CHAPTER

Sources of plant extracts

1

Shabir Ahmad Mir[1], Manzoor Ahmad Shah[2] and Annamalai Manickavasagan[3]

[1]Department of Food Science & Technology, Govt. College for Women, Srinagar, India [2]Department of Food Science & Technology, Govt. Degree College for Women, Anantnag, India [3]School of Engineering, College of Engineering and Physical Sciences, University of Guelph, Guelph, ON, Canada

1.1 Introduction

There is a great demand for natural ingredients in the food industry. Plant materials are good sources of natural ingredients with different functionalities, and these can be used for various applications. The advantages of plant materials are their abundance in nature and wide geographic distribution. Plant extracts are concentrated bioactive compounds with potential antimicrobial, antioxidant, and several other beneficial properties. Plant extracts vary in their properties because of structural diversity and complexity based on their source.

Researchers and industries are working on conventional and emerging extraction techniques for obtaining the extracts from plant material with highest yield, stability, and efficacy. Various types of plants are valuable sources of these extracts such as fruits, vegetables, plantation crops, cereals, spices, and herbs. Plant extracts are obtained from different parts of plants such as leaves (Hauser et al., 2016; Nouri & Nafchi, 2014; Rodríguez, Sibaja, Espitia, & Otoni, 2020), fruits (Ferysiuk, Wójciak, Materska, Chilczuk, & Pabich, 2020; Wang, Marcone, Barbut, & Lim, 2012), seeds (Guo, Huang, Chen, Hou, & Huang, 2020; Reddy et al., 2013; Tan, Lim, Tay, Lee, & Thian, 2015), peels (Aliyari, Bakhshi Kazaj, Barzegar, & Ahmadi Gavlighi, 2020; Zhang, Li, & Jiang, 2020), roots (Hedayati et al., 2021; Jaśkiewicz, Budryn, Nowak, & Efenberger-Szmechtyk, 2020; Norajit, Kim, & Ryu, 2010), and flowers (Khan et al., 2019; Samsudin, Soto-Valdez, & Auras, 2014) (Fig. 1.1).

In the recent years, there has been an increasing demand for natural additives in the food industry. Market trend has been changed due to the healthy lifestyle and consumer awareness about the additives. Plant extracts are simple and safe and have been effectively utilized in the food industry for different applications. They are used as antioxidants, antimicrobial agents, flavoring agents, coloring agents, enzymes, nutrient enhancers, and packaging additives.

Plant Extracts: ***Applications in the Food Industry*****. DOI:** https://doi.org/10.1016/B978-0-12-822475-5.00011-9

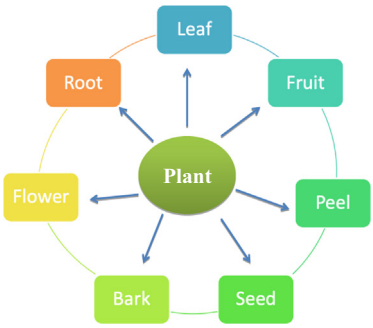

FIGURE 1.1

Plant parts used for the preparation of extracts.

1.2 Plant parts used for the preparation of extracts

1.2.1 Leaf

Leaves are important parts of plant responsible for the photosynthesis and consequent production of oxygen. According to various literature, leaves are rich sources of health beneficial bioactive compounds. Leaves contain carotenoids and anthocyanins responsible for the yellow to orange to red color of leaves during autumn in addition to chlorophyll, which is responsible for green color. These color compounds of leaves are responsible for the rich antioxidant capacity of leaves. Additionally, some leave extracts posses antimicrobial activity due to the presence of flavonoids (Botsoglou, Govaris, Ambrosiadis, Fletouris, & Botsoglou, 2014; Han & Song, 2021a). Leaf extract possess more bioactive compounds as compared to stem, seed, and bark of a tree. Leaf extracts have gained popularity for use in different types of food applications. Leaf extracts have been used as preservative, coloring and antimicrobial agent.

Various studies have indicated the use of leaf extracts for different types of food products (Table 1.1). Lotus leaf is a potential source of phytochemicals and is used in ground pork (Choe et al., 2011). Lotus leaves are rich in polyphenols, flavonoids, and alkaloids (Wang et al., 2021). Amaranthus leaf is rich in betalains and other active compounds. This leaf extract is used in packaging films for shelf life enhancement of chicken and fish meat during storage (Kanatt, 2020). Mango leaf extract is rich in bioactive components like gallic acid, mangiferin, glucosides, and other phenolic compounds (Rambabu, Bharath, Banat, Show, & Cocoletzi, 2019). This extract is incorporated into chitosan-based packaging films for food applications.

Mint leaf extract was used for lamb meat preservation by Kanatt, Chander, and Sharma (2008). Mint leaf extracts are excellent source of phenolic and flavonoid compounds. Mint leaves help to prevent the lipid oxidation and improve the taste and flavor of meat. The leaf extracts of myrtle, rosemary, lemon balm, and nettle were used in beef patties to reduce lipid oxidation and enhance the shelf life (Akarpat, Turhan, & Ustun, 2008). Olive leaf extract used in pork patties delayed the protein oxidation and lipid oxidation of conjugated dienes, hydroperoxides, and malondialdehyde (Botsoglou et al., 2014). Leaf extract obtained from cork oak (*Quercus suber* L.) was used as a natural antioxidant in cooked meat (Lavado, Ladero, & Cava, 2021). *Moringa oleifera* leaf extracts

Table 1.1 Application of leaf extracts in the food industry.

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Green tea	*Camellia*	*Sinesis*	Antioxidant	Packaging films	Increased mechanical, water vapor barrier and antioxidant properties	Siripatrawan and Harte (2010)
			Antioxidant antimicrobial	Beef patties	Delayed microbial spoilage, redness loss and lipid oxidation	Banon et al. (2007)
			Antioxidant	Goat meat	Reduces lipid oxidation during storage	Rababah et al. (2011)
			Antioxidant	Pork meat	Inhibit lipid oxidation	Wójciak et al. (2011)
Rosemary	*Salvia*	*Rosmarinus*	Antioxidant	Packaging film for peanuts	Inhibits lipid oxidative rancidity in peanuts	Wambura, Yang, and Mwakatage (2011)
			Antioxidant	Pork sausage	Shelf life enhancement of sausage	Sebranek, Sewalt, Robbins, and Houser (2005)
			Antioxidant	Beef patties	Reduced lipid oxidation	Akarpat et al. (2008)
			Antioxidant	Pork meat	Inhibit lipid oxidation	Wójciak et al. (2011)
Nettle	*Urtica*	*Dioica*	Antimicrobial, Antioxidant	Ground beef	Inhibition of *Pseudomonas* and psychrotrophic bacteria in the stored ground beef Inhibition of ipid oxidation	Alp and Aksu (2010)
			Antioxidant	Fermented sausage	reduced TBARS value and biogenic amine formation	Karabacak and Bozkurt (2008)
Olive	*Olea*	*Europea*	Antioxidant	Pork patties	Reduced lipid oxidation in cooked pork patties	Hayes, Stepanyan, O'Grady, Allen, and Kerry (2010)
			Antioxidant	Pork sausages	Reduced lipid oxidation in raw and cooked pork sausages	Hayes, Stepanyan, Allen, O'grady, and Kerry (2011)
			Antioxidant	Pork patties	Extract significantly inhibit protein and lipid oxidation in patties	Botsoglou et al. (2014)
			Antioxidant	Packaging film	Films exhibit good barrier and mechanical properties	da Rosa, Vanga, Gariepy, and Raghavan (2020)
			Antimicrobial	Lamb meat	Potential antimicrobial activity during the storage of lamb meat	Martiny, Raghavan, Moraes, Rosa, and Dotto (2020)

(*Continued*)

