ida, E.I.; Silva, R.S.F.; Torres, E.A.F.S.; Shimokomaki, M. Empirical models for describing poultry meat lipid oxidation inhibition by natural antioxidants. Journal of Food Composition and Analysis. 2003; 16, 587–594.

[12] Krishnan, R.K.; Babuskin, S.; Babu, P.A.S.; Sasikala, M.; Sabina, K.; Archana, G.; Sivarajan, M.; Sukumar, M. Antimicrobial and antioxidant effects of spice extracts on the shelf life extension of raw chicken meat. International Journal of Food Microbiology. 2014; 171, 32–40.

[13] Gorji, S.G.; Smyth, H.E.; Sharma, M.; Fitzgerald, M. Lipid oxidation in mayonnaise and the role of natural antioxidants: A review. Trends in Food Science & Technology. 2016; 56, 88-102.

[14] Gray, J.I. Measurement of Lipid Oxidation: A Review. Department of Food Science. 1977; 55, 539-546.

[16] Guo, Q.; Gao, S.; Sun, Y.; Gao, Y.; Wang, X.; Zhang, Z. Antioxidant efficacy of rosemary ethanol extract in palm oil duringfrying and accelerated storage. Industrial Crops and Products. 2016; 94, 82–88.

[16] Caleja, C.; Barros, L.; Antonia, A.L.; Oliveira, M.B.P.P.; Ferreira, I.C.F.R. A comparative study between natural and synthetic antioxidants: Evaluation of their performance after incorporation into biscuits. Food Chemistry. 2017; 216, 342–346.

[17] Jiang, J.; Xiong, Y.L. Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: A review. Meat Science. 2016; 120, 107-117.

[18] Caleja, C.; Barros, L.; Antonio, A.L.; Carocho, M.; Oliveira, M.B.P.P.; Ferreira I.C.F.R. Fortification of yogurts with different antioxidant preservatives: A comparative study between natural and synthetic additives. Food Chemistry. 2016; 210, 262–268.

[19] Teruel, M.R.; Garrido, M.D.; Espinosa, M.C.; Linares, M.B. Effect of different format-solvent rosemary extracts (*Rosmarinus officinalis*) on frozen chicken nuggets quality. Food Chemistry. 2015; 172, 40–46.

[20] Mohamed, H.M.H.; Mansour, H.A. Incorporating essential oils of marjoram and rosemary in the formulation of beef patties manufactured with mechanically deboned poultry meat to improve the lipid stability and sensory attributes. LWT- Food Science and Technology. 2012; 45, 79-87.

[21] Gao, M.; Feng, L.; Jiang, T.; Zhu, J.; Fu, L.; Yuan, D.; Li, J. The use of rosemary extract in combination with nisin to extend the shelf life of pompano (*Trachinotus ovatus*) fillet during chilled storage. Food Control. 2014; 37, 1-8.

[22] Chammem, N.; Saoudi, S.; Sifaoui, I.; Sifi, S.; de Person, M.; Abderraba, M.; Moussa, F.; Hamdi, M. Improvement of vegetable oils quality in frying conditions by adding rosemary extract. Industrial Crops and Products. 2015; 74, 592–599.

[23] Delgado, M.A.; García-Rico, C.; Franco, J.M. The use of rosemary extracts in vegetable oil-based lubricants. Industrial Crops and Products. 2014; 62, 474–480.

[24] Urbizu-Gonzàlez, A.L.; Castillo-Ruiz, O.; Martínez-Àvila, G.C.G.; Torres-Castillo, J.A. Natural variability of essential oil and antioxidants in the medicinal plant Turnera diffusa. Asian Pacific Journal of Tropical Medicine. 2017; 1–5.

[25] Sun, Y.F.; Liang, Z.S.; Shan, C.J.; Viernstein, H.; Unger, F. Comprehensive evaluation of natural antioxidants and antioxidant potentials in *Ziziphus jujuba Mill. var. spinosa (Bunge) Hu ex H. F. Chou* fruits based on geographical origin by TOPSIS method. Food Chemistry. 2011; 124, 1612–1619.

[26] Sàyago-Ayerdi, S.G.; Brenes, A.; Góni, I.; Effect of grape antioxidant dietary fiber on the lipid oxidation of raw and cooked chicken hamburgers. LWT- Food Science and Technology. 2009; 42, 971–976.

[27] Karre, L.; Lopez, K.; Getty, K.J.K. Natural antioxidants in meat and poultry products. Meat Science. 2013; 94, 220–227.

