CHAPTER

6 Plant extracts as food preservatives

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6.1 Introduction

Food preservation is a process in which food quality and safety are increased. Food is handled and treated in such a way to prevent or delay spoilage and prevent foodborne illnesses. The spoilage may be due to the inherent food properties or due to the microbial spoilage while the pathogenic microorganisms are responsible for various foodborne diseases. Different methods of preservation have been employed to overcome these problems. Among these methods, food preservatives have been used for a long time. Food preservatives may be categorized into antimicrobials, antioxidants, and antibrowning agents.

Antimicrobials are used to inhibit or prevent microbial growth in the food products, and their use has increased in recent years due to food safety concerns arising from microbial contamination. The antioxidants are used to inhibit or prevent oxidation reactions and are used primarily to prevent autoxidation, which results in rancidity and off-flavor development in food products. Antibrowning agents are chemicals used to inhibit or prevent browning (enzymatic and nonenzymatic) reactions in food products (Branen, Davidson, Salminen, & Thorngate, 2002).

These preservatives may be synthetic or natural. Despite the efficiency to prevent food spoilage and foodborne diseases, the use of synthetic preservatives has led to the buildup of chemical residues in the food products and thus adversely affects human health (Nazir et al., 2017). Owing to the safety concerns of synthetic chemicals and growing concerns about food safety and natural ingredients, the use of synthetic chemical is in a decline, whereas the research on natural ingredients has increased. The natural ingredients used in food preservation are obtained from plants as they are abundant and provide a wide range of ingredients needed for preservation. Almost every plant has been used in the form of extracts and evaluated for preservation in many food products.

Plant materials are used for the preparation of extracts using different types of techniques. These involve different types of solvents, procedures, and equipment to extract the bioactive components from the plant materials. These extraction methods are aimed to provide the extract with maximum yield and the highest quality. These extracts from plant sources are rich in various bioactive components and thus can be used to replace the synthetic preservatives. The antimicrobial properties of these extracts can be assessed by various microbiological tests, while the antioxidant properties are evaluated by using several chemical tests.

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6.2 Sources

Plants are a renewable source of materials used for the preparation of plant extracts (Tayel & El-Tras, 2012). Different plants or their parts/products are being assessed for their ability to use as natural preservatives. These natural preservatives are prepared from various plant sources such as fruits, vegetables, herbs, and spices. Table 6.1 shows the plant source along with the part used for the preparation of extracts.

6.3 Extraction

Extraction is an important step for the preparation of plant extracts from different types of plant materials. Different types of procedures and techniques are used for extraction and can be categorized into conventional and nonconventional methods. The conventional methods like maceration and soxhlet extraction method have been used since ancient times and is still in use. Nonconventional methods such as microwave assisted extraction, ultrasound assisted extraction, pressurized liquid extraction and supercritical fluid extraction gained the popularity for the extraction of plant extracts due to less use of chemicals and eco-friendly in nature.

The extraction process is aimed to increase the yield of a substance with superior quality. A general procedure to prepare a plant extract is that the plant material to be used for extraction, is cleaned, dried, and powdered and then extracted using a solvent (Fig. 6.1). Different solvents have been exploited for preparation of extracts. These solvents may be used either alone or in combination in different ratios. The main solvents are water, methanol, ethanol and acetone (Shah, Bosco, & Mir, 2014). Sometimes some additional processes like defatting may also be done depending on the plant material. The quality of the extract is greatly influenced by the solvent and the method of extraction employed for the preparation of plant extracts. Literature shows that the extraction method can affect the bioactivity of the extracts (Chan, Lim, & Omar, 2007; Ding et al., 2012; Kothari, Pathan, & Seshadri, 2010; Kothari, 2011; Sikora, Cieslik, Leszcznska, Filipiak-Florkiewicz, & Pisulewski, 2008; Upadhyay, Ramalakshmi, & Rao, 2012; Yeh et al., 2014).