Table 1.1 Application of leaf extracts in the food industry. *Continued*

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Mint	*Mentha*	*Spicata*	Antioxidant Antimicrobial	Meat	Potential antimicrobial and antioxidant agent improving the shelf life of meat	Kanatt et al. (2008)
			Antioxidant	Pork meat	Minimize lipid oxidation in pork products	Biswas, Chatli, and Sahoo (2012)
Drumstick	*Moringa*	*Oleifera*	Antioxidant	Goat meat patties	Protect goat meat patties against oxidative rancidity	Das et al. (2012)
			Antioxidant	Pork patties	Inhibit lipid oxidation in ground pork patties	Muthukumar et al. (2014)
			Antioxidant	Raw beef	Significantly reduced the TBARS value of modified atmosphere packaged raw beef	Shah et al. (2015)
Betel	*Piper*	*Betel*	Antimicrobial	Packaging films	Inhibitory activity against the growth of Gram positive and Gram negative bacteria, Barrier properties of packaging film such as ultraviolet protection, water vapor and oxygen permeation increased	Nouri and Nafchi (2014)
Murta	*Ugni*	*Molinae*	Antimicrobial Antioxidant	Packaging films	Enhanced antimicrobial and antioxidant properties of packaging films	Hauser et al. (2016)
Ginkgo	*Gingko*	*Biloba*	Antioxidant	Packaging films	Excellent antioxidant properties of packaging films, improved barrier properties against UV light and moisture	Li, Miao, Wu, Chen, and Zhang (2014)
Curry	*Murraya*	*Koenigii*	Antioxidant	Pork meat	Minimize lipid oxidation in pork products	Biswas et al. (2012)
Lotus	*Nelumbo*	*Nucifera*	Antioxidant	Porcine and bovine ground meat	Inhibiting meat oxidation	Huang et al. (2011)
Myrtle	*Myrtus*	-	Antioxidant	Beef patties	Reduced lipid oxidation	Akarpat et al. (2008)
Satureja	*Satureja*	*Thymbra*	Antioxidant	Packaging for potato chips	Protects fried potato chips against oxidation	Choulitoudi, Velliopoulou, Tsimogiannis, and Oreopoulou (2020)
Amaranth	*Amaranthus*	*Tricolor*	Antioxidant	Chicken and fish	Inhibit bacterial growth and oxidative rancidity	Kanatt (2020)
Mango	*Mangifera*	*Indica*	Antioxidant Antimicrobial	Packaging films	Extract based films showed good mechanical, UV-light barrier, antioxidant and antimicrobial properties	Bastante et al. (2021)
Blueberry	*Vaccinium*	*Corymbosum*	Antioxidant	Packaging films	Enhanced antioxidant activity of packaging films	Han and Song (2021b)
Cork oak	*Quercus*	*Suber*	Antioxidant	Meat	Inhibit lipid oxidation in cooked meat	Lavado et al. (2021)

were applied in meat for shelf life enhancement by Das, Rajkumar, Verma, and Swarup (2012), Muthukumar, Naveena, Vaithiyanathan, Sen, and Sureshkumar (2014) and Shah, Bosco, and Mir (2015). These leaf extracts are rich source of phenolic compounds, which reduce lipid and protein oxidation in meat and meat products. The barley leaf extract is effective for retarding lipid oxidation in ground pork (Choe et al., 2011).

Tea extract is one of the most popular leaf extracts used for food applications due to the abundance of active compounds. The predominant bioactive components in tea extract are flavanols, flavonoids, phenolic acids, etc. These extracts are widely applied in meat and other food products to delay the lipid oxidation and to enhance their shelf-life (Banon, Díaz, Rodríguez, Garrido, & Price, 2007; Rababah et al., 2011; Wójciak, Dolatowski, & Okoń, 2011). Roasted coffee extracts are rich sources of antioxidants and effective for lowering the lipid oxidation in beef (Lin, Toto, & Were, 2015).

Herb extracts are excellent source of active compounds, which improve the quality of food products. Extract of rosemary, sage, and marjoram were used to minimize the lipid oxidation, enhance the color and sensory properties of irradiated ground beef (Mohamed, Mansour, & Farag, 2011). Extracts of peony, sappanwood, rehmania, and angelica with antioxidant properties were used in the meat industry (Han & Rhee, 2005). These herbal extracts effectively reduced lipid oxidation and improved the quality of ground meat. Epazote herb extracts were used as antioxidants in ground beef by Villalobos-Delgado, González-Mondragón, Ramírez-Andrade, Salazar-Govea, and Santiago-Castro (2020). The epazote extract effectively prevented the lipid oxidation and enhanced the sensory attributes of beef.

Plant extracts have been used as an important ingredient in active packaging films. Bastante et al. (2021) impregnated the mango leaf extract into packaging films and showed the antimicrobial activity against gram positive and gram negative bacteria. Han and Song (2021b) developed the active packaging material by incorporating the blueberry leaf extract into polysaccharide based films. Sago starch film incorporated with betel leaf extract showed inhibitory activity against the bacteria and also improved mechanical properties of developed packaging films (Nouri & Nafchi, 2014). Coffee and cocoa extracts were used in polylactide films for food packaging applications (Moraczewski et al., 2019). Tea extracts are used as antimicrobial and antioxidant agents in active packaging films (Siripatrawan & Harte, 2010).

1.2.2 Fruits and vegetables

Fruits are diverse in nature and grown in different geographical regions such as temperate, tropical, sub-tropical, and arid zones of the world. Fruits are rich sources of different types of functional compounds. Extracts are obtained from different sources and varieties of fruits. These extracts are rich sources of phenolic compounds and include phenolic acids, stilbenes, lignans, flavonoids, and tannins or proanthocyanidins. The most abundant phenolic compounds in the fruits are phenolic acids such as derivatives of benzoic and cinnamic acids and flavonoids. These special compounds of fruit extracts have considerable applications in food industry. Extracts are obtained from different fruits such as grape, blueberry, raspberry, pomegranate, murta, chestnut, etc. have been prepared by various extraction technologies and are used in different types of food products such as meat, cheese, poultry and fish (Table 1.2).

Table 1.2 Application of fruit extracts in the food industry.

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Black mulberry	*Morus*	*Nigra*	Antioxidant Antimicrobial	Beef patties	Lipid oxidation and microbial growth decreased during storage, improving redness of patties	Turan and Şimşek (2021)
Chestnut	*Castanea*	*Sativa*	Antioxidant Antimicrobial	Packaging films for pasta	Prevents microbial spoilage of pasta	Kõrge, Bajić et al. (2020)
Chestnut	*Castanea*	*Sativa*	Antimicrobial	Cheese	Potential antimicrobial properties	Kõrge, Šeme, Bajić, Likozar, & Novak, (2020)
Jabuticaba	*Myrciaria*	*Jaboticaba*	Antioxidant Color enhancer	Bakery products	Enhances the nutritional value and color of product	Albuquerque et al. (2020)
Hawthorn	*Crataegus*	*Pinnatifida*	Antioxidant	Beef and chicken breast meat	Inhibition of heterocyclic aromatic amine formation at higher temperature	Tengilimoglu-Metin et al. (2017)
Murta	*Ugni*	*Molinae*	Antioxidant Antimicrobial	Packaging films	Improved mechanical, antioxidant and antimicrobial properties	de Dicastillo et al. (2016)
Red raspberry	*Rubus*	*Strigosus*	Packaging aid	Packaging films	Enhanced tensile strength and percent elongation at break	Wang et al. (2012)
Blueberry	*Vaccinium*	*Vitis-idaea*	Antioxidant	Lard	Delayed the oxidation of packaged lard	Zhang et al. (2010)
Carob	*Ceratonia*	*Siliqua*	Antioxidant	Cooked pork	Reduce fat oxidation	Bastida et al. (2009)

Howthorn fruit extracts were used in beef and chicken breast meat by Tengilimoglu-Metin, Hamzalioglu, Gokmen, and Kizil (2017). Howthorn extracts reduced the formation of carcinogenic heterocyclic aromatic amine in meat. Acorn fruit extract exhibited the potential antioxidant activity in raw chicken meat during refrigerated storage (Özünlü, Ergezer, & Gökçe, 2018). This extract inhibited the lipid oxidation and also enhanced the flavor of the chicken meat. Black mulberry fruit extracts were used in beef patties stored under aerobic and vacuum packaged conditions (Turan & Şimşek, 2021). The black mulberry extracts were rich in phenolics and anthocyanins and showed remarkable effect on antioxidant, antimicrobial and color properties of patties. Mulberry extract decreased the lipid oxidation and microbial spoilage and prevented the formation of metmyoglobin and improved the redness in patties. Red pitaya fruit extract acted as an antioxidant and natural colorant in pork patties (Bellucci, Munekata, Pateiro, Lorenzo, & da Silva Barretto, 2021). Bastida et al. (2009) used carob fruit extract in cooked pork.

Blueberry fruit extract is used in active packaging films (Zhang et al., 2010). Raspberry fruit extract is used in soy protein based packaging films (Wang et al., 2012). The murta fruit extract is incorporated in methyl cellulose based films (de Dicastillo, Bustos, Guarda, & Galotto, 2016). Kõrge, Bajić, Likozar, and Novak (2020) used chestnut fruit extract in chitosan films for shelf life enhancement of pasta.