[28] Bakirtzi, C.; Triantafyllidou, K.; Makris, D.P. Novel lactic acid-based natural deep eutectic solvents: Efficiency inthe ultrasound-assisted extraction of antioxidant polyphenols fromcommon native Greek medicinal plants. Journal of Applied Research on Medicinal and Aromatic Plants. 2016; 3, 120–127.

[29] Pires, C.M.S.; Martins, N.; Carvalho, A.M.; Barros, L.; Ferreira, I.C.F.R. Phytopharmacologic preparations as predictors of plant bioactivity: A particular approach to *Echinacea purpurea* (L.) Moench antioxidant properties. Nutrition. 2016; 32, 834–839.

[30] Kraujaliené, V.; Pukalskas, A.; Kraujalis, P.; Venskutonis, P.R. Biorefining of *Bergenia crassifolia* L. roots and leaves by high pressure extraction methods and evaluation of antioxidant properties andmain phytochemicals in extracts and plant material. Industrial Crops and Products. 2016; 89, 390–398.

[31] Embuscado, M.E. Spices and herbs: Natural sources of antioxidants – a mini review. Food of functional foods. 2015; 18, 811-819.

[32] Tang, S.; Kerry, J.P.; Sheehan, D.; Buckley, D.J.; Morrissey, P.A. Antioxidative effect of added tea catechins on suscepttibility of cooked red meat, poultry and fish patties to lipid oxidation. Food Research International. 2001; 34, 651-657.

[33] Shah, M.A.; Bosco, S.J.D.; Mir, S.A. Plant extracts as natural antioxidants in meat and meat products. Meat Science. 2014; 98, 21–33.

[34] Pereira, M.P.; Tavano, O.L. Use of Different Spices as Potential Natural Antioxidant Additives on Cooked Beans (*Phaseolus vulgaris*). Increase of DPPH Radical Scavenging Activity and Total Phenolic Content. Plant Foods for Human Nutrition. 2014; 69, 337–343.

[35] Lee, C.Y.; Sharma, A.; Uzarski, R.L.; Cheong, J.E.; Xu, H.; Held, R.A. Upadhaya, S.K.; Nelson, J.L. Potent antioxidant dendrimers lacking pro-oxidant activity. Free Radical Biology&Medicine. 2011; 50, 918–925.

[36] Prieto, M.A.; Murado, M.A.; Vázquez, J.A.; Curran, T.P. Analytical criteria to quantify and compare the antioxidant and pro-oxidant capacity in competition assays: The bell protection function. Food Research International. 2014; 60, 48–58.

[37] Zhi-Shen, X.; Ling-Jun, Z.; Xiao-Meng, W.; Meng-Ning, L.; Hua, Y.; Ping, L.; Xiao-Jun, X. Petroleum ether sub-fraction of rosemary extract improves hyperlipidemia and insulin resistance by inhibiting SREBPs. Chinese Journal of Natural Medicines. 2016; 14(10), 746-756.

[38] Tawfeeq, A.; Culham, A.; Davis, F.; Reeves, M. Does fertilizer type and method of application cause significantdifferences in essential oil yield and composition in rosemary (*Rosmarinus officinalis* L.)? Industrial Crops and Products. 2016; 88, 17–22.

[39] Bensebia, O.; Allia, K. Laboratoire Analysis of adsorption–desorption moisture isotherms of rosemary leaves. Journal of Applied Research on Medicinal and Aromatic Plants. 2016; 3, 79–86.

[40] Huang, S.; Liu, B.; Ge, D.; Dai, J. Effect of combined treatment with supercritical CO_2 and rosemary on microbiological and physicochemical properties of ground pork stored at 4 °C. Meat Science. 2017; 125, 114–120.

[41] Erdmann, M.E.; Lautenschlaeger, R.; Zeeb, B.; Gibis, M.; Weiss, J. Effect of differently sized O/W emulsions loaded with rosemary extract on lipid oxidation in cooked emulsion-type sausages rich in n-3 fatty acids. LWT- Food Science and Technology. 2017; 79, 496-502.

[42] Rashidinejad, A.; Birch, E.J.; Everett, D.W. Antioxidant activity and recovery of green tea catechins in full-fat cheese following gastrointestinal simulated digestion. Journal of Food Composition and Analysis. 2016; 48, 13–24.

[43] Gerolis, L.G.L.; Lameiras, F.S.; Krambrock, K.; Neves, M.J. Effect of gamma radiation on antioxidant capacity of green tea, yerba mate, and chamomile tea as evaluated by different methods. Radiation Physics and Chemistry. 2017; 130, 177–185.

[44] Duong , D.N.; Qin, J.G.; Harris, J.O.; Hoang, T.H.; Bansemer, M.S.; Currie, K.L.; Phan-Thien, K.Y.; Dowell, A.; Stone, D.A.J. Effects of dietary grape seed extract, green tea extract, peanut extract and vitamin C supplementation on metabolism and survival of greenlip abalone (*Haliotis laevigata* Donovan) cultured at high temperature. Aquaculture. 2016; 464, 364–373.