There are several factors that affect the extraction efficiency such as the composition and structure of phytochemicals, the extraction technique employed, nature of the sample, the type of solvent used, and the interfering components present in the sample (Stalikas, 2007). The extract yield is affected by the nature of the solvent, pH, temperature, time of extraction and chemical composition and structure of the sample. When the time and temperature are kept constant, then solvent and sample composition were found to be the most significant factors affecting the extract yield (Turkmen, Sari, & Velioglu, 2006).

6.4 Plant extracts as antimicrobials

The contamination of foods with microorganisms results in spoilage of food and/or various foodborne diseases. These problems can be solved by the application of antimicrobial agents to the foods. The plant extracts are considered as natural antimicrobial agents. Many researchers have

Table 6.1 Plant sources and their parts used for the preparation of natural preservatives.

Source	Scientific name	Part used
Acanthopanax	*Acanthopanax sessiliflorum*	Leaf
Amla	*Emblica officianalis*	Fruit
Black seed	*Nigella sativa*	Seeds
Blackcurrant	*Ribes nigrum* L.	Leaf
Bok choy	*Brassica campestris* L.	Leaf
Broccoli	*Brassica oleracea*	Flowering head
Butterbur	*Petasites japonicus*	Leaf
Chamnamul	*Pimpinella brachycarpa*	Leaf
Chinese chives/Leek	*Allium tuberosum*	Leaf
Cherry	*Prunus cerasus* L.	Leaf
Cinnamon	*Cinnamomum verum*	Bark
Cinnamon stick	*Cinnamomum burmannii*	Cortex
Clove	*Eugenia caryophylata*	Bud
Crown daisy	*Chrysanthemum coronarium*	Leaf
Curry	*Murraya koenigii*	Leaf
Cyprus	*Citrus aurantium* L.	Flower
Date	*Phoenix dactylifera*	Pits
Drumstick	*Moringa oleifera*	Leaf
Eleutherine	*Eleutherine americana*	Bulb
Fatsia	*Aralia elata* Seem	Leaf
Fenugreek	*Trigonella foenum-graecum*	Seed
Garlic	*Allium sativum*	Aerial parts, bulb
Ginger	*Zingiber officinale*	Rhizome
Grape	*Vitis vinifera*	Seed, pomace
Green tea	*Camellia sinensis*	Leaf
Hyssop	*Hyssopus officinalis*	Leaf and secondary branches
Kinnow	*Citrus reticulate*	Peel
Lemon balm	*Melissa officinalis*	Leaf
Lemon grass	*Cymbopogon citratus*	Leaf
Licorice	*Glycyrrhiza glabra*	Root
Lotus	*Nelumbo nucifera*	Leaf, rhizome knot
Mint	*Mentha spicata*	Leaf
Mugwort extract	*Artemisia princeps*	Leaf
Myrtle	*Myrtus communis myrtillus*	Leaf
Nettle	*Urtica dioica*	Leaf, flower
Onion	*Allium cepa* L.	Bulb
Oregano	*Origanum vulgare*	Leaf
Peanut	*Arachis hypogaea*	Skin
Pomegranate	*Punica granatum*	Peel
Potato	*Solanum tuberosum*	Peel

(*Continued*)

Table 6.1 *Continued*

Source	Scientific name	Part used
Pumpkin	*Curcubita moschata*	Leaf
Roselle	*Hibiscus sabdariffa*	Flower
Rosemary	*Rosmarinus officinalis*	Leaf and secondary branches
Sea buckthorn	*Hippophae rhamnoides*	Seeds
Soybean	*Glycine max*	Leaf
Stonecrop	*Sedum sarmentosum*	Leaf
Summer savory	*Satureja hortensis*	Leaf

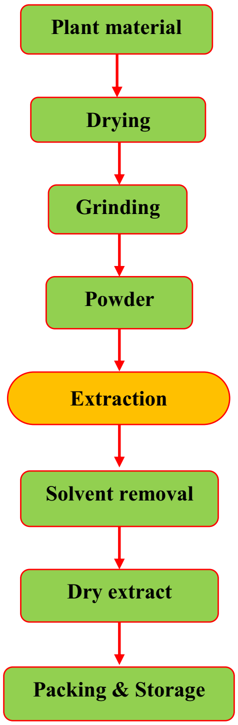

FIGURE 6.1

Flow sheet for the preparation of plant extract.

reported that plant extracts show antimicrobial properties against food spoilage as well as food-borne pathogenic microorganisms. Several methods have been used to assess the antimicrobial properties of plant extracts. The methods based on agar are pour plate disk diffusion, streak plate disk diffusion and agar-well diffusion method was assessed by using agar-well diffusion method.