Vegetables are also used for the production of plant extracts. Vegetables are rich in phenolic compounds, flavonoid glycosides, carotenoids, tannins, vitamins C and E. Furthermore, attention has been given to the extracts from waste material of vegetables, which are also good sources of bioactive compounds. Vegetable-based extracts have widely used in the food industry such as meat products, fish products, and poultry products, etc. Chamnamul (*Pimpinella brachycarpa*), fatsia (*Aralia elata*), chinese chives (*Allium tuberosum*), broccoli (*Brassia oleracea*) exhibit signifiant antioxidant and antimicrobial properties. These extracts were used as prevertaive for the shelf life enhancement of raw beef patties (Kim, Cho, & Han, 2013). The extract of broccoli are rich in phenolic antioxidants which have excellent radical scavanning capacity. The extract significantly reduced the lipid peroxidation and improved the shelf life of goat meat nuggets (Banerjee et al., 2012). Potato extracts used in fresh and precooked beef patties improved their shelf life stability and sensory characteristics (Colle et al., 2019). Red pepper extract was used in cooked pork by Wójciak et al. (2011). Sweet pepper extract was used in refrigerated pork by Ferysiuk et al. (2020).

1.2.3 Peel and skin

Peel is considered as a waste of the food processing and represents a good percentage and an excellent source of photochemical compounds. Peel is superior in antioxidant potential as compared to pulp. Peel extracts have potential application as antimicrobial and antioxidant agents in various food products (Table 1.3). Kinnow and pomegranate peel extracts were applied to goat meat patties (Devatkal, Narsaiah, & Borah, 2010). Pomegranate peel extract was used in ground goat meat and nuggets (Devatkal, Thorat, & Manjunatha, 2014). Kanatt, Rao, Chawla, and Sharma (2012) used pomegranate peel extract into chitosan based films. Potato peel contains phenolic compounds and glycoalkaloids which showed the potential applications in food industry (Sampaio et al., 2020). Pitaya peel extracts were used to improve the oxidative stability of refrigerated ground pork patties (Cunha et al., 2018). Chitosan packaging films were incorporated with banana peel extract by

Table 1.3 Application of peel extracts in the food industry.

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Pomegranate	*Punica*	*Granatum*	Antibacterial Antioxidant	Raw pork	Reduce numbers of pathogenic bacteria, color degradation and lipid oxidation in raw pork	Shan, Cai, Brooks, and Corke (2009)
			Antioxidant	Ground goat meat and nuggets	Significantly reduced TBARS value	Devatkal et al. (2014)
			Packaging aid	Packaging films	mechanical properties, antioxidant properties and antibacterial properties considerably increased	Moghadam, Salami, Mohammadian, Khodadadi, and Emam-Djomeh (2020)
			Antimicrobial	Packaging films	Antimicrobial activity of extract were more pronounced against gram-positive as compared to gram-negative bacteria	Emam-Djomeh, Moghaddam, and Yasini Ardakani (2015)
			Antimicrobial Antioxidant	Sausages	Reduces lipid oxidation and microbial growth	Aliyari et al. (2020)
Blood orange	*Citrus*	*Sinensis*	Antimicrobial Antioxidant	Cheese	Enhancing the microbial stability of cheese during storage, improving nutritional value of cheese	Jridi et al. (2020)
Kiwifruit	*Actinidia*	*Chinensis*	Antioxidant	Chicken meat	Retarded lipid oxidation in chicken thigh meat	Han and Song (2021a)
Banana	*Musa*	*Paradisiaca*	Antioxidant	Packaging films	Films exhibit excellent antioxidant activity	Zhang et al. (2020)
Pitaya	*Hylocereus*	*Costaricensis*	Antioxidant	Pork patties	Enhanced oxidative stability	Cunha et al. (2018), Cunha et al. (2021)

Zhang et al. (2020). The developed films showed excellent antioxidant activity and enhanced the shelf life of apple fruit during storage.

Yu, Ahmedna, and Goktepe (2010) utilized the peanut skin extract for raw and cooked ground beef for shelf life enhancement. They reported that peanut skin extracts inhibit lipid oxidation and enhance the shelf life of beef. The addition of rice bran extracts in meat products have been reported to increase the nutritional value, retard the oxidative degradation, and increase the health promoting properties (Kim, 2000). Hao and Beta (2012) incorporated the barley hull and flaxseed hull extracts into Chinese steamed bread. These extracts significantly increased the phytochemical profile and antioxidant capacity of developed bread. Rye and wheat bran extracts containing phenolic compounds were tested in beef hamburgers (Šulniūtė, Jaime, Rovira, & Venskutonis, 2016). The bran extracts showed promising results by inhibiting the production of oxidation products, hexanal and malondialdehyde during storage. Furthermore, these extracts also enhanced the nutritional profile of beef hamburgers.

1.2.4 Seeds

Seed is one of the inedible parts of fruits and vegetables, which is considered as a waste in the food industry. Nowadays, seed extracts have been widely used in food products as a source of natural ingredients in the food industry, as these are rich sources of diverse bioactive compounds (Table 1.4). Grape seeds have been used for wide applications in the food industry. Grape seeds extracts are rich in phenolic compounds such as catechin, epicatechin, proanthocyanidin, gallate, flanonols, etc. (Chen et al., 2020). Grape seed extract was used for shelf life enhancement of meat (Reddy et al., 2013), sausage (Jayawardana et al., 2011) and Suisse cheese (Deolindo et al., 2019) due to its potential antioxidant properties. Tajik, Farhangfar, Moradi, and Razavi Rohani (2014) investigated the effect of grape seed extract on lipid oxidation of buffalo meat patties during storage. Grape seed extract were used in restructured mutton for shelf life enhancement stored at refrigerated temperatures by Reddy et al. (2013). This extract was also evaluated in roasted chicken stored under modified atmospheric packaging (Guo et al., 2020). Grape seed extract contains potential antioxidant properties which inhibit the lipid oxidation and was used in raw and cooked ground muscle during different storage conditions (Brannan & Mah, 2007). This extract was also used in frankfurters (Özvural & Vural, 2012). The grape fruit seed extract was incorporated in carrageenan-based packaging films by Kanmani and Rhim (2014) and Tan et al. (2015). Sivarooban, Hettiarachchy, and Johnson (2008) used the grape seed extract in soy protein based films.

Baobad seed extracts were used to assess the qualities of beef patties (Al-Juhaimi et al., 2020). Baobad extract showed good antioxidant potential and antibacterial properties, which help to improve the storage stability of beef patties. Guarana seed extract is a power source of phenolic antioxidant used in food industry. Guarana extract preserves the color and also protects the patties against lipid and protein oxidation (Pateiro et al., 2018). Adzuki bean extract has been utilized for cured and uncured cooked pork sausages (Jayawardana et al., 2011). The extract effectively reduced the lipid oxidation and results are par with the artificial antioxidants.

Spice seeds posses excellent antioxidant activity because of the presence of flavonoids, carotenoids, terpenoids, polyphenolics, coumarins, and curcumins. Zhang, Kong, Xiong, and Sun (2009) used extracts of pepper, aniseed, fennel, cardamom etc. in modified and vacuum packaged pork. The extracts of these spices was capable of inhibiting the spoilage causing microorganisms such as

Table 1.4 Application of seed extracts in food industry.