[45] Sharpe, E.; Hua, F.; Schuckers, S.; Andreescu, S.; Bradley, Ryan. Effects of brewing conditions on the antioxidant capacity of twenty-four commercial green tea varieties. Food Chemistry. 2016; 192, 380–387.

[46] Jiao, J.; Wei, Y.; Chen, J.; Chen, X.; Zhang, Y. Anti-aging and redox state regulation effects of A-type proanthocyanidins-rich cranberry concentrate and its comparison with grape seed extract in mice. Journal of Functional Foods. 2017; 30, 63–73.

[47] Charradi, K.; Mohamed, M.; Bedhiafi, T.; Kadri, S.; Elkahouia, S.; Limam, F.; Aouani, E. Dietary supplementation of grape seed and skin flour mitigates brain oxidative damage induced by a high-fat diet in rat: Gender dependency. Biomedicine & Pharmacotherapy. 2017; 87, 519–526.

[48] Quijada-Morín, N.; García-Estévez, I.; Nogales-Bueno, J.; Rodríguez-Pulido, F.J.; Heredia, F.J.; Rivas-Gonzalo, J.C.; Escribano-Bailón, M.T.; Hernández-Hierro, J.M. Trying to set up the flavanolic phases during grape seed ripening: A spectral and chemical approach. Talanta. 2016;. 160, 556–561.

[49] Martínez, J.; Nieto, G.; Castillo, J.; Ros, G. Influence of in vitro gastrointestinal digestion and/or grape seed extract addition on antioxidant capacity of meat emulsions. LWT- Food Science and Technology. 2014; 59, 834-840.

[50] Sano, A. Safety assessment of 4-week oral intake of proanthocyanidin-rich grape seed extract in healthy subjects. Food and Chemical Toxicology. 2016; 1-5.

[51] Muppalla, S.R.; Kanatt, S.R.; Chawla, S.P.; Sharma, A. Carboxymethyl cellulose–polyvinyl alcohol films with clove oil for active packaging of ground chicken meat. Food Packaging and Shelf Life. 2014; 2, 51-58.

[52] Lee, N.K.; Jung, B.S.; Na, D.S.; Yu, H.H.; Kim, J.S.; Paik, H.D. The impact of antimicrobial effect of chestnut inner shell extracts against Campylobacter jejuni in chicken meat. LWT- Food Science and Technology. 2016; 65, 746-750.

[53] Bonilla, J.; Sobral, P.J.A. Investigation of the physicochemical, antimicrobial andantioxidant properties of gelatin-chitosan edible film mixed with plant ethanolic extracts. Food Bioscience. 2016; 16, 17–25.

[54] Su, S.; Wang, L.J.; Feng, C.Y.; Liu, Y.; Li, C.H.; Du, H.; Tang, Z.Q.; Xu, Y.J.; Wang, L.S. Fingerprints of anthocyanins and flavonols of Vaccinium uliginosum berries from different geographical origins in the Greater Khingan Mountains and their antioxidant capacities. Food Control. 2016; 64, 218-225.

[55] Hygreeva, D.; Pandey, M.C.; Radhakrishna, K. Potential applications of plant based derivatives as fat replacers, antioxidants and antimicrobials in fresh and processed meat products. Meat Science. 2014; 98, 47–57.

[56] Naveena, B.M.; Sen, A.R.; Vaithiyanathan, S.; Babji, Y.; Kondaiah, N. Comparative efficacy of pomegranate juice, pomegranate rind powder extract and BHT as antioxidants in cooked chicken patties. Meat Science. 2008; 80, 304–308.

[57] Bazargani-Gilani, B.; Aliakbarlu, J.; Tajik, H. Effect of pomegranate juice dipping and chitosan coating enriched with Zataria multiflora Boiss essential oil on the shelf-life of chicken meat during refrigerated storage. Innovative Food Science and Emerging Technologies. 2015; 29, 280–287.

[58] Gallo, M.; Ferracane, R.; Naviglio, D. Antioxidant addition to prevent lipid and protein oxidation in chicken meat mixed with supercritical extracts of Echinacea angustifolia. J. of Supercritical Fluids. 2012; 72, 198– 204.

[59] Selani, M.M.; Contreras-Castillo, C.J.; Shirahigue, L.D.; Gallo, C.R.; Plata-Oviedo, M.; Montes-Villanueva, N.D. Wine industry residues extracts as natural antioxidants in raw and cooked chicken meat during frozen storage. Meat Science. 2011; 88, 397–403.