Plant	*genus*	*species*	uses	Application industries	Remarks	References
Grape	*Vitis*	*Vinifera*	Antimicrobial	Active packaging films	Extract increased the thickness, puncture and tensile strength of packaging films Showed inhibitory activity against microbes	Sivarooban et al. (2008)
			Antioxidant	Active packaging films	Extract improved the barrier to UV light and moisture of packaging films, Films posses excellent antioxidant activity	Li et al. (2014)
			Antioxidant	Refrigerated cooked beef and pork patties	Reduces oxidative rancidity	Rojas and Brewer (2007)
			Antioxidant	Frozen, vacuum packaged beef and pork patties	Reduces oxidative rancidity	Rojas and Brewer (2008)
			Antioxidant	Beef patties	Reduces oxidative rancidity	Colindres and Susan Brewer (2011)
			Antioxidant Flavor enhancer	Beef sausage	Reduces oxidative rancidity	Kulkarni, DeSantos, Kattamuri, Rossi, and Brewer (2011)
			Antioxidant Color enhancer	Raw and cooked goat meat	Reduces lipid oxidation	Rababah et al. (2011)
			Antioxidant	Frankfurters	Reduces oxidative rancidity	Özvural and Vural (2012)
			Antioxidant Antimicrobial	Restructured mutton slices	Reduces oxidative rancidity	Reddy et al. (2013)
			Antioxidant	Raw and cooked ground muscle	Reduces oxidative rancidity	Brannan and Mah (2007)
			Antioxidant	Mayonnaise	Reduces oxidative rancidity	Altunkaya et al. (2013)
			Antioxidant	Prevents shrimp discoloration	Inhibition melanosis in shrimp	Gokoglu and Yerlikaya (2008)
			Antimicrobial, flavor and color enhancer	Fresh produce	Modified color and flavor	Hollis et al. (2020)

Grapefruit	*Citrus*	*Paradisi*	Antimicrobial	Packaging films	Improved antimicrobial activity of packaging film	Lim, Jang, and Song (2010)
			Antimicrobial	Packaging films	Bacteriocidal and bacteriostatic capacity against different food borne pathogens	Wang, Lim, Tong, and San Thian (2019)
			Antimicrobial	Packaging films	Strong antimicrobial activity against various Gram-positive and Gram-negative food borne pathogens	Kanmani and Rhim (2014)
			Antimicrobial	Packaging films	Antimicrobial activity of packaging film, Extract increased the elongation at break of films	Tan et al. (2015)
			Antimicrobial Antioxidant	Salmon packaging	Increased shelf life of packaged salmon	Song, Shin, and Song (2012)
			Antimicrobial	Strawberry packaging	Extract increased the shelf life of packaged strawberries	Jang, Shin, and Song (2011)
Cumin	Nigella	Sativa	Antioxidant	Beef patties	Reduces oxidative rancidity	Rahman et al. (2021)
Guarana	*Paullinia*	*Cupana*	Antioxidant Antimicrobial Enhances color	Pork patties	Enhances shelf life, Protect patties against protein and lipid oxidation	Pateiro et al. (2018)
Baobab	Adansonia	Digitata	Antimicrobial Antioxidant	Beef patties	Improves lipid and microbial stability	Al-Juhaimi et al. (2020)

Listeria monocytogenes, Escherichia coli, and *Pseudomonas fluorescens* in pork. Black cumin extract used in beef patties shows excellent antioxidant activity and enhances the shelf life during refrigerated storage (Rahman, Alam, Monir, & Ahmed, 2021).

1.2.5 Flowers

Many species of flowers are considered as more than a delicacy or a garnish due to their nutritional value and the presence of special compounds. Flowers have attained significant attention during the recent years in food industry. Floral extracts contain abundant active compounds exhibiting rich bioactivity and promising health beneficial properties. Flower extracts are endowed with antioxidant, antimicrobial, color, and flavoring properties. Flower extracts have been incorporated in many products such as meat, beverages, packaging films, sausages etc. (Table 1.5)

Chrysanthemum morifolium flower extract was incorporated in goat meat patties cooked at different temperature (Khan et al., 2019). The flower extracts are effective for decreasing the heterocyclic amines in deep fried patties. Karabacak and Bozkurt (2008) utilized the *Urtica dioica* and *Hibiscus sabdariffa* L. flowers extracts in Turkish fermented sausage. Litchi flower extracts were found to be rich source of antioxidant used in pork meatballs significantly reduced the lipid and protein oxidation in frozen cooked meat products (Ding, Wang, Yang, Chang, & Chen, 2015). The incorporation of marigold flower extract into packaging film was found to be effective for enhancing the oxidative stability of fatty foods (Samsudin et al., 2014). Wang, Wang, Tong, and Zhou (2017) explored the use of honeysuckle flower extract in chitosan films for active food packaging. Extract-based films showed the potential application in food industry. Pullulan packaging films were incorporated with meadow sweet flower extracts. These extracts have excellent antimicrobial properties, which improve the shelf life and market value of apples (Gniewosz et al., 2014).

1.2.6 Barks

Tree bark is a major byproduct produced from the pulp and paper industries as well as during the processing of wood. Bark contains higher amounts of phenolic compounds as compared to wood, which plays an important role in the defense mechanisms. Limited studied are available on the exploitation of tree bark extract for food applications (Table 1.6). Pine bark extract is a source of flavanols and flavonoids such as catechin and taxifolin and have been used as antioxidant in meat industry (Mármol, Quero, Jiménez-Moreno, Rodríguez-Yoldi, & Ancín-Azpilicueta, 2019). Han, Yu, and Wang (2018) observed that pine bark extract is a good source of oligomeric procyanidins and has excellent antioxidant activity. These authors used this extract into packaging films which showed the antimicrobial and improved barrier properties. Edible films were prepared from hydroxypropyl methylcellulose and K-carrageen and incorporated with cork bark extract (Zhang, Sun, Li, & Wang, 2021). The developed packaging films incorporated with bark extract were endowed with potential antimicrobial and antioxidant properties. Tayel and El-tras (2012) used cinnamon bark extract in ground beef. Antimicrobial and antioxidant properties of *Citrus paradise* fruit bark extracts were investigated in turkey sausage. The results demonstrate that bark extracts reduced the lipid oxidation and microbial storage of turkey sausage during storage (Sayari et al., 2015).

Table 1.5 Application of flower extracts in food industry.

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Litchi	*Litchi*	*Chinensis*	Antioxidant	Pork meatballs	Reduced lipid peroxidation and protein degradation in meat balls	Ding et al. (2015)
Marigold	*Tagetes*	*Erecta*	Antioxidant	Fatty foods	Reduces oxidative rancidity	Samsudin et al. (2014)
Meadowsweet	*Filipendulae*	*Ulmariae*	Antimicrobial	Apple fruit	Protects fruit from bacterial and mold growth	Gniewosz et al. (2014)
Bitter orange	*Citrus*	*Aurantium*	Antimicrobial	Rice pudding	Potential preservative against food spoilage microorganisms	Degirmenci and Erkurt (2020)
Florist's daisy	*Chrysanthemum*	*Morifolium*	Preservative	Goat meat patties	Reduces formation of heterocyclic amines in pan and deep fat frying	Khan et al. (2019)
Broccoli	*Brassica*	*Oleracea*	Antioxidant Nutrient enhancer	Goat meat nuggets	Reduced TBARS value, improves phenolic content	Banerjee et al. (2012)
Hibiscus	*Hibiscus*	*Sabdariffa*	Antioxidant	Fermented sausage	Reduced TBARS value and biogenic amine formation	Karabacak and Bozkurt (2008)

Table 1.6 Application of bark extracts in food industry.

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Pine bark	*Pinus*	*Densiflora*	Antioxidant	Meat	Inhibit protein and lipid oxidation in meat	Mármol et al. (2019)
			Antioxidant	Packaging films	Extract improved thermal stability, water and oxygen barrier properties of films	Han et al. (2018)
Grapefruit	*Citrus*	*Paradisi*	Antioxidant Antimicrobial	Sausage	Minimize lipid oxidation and improve microbial stability	Sayari et al. (2015)
Cork bark	*Quercus*	*Suber*	Packaging aid	Packaging films	Enhanced flexibility and light resistance of films, improved antioxidant and antimicrobial properties	Zhang et al. (2021)
Cinnamon	Cinnamomum	Verum	Antimicrobial Antioxidant	Raw pork	Reduce number of pathogenic bacteria and lipid oxidation in raw pork	Shan et al. (2009)
			Antioxidant	Chicken meat	Improves oxidative stability and redness of chicken meat balls	Chan et al. (2014)

1.2.7 Roots

Roots have been studied for their potential health benefits as they are rich source of phytochemical compounds. Root extracts have been also used in various food applications (Table 1.7). Chinese chive (*A. tuberosum*) root extract is a good source of polyphenols and antimicrobial compounds (Riaz et al., 2020). Chive root extract has been used in packaging films in the food industry. The incorporation of liquorice extract into biocomposite films prevents the food from lipid oxidation (Singh, Agrawal, Mendiratta, & Chauhan, 2021). Chicory root extract shows potential antimicrobial activity in biodegradable starch films (Jaśkiewicz et al., 2020). The utilization of lotus root extract in the pork patties led to the inhibition of lipid oxidation (Shin, Choe, Hwang, Kim, & Jo, 2019).

Table 1.7 Application of root extracts in food industry.

Plant	*Genus*	*Species*	Uses	Application industries	Remarks	References
Chinese chive	*Allium*	*Tuberosum*	Antimicrobial Antioxidant	Packaging films	Extract improved physical properties, decreased water vapor permeability, films exhibited good antioxidant and antimicrobial property	Riaz et al. (2020)
Beetroot	*Beta*	*Vulgaris*	Antioxidant	Packaging films	Protect polymer against photo-degradation, plasticizing property	Akhtar et al. (2012)
Carrot	*Daucus*	*Carota*	Antioxidant	Packaging films	Protect polymer against photo-degradation, plasticizing property	Akhtar et al. (2012)
Licorice	*Glycyrrhiza*	*Glabra*	Antioxidant antimicrobial	Packaging films for chhana balls	Protects against microbial spoilage and lipid oxidaiton	Singh et al. (2021)
Hooker chives	*Allium*	*Hookeri*	Preservative	Pork patties	Retards lipid oxidation	Cho et al. (2015)
Lotus	*Nelumbo*	*Nucifera*	Antioxidant	Pork patties	Reduces oxidative rancidity	Shin et al. (2019)
Kudzu	*Pueraria*	*Radix*	Nutrient enhancer	Beef patties	Increased nutritive value of patties	Kumari, Raines, Martin, and Rodriguez (2015)
Chicory	*Cichorium*	*Intybus*	Antimicrobial	Packaging films	Broad-spectrum inhibitory effect on microbial growth	Jaśkiewicz et al. (2020)

Beetroot is known as a health promoting food due to the presence of special compounds such as phenolics, carotenoids, vitamins, ascorbic acids, and betalains that promote health. The beetroot extract is used as a coloring and antioxidant agent in different types of food products such as jams, jellies, breakfast cereals, ketchups, dairy products, candy, etc. (Chhikara, Kushwaha, Sharma, Gat, & Panghal, 2019). Akhtar et al. (2012) exploited beetroot and carrot extracts in the hydroxypropyl methylcellulose film.

1.3 Conclusion

In the food industry, various synthetic additives are used as antimicrobial, antioxidant, flavoring, and coloring agents. However, the use of synthetic additives is limited because of their negative health effects. Recently, plant extracts have gained increased popularity in the food industry and

will reduce the application of artificial additives. Furthermore, the demand from consumer and market trend for natural additives leads to the identification and extraction of compounds from plant sources. In this regard, extracts from fruits and vegetables, spices and herbs and plantation crops are being used for different applications in the food industry as preservative, nutrient enhancer, as well as coloring and flavoring agents.

References

Akarpat, A., Turhan, S., & Ustun, N. S. (2008). Effects of hot-water extracts from myrtle, rosemary, nettle and lemon balm leaves on lipid oxidation and color of beef patties during frozen storage. *Journal of Food Processing and Preservation*, *32*(1), 117−132.

Akhtar, M. J., Jacquot, M., Jasniewski, J., Jacquot, C., Imran, M., Jamshidian, M., & Desobry, S. (2012). Antioxidant capacity and light-aging study of HPMC films functionalized with natural plant extract. *Carbohydrate Polymers*, *89*(4), 1150−1158.

Albuquerque, B. R., Pereira, C., Calhelha, R. C., Alves, M. J., Abreu, R. M., Barros, L., & Ferreira, I. C. (2020). Jabuticaba residues (Myrciaria jaboticaba (Vell.) Berg) are rich sources of valuable compounds with bioactive properties. *Food Chemistry*, *309*, 125735.

Aliyari, P., Bakhshi Kazaj, F., Barzegar, M., & Ahmadi Gavlighi, H. (2020). Production of functional sausage using pomegranate peel and pistachio green hull extracts as natural preservatives. *Journal of Agricultural Science and Technology*, *22*(1), 159−172.

Al-Juhaimi, F., Babtain, I. A., Ahmed, I. A. M., Alsawmahi, O. N., Ghafoor, K., Adiamo, O. Q., & Babiker, E. E. (2020). Assessment of oxidative stability and physicochemical, microbiological, and sensory properties of beef patties formulated with baobab seed (Adansonia digitata) extract. *Meat Science*, *162*, 108044.

Alp, E., & Aksu, M. İ. (2010). Effects of water extract of Urtica dioica L. and modified atmosphere packaging on the shelf life of ground beef. *Meat Science*, *86*(2), 468−473.

Altunkaya, A., Hedegaard, R. V., Harholt, J., Brimer, L., Gökmen, V., & Skibsted, L. H. (2013). Oxidative stability and chemical safety of mayonnaise enriched with grape seed extract. *Food & Function*, *4*(11), 1647−1653.

Banerjee, R., Verma, A. K., Das, A. K., Rajkumar, V., Shewalkar, A. A., & Narkhede, H. P. (2012). Antioxidant effects of broccoli powder extract in goat meat nuggets. *Meat Science*, *91*(2), 179−184.

Banon, S., Díaz, P., Rodríguez, M., Garrido, M. D., & Price, A. (2007). Ascorbate, green tea and grape seed extracts increase the shelf life of low sulphite beef patties. *Meat Science*, *77*(4), 626−633.

Bastante, C. C., Silva, N. H., Cardoso, L. C., Serrano, C. M., de la Ossa, E. J. M., Freire, C. S., & Vilela, C. (2021). Biobased films of nanocellulose and mango leaf extract for active food packaging: Supercritical impregnation vs solvent casting. *Food Hydrocolloids*, *117*, 106709.

Bastida, S., Sánchez-Muniz, F. J., Olivero, R., Pérez-Olleros, L., Ruiz-Roso, B., & Jiménez-Colmenero, F. (2009). Antioxidant activity of Carob fruit extracts in cooked pork meat systems during chilled and frozen storage. *Food Chemistry*, *116*(3), 748−754.

Bellucci, E. R. B., Munekata, P. E., Pateiro, M., Lorenzo, J. M., & da Silva Barretto, A. C. (2021). Red pitaya extract as natural antioxidant in pork patties with total replacement of animal fat. *Meat Science*, *171*, 108284.

Biswas, A. K., Chatli, M. K., & Sahoo, J. (2012). Antioxidant potential of curry (Murraya koenigii L.) and mint (Mentha spicata) leaf extracts and their effect on color and oxidative stability of raw ground pork meat during refrigeration storage. *Food Chemistry*, *133*(2), 467−472.

Botsoglou, E., Govaris, A., Ambrosiadis, I., Fletouris, D., & Botsoglou, N. (2014). Effect of olive leaf (Olea europea L.) extracts on protein and lipid oxidation of long-term frozen n-3 fatty acids-enriched pork patties. *Meat Science*, *98*(2), 150−157.

Brannan, R. G., & Mah, E. (2007). Grape seed extract inhibits lipid oxidation in muscle from different species during refrigerated and frozen storage and oxidation catalyzed by peroxynitrite and iron/ascorbate in a pyrogallol red model system. *Meat Science*, *77*(4), 540−546.

Chan, K. W., Khong, N. M., Iqbal, S., Ch'Ng, S. E., Younas, U., & Babji, A. S. (2014). 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*, *51*(11), 3269−3276.

Chen, Y., Wen, J., Deng, Z., Pan, X., Xie, X., & Peng, C. (2020). Effective utilization of food wastes: Bioactivity of grape seed extraction and its application in food industry. *Journal of Functional Foods*, *73*, 104113.

Chhikara, N., Kushwaha, K., Sharma, P., Gat, Y., & Panghal, A. (2019). Bioactive compounds of beetroot and utilization in food processing industry: A critical review. *Food Chemistry*, *272*, 192−200.

Cho, H. S., Park, W., Hong, G. E., Kim, J. H., Ju, M. G., & Lee, C. H. (2015). Antioxidant activity of Allium hookeri root extract and its effect on lipid stability of sulfur-fed pork patties. *Korean Journal for Food Science of Animal Resources*, *35*(1), 41.

Choe, J. H., Jang, A., Lee, E. S., Choi, J. H., Choi, Y. S., Han, D. J., & Kim, C. J. (2011). Oxidative and color stability of cooked ground pork containing lotus leaf (Nelumbo nucifera) and barley leaf (Hordeum vulgare) powder during refrigerated storage. *Meat Science*, *87*(1), 12−18.

Choulitoudi, E., Velliopoulou, A., Tsimogiannis, D., & Oreopoulou, V. (2020). Effect of active packaging with Satureja thymbra extracts on the oxidative stability of fried potato chips. *Food Packaging and Shelf Life*, *23*, 100455.