[60] Hung, Y.; Verbeke, W.; Kok, M.T. Stakeholder and consumer reactions towards innovative processed meat products: Insights from a qualitative study about nitrite reduction and phytochemical addition. Food Control. 2016; 60, 690-698.

[61] Sampaio, G.R.; Saldanha, T.; Soares, R.A.M; Torres, E.A.F.S. Effect of natural antioxidant combinations on lipid oxidation in cooked chicken meat during refrigerated storage. Food Chemistry. 2012; 135, 1383–1390.

[62] Mariutti, L.R.B.; Nogueira, G.C.; Bragagnolo, N. Lipid and Cholesterol Oxidation in Chicken Meat Are Inhibited by Sage but Not by Garlic. Journal of Food Science. 2011; 76, C909-C915.

[63] Haskaraca, G.; Demirok, E.; Kolsarıcı, N.; Öz, F.; Özsaraç, N. Effect of green tea extract and microwave pre-cooking on the formation of heterocyclic aromatic amines in fried chicken meat products. Food Research International. 2014; 63, 373–381.

[64] Mielnik, M. B.; Aaby, K.; Skrede, G. Commercial antioxidants control lipid oxidation in mechanically deboned turkey meat. Meat Science. 2003; 65, 1147–1155.

[65] Can, Ö.P.; Ağaoğlu, S.; Alemdar, S. Biberiye Ekstraktı İlavesinin Tavuk Köftesinin Kalite Özellikleri Üzerine Etkisi. Cumhuriyet Üniversitesi Sağlık Bilimleri Enstitüsü Dergisi. 2016; 1(1), 01-06.

[66] Lee, E. J.; Ahn, D.U. Quality characteristics of irradiated turkey breast rolls formulated with plum extract. Meat Science. 2005; 71, 300–305.

[67] Hassan, O.; Fan, L.S. The anti-oxidation potential of polyphenol extract from cocoa leaves on mechanically deboned chicken meat (MDCM). LWT. 2005; 38, 315–321.

[68] Brettonnet, A.; Hewavitarana, A.; DeJong, S.; Lanari, M.C. Phenolic acids composition and antioxidant activity of canola extracts in cooked beef, chicken and pork. Food Chemistry. 2010; 121, 927–933.

[69] Devatkal, S.K.; Kamboj, R.; Paul, D. Comparative antioxidant effect of BHT and water extracts of banana and sapodilla peels in raw poultry meat. Journal of Food Science and Technology. 2014; 51(2), 387–391.

[70] Chan, K.W.; Khong, N.M.H.; Iqbal, S.; Ch'ng, S.E.; Younas, U.; Babji, A.S. Cinnamon bark deodorised aqueous extract as potential natural antioxidant in meat emulsion system: a comparative study with synthetic and natural food antioxidants. Journal of Food Science and Technology. 2014; 51(11), 3269–3276.

[71] Vaithiyanathan, S.; Naveena, B.M.; Muthukumar, M.; Girish, P.S.; Kondaiah, N. Effect of dipping in promegranate (*Punica granatum*) fruit juice phenolic solution on the shelf life of chicken meat under refrigerated storage (4 °C). Meat Science. 2011; 88, 409–414.

[72] Gonzalez, M.T.N.; Hafley, B.S.; Boleman, R.M.; Miller, R.K.; Rhee, K.S.; Keeton, J.T. Qualitative effects of fresh and dried plum ingredients on vacuum-packaged, sliced hams. Meat Science. 2009; 83, 74–81.

[73] Alves, A.B.; Bragagnolo, N.; Silva, M.G.; Skibsted, L.H.; Orlien V. Antioxidant protection of high-pressure processed minced chicken meat by industrial tomato products. Food and Bioproducts Processing. 2012; 90, 499-505.

[74] Jayawardana, B.C.; Liyanage, R.; Lalantha, N.; Iddamalgoda, S.; Weththasinghe, P. Antioxidant and antimicrobial activity of drumstick (Moringa oleifera) leaves in herbal chicken sausages. LWT - Food Science and Technology. 2015; 64, 1204-1208.

[75] Lee, C.H.; Reed J.D.; Richards M.P. Ability Of Various Polyphenolic Classes From Cranberry To Inhibit Lipid Oxidation In Mechanıcally Separated Turkey And Cooked Ground Pork. Muscle Biology and Meat Science Laboratory Department of Animal Sciences University of Wisconsin. 2006; 248-266.

[76] Hasapidou, A.; Savvaidis, I.N. The effects of modified atmosphere packaging, EDTA and oregano oil on the quality of chicken liver meat. Food Research International. 2011; 44, 2751–2756.