Colindres, P., & Susan Brewer, M. (2011). Oxidative stability of cooked, frozen, reheated beef patties: Effect of antioxidants. *Journal of the Science of Food and Agriculture*, *91*(5), 963−968.

Colle, M. C., Richard, R. P., Smith, D. M., Colle, M. J., Loucks, W. I., Gray, S. J., & Doumit, M. E. (2019). Dry potato extracts improve water holding capacity, shelf life, and sensory characteristics of fresh and precooked beef patties. *Meat Science*, *149*, 156−162.

Cunha, L. C., Monteiro, M. L. G., Costa-Lima, B. R., Guedes-Oliveira, J. M., Alves, V. H., Almeida, A. L., … Conte-Junior, C. A. (2018). Effect of microencapsulated extract of pitaya (Hylocereus costaricensis) peel on color, texture and oxidative stability of refrigerated ground pork patties submitted to high pressure processing. *Innovative Food Science & Emerging Technologies*, *49*, 136−145.

Cunha, L. C. M., Monteiro, M. L. G., da Costa-Lima, B. R. C., Guedes-Oliveira, J. M., Rodrigues, B. L., Fortunato, A. R., & Conte-Junior, C. A. (2021). Effect of microencapsulated extract of pitaya (*Hylocereus costaricensis*) peel on oxidative quality parameters of refrigerated ground pork patties subjected to UV-C radiation. *Journal of Food Processing and Preservation*, *45*(3), e15272.

da Rosa, G. S., Vanga, S. K., Gariepy, Y., & Raghavan, V. (2020). Development of biodegradable films with improved antioxidant properties based on the addition of carrageenan containing olive leaf extract for food packaging applications. *Journal of Polymers and the Environment*, *28*(1), 123−130.

Das, A. K., Rajkumar, V., Verma, A. K., & Swarup, D. (2012). Moringa oleiferia leaves extract: A natural antioxidant for retarding lipid peroxidation in cooked goat meat patties. *International Journal of Food Science & Technology*, *47*(3), 585−591.

de Dicastillo, C. L., Bustos, F., Guarda, A., & Galotto, M. J. (2016). Cross-linked methyl cellulose films with murta fruit extract for antioxidant and antimicrobial active food packaging. *Food Hydrocolloids*, *60*, 335−344.

Degirmenci, H., & Erkurt, H. (2020). Chemical profile and antioxidant potency of Citrus aurantium L. flower extracts with antibacterial effect against foodborne pathogens in rice pudding. *LWT*, *126*, 109273.

Deolindo, C. T. P., Monteiro, P. I., Santos, J. S., Cruz, A. G., da Silva, M. C., & Granato, D. (2019). Phenolic-rich Petit Suisse cheese manufactured with organic Bordeaux grape juice, skin, and seed extract: Technological, sensory, and functional properties. *LWT*, *115*, 108493.

Devatkal, S. K., Narsaiah, K., & Borah, A. (2010). Anti-oxidant effect of extracts of kinnow rind, pomegranate rind and seed powders in cooked goat meat patties. *Meat Science*, *85*(1), 155−159.

Devatkal, S. K., Thorat, P., & Manjunatha, M. (2014). Effect of vacuum packaging and pomegranate peel extract on quality aspects of ground goat meat and nuggets. *Journal of Food Science and Technology*, *51*(10), 2685−2691.

Ding, Y., Wang, S. Y., Yang, D. J., Chang, M. H., & Chen, Y. C. (2015). Alleviative effects of litchi (Litchi chinensis Sonn.) flower on lipid peroxidation and protein degradation in emulsified pork meatballs. *Journal of Food and Drug Analysis*, *23*(3), 501−508.

Emam-Djomeh, Z., Moghaddam, A., & Yasini Ardakani, S. A. (2015). Antimicrobial activity of pomegranate (Punica granatum L.) peel extract, physical, mechanical, barrier and antimicrobial properties of pomegranate peel extract-incorporated sodium caseinate film and application in packaging for ground beef. *Packaging Technology and Science*, *28*(10), 869−881.

Ferysiuk, K., Wójciak, K. M., Materska, M., Chilczuk, B., & Pabich, M. (2020). Modification of lipid oxidation and antioxidant capacity in canned refrigerated pork with a nitrite content reduced by half and addition of sweet pepper extract. *LWT*, *118*, 108738.

Gniewosz, M., Synowiec, A., Kraśniewska, K., Przybył, J. L., Bączek, K., & Węglarz, Z. (2014). The antimicrobial activity of pullulan film incorporated with meadowsweet flower extracts (Filipendulae ulmariae flos) on postharvest quality of apples. *Food Control*, *37*, 351−361.

Gokoglu, N., & Yerlikaya, P. (2008). Inhibition effects of grape seed extracts on melanosis formation in shrimp (Parapenaeus longirostris). *International Journal of Food Science & Technology*, *43*(6), 1004−1008.

Guo, Y., Huang, J., Chen, Y., Hou, Q., & Huang, M. (2020). Effect of grape seed extract combined with modified atmosphere packaging on the quality of roast chicken. *Poultry Science*, *99*(3), 1598−1605.

Han, H. S., & Song, K. B. (2021a). Antioxidant properties of watermelon (Citrullus lanatus) rind pectin films containing kiwifruit (Actinidia chinensis) peel extract and their application as chicken thigh packaging. *Food Packaging and Shelf Life*, *28*, 100636.

Han, H. S., & Song, K. B. (2021b). Noni (Morinda citrifolia) fruit polysaccharide films containing blueberry (Vaccinium corymbosum) leaf extract as an antioxidant packaging material. *Food Hydrocolloids*, *112*, 106372.

Han, J., & Rhee, K. S. (2005). Antioxidant properties of selected Oriental non-culinary/nutraceutical herb extracts as evaluated in raw and cooked meat. *Meat Science*, *70*(1), 25−33.

Han, Y., Yu, M., & Wang, L. (2018). Bio-based films prepared with soybean by-products and pine (Pinus densiflora) bark extract. *Journal of Cleaner Production*, *187*, 1−8.

Hao, M., & Beta, T. (2012). Development of Chinese steamed bread enriched in bioactive compounds from barley hull and flaxseed hull extracts. *Food Chemistry*, *133*(4), 1320−1325.

Hauser, C., Peñaloza, A., Guarda, A., Galotto, M. J., Bruna, J. E., & Rodríguez, F. J. (2016). Development of an active packaging film based on a methylcellulose coating containing murta (Ugni molinae turcz) leaf extract. *Food and Bioprocess Technology*, *9*(2), 298−307.

Hayes, J. E., Stepanyan, V., Allen, P., O'grady, M. N., & Kerry, J. P. (2011). Evaluation of the effects of selected plant-derived nutraceuticals on the quality and shelf-life stability of raw and cooked pork sausages. *LWT-Food Science and Technology*, *44*(1), 164−172.

Hayes, J. E., Stepanyan, V., O'Grady, M. N., Allen, P., & Kerry, J. P. (2010). Evaluation of the effects of selected phytochemicals on quality indices and sensorial properties of raw and cooked pork stored in different packaging systems. *Meat Science*, *85*(2), 289−296.

Hedayati, S., Niakousari, M., Damyeh, M. S., Mazloomi, S. M., Babajafari, S., & Ansarifar, E. (2021). Selection of appropriate hydrocolloid for eggless cakes containing chubak root extract using multiple criteria decision-making approach. *LWT*, *141*, 110914.

Hollis, F. H., Denney, S., Halfacre, J., Jackson, T., Link, A., & Orr, D. (2020). Human perception of fresh produce treated with grape seed extract: A preliminary study. *Journal of Sensory Studies*, *35*(2), e12554.

Huang, B., He, J., Ban, X., Zeng, H., Yao, X., & Wang, Y. (2011). Antioxidant activity of bovine and porcine meat treated with extracts from edible lotus (Nelumbo nucifera) rhizome knot and leaf. *Meat Science*, *87* (1), 46–53.

Jang, S. A., Shin, Y. J., & Song, K. B. (2011). Effect of rapeseed protein–gelatin film containing grapefruit seed extract on 'Maehyang'strawberry quality. *International Journal of Food Science & Technology*, *46* (3), 620–625.

Jaśkiewicz, A., Budryn, G., Nowak, A., & Efenberger-Szmechtyk, M. (2020). Novel biodegradable starch film for food packaging with antimicrobial chicory root extract and phytic acid as a cross-linking agent. *Foods*, *9*(11), 1696.

Jayawardana, B. C., Hirano, T., Han, K. H., Ishii, H., Okada, T., Shibayama, S., & Shimada, K. I. (2011). Utilization of adzuki bean extract as a natural antioxidant in cured and uncured cooked pork sausages. *Meat Science*, *89*(2), 150–153.

Jridi, M., Abdelhedi, O., Salem, A., Kechaou, H., Nasri, M., & Menchari, Y. (2020). Physicochemical, antioxidant and antibacterial properties of fish gelatin-based edible films enriched with orange peel pectin: Wrapping application. *Food Hydrocolloids*, *103*, 105688.

Kanatt, S. R. (2020). Development of active/intelligent food packaging film containing Amaranthus leaf extract for shelf life extension of chicken/fish during chilled storage. *Food Packaging and Shelf Life*, *24*, 100506.

Kanatt, S. R., Chander, R., & Sharma, A. (2008). Chitosan and mint mixture: A new preservative for meat and meat products. *Food Chemistry*, *107*(2), 845–852.

Kanatt, S. R., Rao, M. S., Chawla, S. P., & Sharma, A. (2012). Active chitosan–polyvinyl alcohol films with natural extracts. *Food Hydrocolloids*, *29*(2), 290–297.

Kanmani, P., & Rhim, J. W. (2014). Antimicrobial and physical-mechanical properties of agar-based films incorporated with grapefruit seed extract. *Carbohydrate Polymers*, *102*, 708–716.

Karabacak, S., & Bozkurt, H. (2008). Effects of Urtica dioica and Hibiscus sabdariffa on the quality and safety of sucuk (Turkish dry-fermented sausage). *Meat Science*, *78*(3), 288–296.

Khan, I. A., Liu, D., Yao, M., Memon, A., Huang, J., & Huang, M. (2019). Inhibitory effect of Chrysanthemum morifolium flower extract on the formation of heterocyclic amines in goat meat patties cooked by various cooking methods and temperatures. *Meat Science*, *147*, 70–81.

Kim, J. S. (2000). Functional beef product containing rice bran extracts influence cholesterol oxidation and nutritional profile. *Food Industry and Nutrition*, *5*(3), 66–73.

Kim, S. J., Cho, A. R., & Han, J. (2013). Antioxidant and antimicrobial activities of leafy green vegetable extracts and their applications to meat product preservation. *Food Control*, *29*(1), 112–120.

Kõrge, K., Bajić, M., Likozar, B., & Novak, U. (2020). Active chitosan–chestnut extract films used for packaging and storage of fresh pasta. *International Journal of Food Science & Technology*, *55*(8), 3043–3052.

Kõrge, K., Šeme, H., Bajić, M., Likozar, B., & Novak, U. (2020). Reduction in spoilage microbiota and cyclopiazonic acid mycotoxin with chestnut extract enriched chitosan packaging: Stability of inoculated Gouda Cheese. *Foods*, *9*(11), 1645.

Kulkarni, S., DeSantos, F. A., Kattamuri, S., Rossi, S. J., & Brewer, M. S. (2011). Effect of grape seed extract on oxidative, color and sensory stability of a pre-cooked, frozen, re-heated beef sausage model system. *Meat Science*, *88*(1), 139–144.

Kumari, S., Raines, J. M., Martin, J. M., & Rodriguez, J. M. (2015). Thermal stability of kudzu root (Pueraria radix) isoflavones as additives to beef patties. *Journal of Food Science and Technology*, *52*(3), 1578–1585.
Lavado, G., Ladero, L., & Cava, R. (2021). Cork oak (*Quercus suber* L.) leaf extracts potential use as natural antioxidants in cooked meat. *Industrial Crops and Products*, *160*, 113086.
Li, J. H., Miao, J., Wu, J. L., Chen, S. F., & Zhang, Q. Q. (2014). Preparation and characterization of active gelatin-based films incorporated with natural antioxidants. *Food Hydrocolloids*, *37*, 166–173.
Lim, G. O., Jang, S. A., & Song, K. B. (2010). Physical and antimicrobial properties of Gelidium corneum/nano-clay composite film containing grapefruit seed extract or thymol. *Journal of Food Engineering*, *98*(4), 415–420.
Lin, C., Toto, C., & Were, L. (2015). Antioxidant effectiveness of ground roasted coffee in raw ground top round beef with added sodium chloride. *LWT-Food Science and Technology*, *60*(1), 29–35.
Mármol, I., Quero, J., Jiménez-Moreno, N., Rodríguez-Yoldi, M. J., & Ancín-Azpilicueta, C. (2019). A systematic review of the potential uses of pine bark in food industry and health care. *Trends in Food Science & Technology*, *88*, 558–566.
Martiny, T. R., Raghavan, V., Moraes, C. C. D., Rosa, G. S. D., & Dotto, G. L. (2020). Bio-based active packaging: Carrageenan film with olive leaf extract for lamb meat preservation. *Foods*, *9*(12), 1759.
Moghadam, M., Salami, M., Mohammadian, M., Khodadadi, M., & Emam-Djomeh, Z. (2020). Development of antioxidant edible films based on mung bean protein enriched with pomegranate peel. *Food Hydrocolloids*, *104*, 105735.
Mohamed, H. M., Mansour, H. A., & Farag, M. D. E. D. H. (2011). The use of natural herbal extracts for improving the lipid stability and sensory characteristics of irradiated ground beef. *Meat Science*, *87*(1), 33–39.
Moraczewski, K., Stepczyńska, M., Malinowski, R., Karasiewicz, T., Jagodziński, B., & Rytlewski, P. (2019). The effect of accelerated aging on polylactide containing plant extracts. *Polymers*, *11*(4), 575.
Muthukumar, M., Naveena, B. M., Vaithiyanathan, S., Sen, A. R., & Sureshkumar, K. (2014). Effect of incorporation of Moringa oleifera leaves extract on quality of ground pork patties. *Journal of Food Science and Technology*, *51*(11), 3172–3180.
Norajit, K., Kim, K. M., & Ryu, G. H. (2010). Comparative studies on the characterization and antioxidant properties of biodegradable alginate films containing ginseng extract. *Journal of Food Engineering*, *98*(3), 377–384.
Nouri, L., & Nafchi, A. M. (2014). Antibacterial, mechanical, and barrier properties of sago starch film incorporated with betel leaves extract. *International Journal of Biological Macromolecules*, *66*, 254–259.
Özünlü, O., Ergezer, H., & Gökçe, R. (2018). Improving physicochemical, antioxidative and sensory quality of raw chicken meat by using acorn extracts. *LWT*, *98*, 477–484.
Özvural, E. B., & Vural, H. (2012). The effects of grape seed extract on quality characteristics of frankfurters. *Journal of Food Processing and Preservation*, *36*(4), 291–297.
Pateiro, M., Vargas, F. C., Chincha, A. A., Sant'Ana, A. S., Strozzi, I., Rocchetti, G., & Lorenzo, J. M. (2018). Guarana seed extracts as a useful strategy to extend the shelf life of pork patties: UHPLC-ESI/QTOF phenolic profile and impact on microbial inactivation, lipid and protein oxidation and antioxidant capacity. *Food Research International*, *114*, 55–63.
Rababah, T. M., Ereifej, K. I., Alhamad, M. N., Al-Qudah, K. M., Rousan, L. M., Al-Mahasneh, M. A., & Yang, W. (2011). Effects of green tea and grape seed and TBHQ on physicochemical properties of Baladi goat meats. *International Journal of Food Properties*, *14*(6), 1208–1216.
Rahman, M. H., Alam, M. S., Monir, M. M., & Ahmed, K. (2021). Comprehensive effects of black cumin (Nigella sativa) and synthetic antioxidant on sensory and physicochemical quality of beef patties during refrigerant storage. *Journal of Agriculture and Food Research*, *4*, 100145.
Rambabu, K., Bharath, G., Banat, F., Show, P. L., & Cocoletzi, H. H. (2019). Mango leaf extract incorporated chitosan antioxidant film for active food packaging. *International Journal of Biological Macromolecules*, *126*, 1234–1243.

Reddy, G. B., Sen, A. R., Nair, P. N., Reddy, K. S., Reddy, K. K., & Kondaiah, N. (2013). Effects of grape seed extract on the oxidative and microbial stability of restructured mutton slices. *Meat Science*, *95*(2), 288–294.

Riaz, A., Lagnika, C., Luo, H., Dai, Z., Nie, M., Hashim, M. M., & Li, D. (2020). Chitosan-based biodegradable active food packaging film containing Chinese chive (Allium tuberosum) root extract for food application. *International Journal of Biological Macromolecules*, *150*, 595–604.

Rodríguez, G. M., Sibaja, J. C., Espitia, P. J., & Otoni, C. G. (2020). Antioxidant active packaging based on papaya edible films incorporated with Moringa oleifera and ascorbic acid for food preservation. *Food Hydrocolloids*, *103*, 105630.

Rojas, M. C., & Brewer, M. S. (2007). Effect of natural antioxidants on oxidative stability of cooked, refrigerated beef and pork. *Journal of Food Science*, *72*(4), S282–S288.

Rojas, M. C., & Brewer, M. S. (2008). Effect of natural antioxidants on oxidative stability of frozen, vacuum-packaged beef and pork. *Journal of Food Quality*, *31*(2), 173–188.

Sampaio, S. L., Petropoulos, S. A., Alexopoulos, A., Heleno, S. A., Santos-Buelga, C., Barros, L., & Ferreira, I. C. (2020). Potato peels as sources of functional compounds for the food industry: A review. *Trends in Food Science & Technology*, *103*, 118–129.

Samsudin, H., Soto-Valdez, H., & Auras, R. (2014). Poly (lactic acid) film incorporated with marigold flower extract (Tagetes erecta) intended for fatty-food application. *Food Control*, *46*, 55–66.

Sayari, N., Sila, A., Balti, R., Abid, E., Hajlaoui, K., Nasri, M., & Bougatef, A. (2015). Antioxidant and antibacterial properties of Citrus paradisi barks extracts during turkey sausage formulation and storage. *Biocatalysis and Agricultural Biotechnology*, *4*(4), 616–623.

Sebranek, J. G., Sewalt, V. J. H., Robbins, K., & Houser, T. A. (2005). Comparison of a natural rosemary extract and BHA/BHT for relative antioxidant effectiveness in pork sausage. *Meat Science*, *69*(2), 289–296.

Shah, M. A., Bosco, S. J. D., & Mir, S. A. (2015). Effect of Moringa oleifera leaf extract on the physicochemical properties of modified atmosphere packaged raw beef. *Food Packaging and Shelf Life*, *3*, 31–38.

Shan, B., Cai, Y. Z., Brooks, J. D., & Corke, H. (2009). Antibacterial and antioxidant effects of five spice and herb extracts as natural preservatives of raw pork. *Journal of the Science of Food and Agriculture*, *89*(11), 1879–1885.

Shin, D. J., Choe, J., Hwang, K. E., Kim, C. J., & Jo, C. (2019). Antioxidant effects of lotus (Nelumbo nucifera) root and leaf extracts and their application on pork patties as inhibitors of lipid oxidation, alone and in combination. *International Journal of Food Properties*, *22*(1), 383–394.

Singh, T. P., Agrawal, R. K., Mendiratta, S. K., & Chauhan, G. (2021). Preparation and characterization of licorice root extract infused bio-composite film and their application on storage stability of chhana balls-a Sandesh like product. *Food Control*, *125*, 107993.

Siripatrawan, U., & Harte, B. R. (2010). Physical properties and antioxidant activity of an active film from chitosan incorporated with green tea extract. *Food Hydrocolloids*, *24*(8), 770–775.

Sivarooban, T., Hettiarachchy, N. S., & Johnson, M. G. (2008). Physical and antimicrobial properties of grape seed extract, nisin, and EDTA incorporated soy protein edible films. *Food Research International*, *41*(8), 781–785.

Song, H. Y., Shin, Y. J., & Song, K. B. (2012). Preparation of a barley bran protein–gelatin composite film containing grapefruit seed extract and its application in salmon packaging. *Journal of Food Engineering*, *113*(4), 541–547.

Šulniūtė, V., Jaime, I., Rovira, J., & Venskutonis, P. R. (2016). Rye and wheat bran extracts isolated with pressurized solvents increase oxidative stability and antioxidant potential of beef meat hamburgers. *Journal of Food Science*, *81*(2), H519–H527.

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. *Journal of Food Processing and Preservation*, *38*(1), 31–38.

Tan, Y. M., Lim, S. H., Tay, B. Y., Lee, M. W., & Thian, E. S. (2015). Functional chitosan-based grapefruit seed extract composite films for applications in food packaging technology. *Materials Research Bulletin*, *69*, 142–146.

Tayel, A. A., & El-tras, W. F. (2012). Plant extracts as potent biopreservatives for Salmonella typhimurium control and quality enhancement in ground beef. *Journal of Food Safety*, *32*(1), 115–121.

Tengilimoglu-Metin, M. M., Hamzalioglu, A., Gokmen, V., & Kizil, M. (2017). Inhibitory effect of hawthorn extract on heterocyclic aromatic amine formation in beef and chicken breast meat. *Food Research International*, *99*, 586–595.

Turan, E., & Şimşek, A. (2021). Effects of lyophilized black mulberry water extract on lipid oxidation, metmyoglobin formation, color stability, microbial quality and sensory properties of beef patties stored under aerobic and vacuum packaging conditions. *Meat Science*, 108522.

Villalobos-Delgado, L. H., González-Mondragón, E. G., Ramírez-Andrade, J., Salazar-Govea, A. Y., & Santiago-Castro, J. T. (2020). Oxidative stability in raw, cooked, and frozen ground beef using Epazote (Chenopodium ambrosioides L.). *Meat Science*, *168*, 108187.

Wambura, P., Yang, W., & Mwakatage, N. R. (2011). Effects of sonication and edible coating containing rosemary and tea extracts on reduction of peanut lipid oxidative rancidity. *Food and Bioprocess Technology*, *4*(1), 107–115.

Wang, K., Lim, P. N., Tong, S. Y., & San Thian, E. (2019). Development of grapefruit seed extract-loaded poly (ε-caprolactone)/chitosan films for antimicrobial food packaging. *Food Packaging and Shelf Life*, *22*, 100396.

Wang, L., Wang, Q., Tong, J., & Zhou, J. (2017). Physicochemical properties of chitosan films incorporated with honeysuckle flower extract for active food packaging. *Journal of Food Process Engineering*, *40*(1), e12305.

Wang, S., Marcone, M., Barbut, S., & Lim, L. T. (2012). The impact of anthocyanin-rich red raspberry extract (ARRE) on the properties of edible soy protein isolate (SPI) films. *Journal of Food Science*, *77*(4), C497–C505.

Wang, Z., Cheng, Y., Zeng, M., Wang, Z., Qin, F., Wang, Y., & He, Z. (2021). Lotus (Nelumbo nucifera Gaertn.) leaf: A narrative review of its Phytoconstituents, health benefits and food industry applications. *Trends in Food Science & Technology*, *112*, 631–650.

Wójciak, K. M., Dolatowski, Z. J., & Okoń, A. (2011). The effect of water plant extracts addition on the oxidative stability of meat products. *Acta Scientiarum Polonorum Technologia Alimentaria*, *10*(2), 175–188.

Yu, J., Ahmedna, M., & Goktepe, I. (2010). Potential of peanut skin phenolic extract as antioxidative and antibacterial agent in cooked and raw ground beef. *International Journal of Food Science & Technology*, *45*(7), 1337–1344.

Zhang, C., Guo, K., Ma, Y., Ma, D., Li, X., & Zhao, X. (2010). Incorporations of blueberry extracts into soybean-protein-isolate film preserve qualities of packaged lard. *International Journal of Food Science & Technology*, *45*(9), 1801–1806.

Zhang, C., Sun, G., Li, J., & Wang, L. (2021). A green strategy for maintaining intelligent response and improving antioxidant properties of κ-carrageenan-based film via cork bark extractive addition. *Food Hydrocolloids*, *113*, 106470.

Zhang, H., Kong, B., Xiong, Y. L., & Sun, X. (2009). Antimicrobial activities of spice extracts against pathogenic and spoilage bacteria in modified atmosphere packaged fresh pork and vacuum packaged ham slices stored at 4 C. *Meat Science*, *81*(4), 686–692.

Zhang, W., Li, X., & Jiang, W. (2020). Development of antioxidant chitosan film with banana peels extract and its application as coating in maintaining the storage quality of apple. *International Journal of Biological Macromolecules*, *154*, 1205–1214.