The other method is the broth dilution assay (Othman et al., 2011). These methods are used to determine the minimum inhibitory concentration of the extracts.

Verma, Singh, Tiwari, Srivastava, and Verma (2012) studied the antibacterial properties of extracts (*Punica granatum*, *Citrus limon* and *Allium sativum*) against *Salmonella typhi*, *Escherichia coli*, *Bacillus cereus* and *Staphylococcus aureus*. They reported that these plant extracts were potentially effective against all of these microorganisms. Also, the extract prepared from *P. granatum* showed the highest effectiveness at a concentration of 500 mg/mL. Several other authors also revealed that the extracts prepared from the peels of *P. granatum* showed antimicrobial activity against *Micrococcus luteus*, *S. aureus*, *Bacillus megaterium, E. coli* and *Pseudomonas aeruginosa*. The concentration of the extract showing maximum effective ranged from 30 to 50 mg/mL (Dey et al., 2012; Duman, Ozgen, Dayisoylu, Eribl, & Durgac, 2009; Sadeghian, Ghorbani, Mohamadi_Nejad, & Rakhshandeh, 2011). The extracts from *P. granatum* exhibited antimicrobial activity against both the spoilage as well as pathogenic microorganisms. These extracts were found to be effective against *S. aureus*, *B. cereus, E. coli* and *S. typhi* (Alzoreky, 2009; Mahboubi, Asgarpanah, Sadaghiqani, & Faizi, 2015). Thus, these extracts can act as effective antimicrobial agents for food preservation and the prevention of foodborne illnesses.

Spices are rich sources of antimicrobial compounds, and several authors have their use against foodborne pathogens and food spoilage microorganisms. Cloves (*Syzygium aromaticum*) have a characteristic aroma and possess antimicrobial properties and thus can be used as a flavoring agent and as a preservative in foods. It has been reported that clove extracts show antimicrobial activity against *E. coli*, *S. aureus*, *B. cereus, L. monocytogenes, Listeria innocua* and *Salmonella enteric*. Cloves contain an active compound known as eugenol which inhibited the growth of *H. pylori* (Devi, Nisha, Sakthivel, & Pandian, 2010; Hill, Gomes, & Taylor, 2013; Sofia, Prasad, Vijay, & Srivastava, 2007). Mahfuzul_Hoque, Bari, Juneja, and Kawamoto (2007) reported that the clove extracts prepared using ethanol showed antimicrobial activity against *S. aureus*, *V. parahaemolyticus* and *P. aeruginosa* but were ineffective against *E. coli* and *Salmonella enteritidis*. In another study, Pandey and Singh (2011) reported that the MIC was between 0.1 and 2.31 mg/mL for methanolic extract from cloves and were effective against *S. aureus*, *P. aeruginosa* and *E. coli*.

Cumin (*Cuminum cyminum*) seeds extract showed antimicrobial activity against several types of bacteria involved in food poisoning. The cumin extracts with MIC range from 6.25 and 25 mg/mL, showed effectiveness against *E. coli*, *P. aeruginosa*, *S. aureus* and *B. pumilus* (Dua, Gaurav, Balkar, & Mahajan, 2013). Qader, Khalid, and Abdullah (2013) investigated the antimicrobial properties of several plant extracts prepared using ethanol and water against some pathogenic bacteria. They reported that the extract from *P. granatum* showed antimicrobial activity with MIC of 0.2 mg/mL. The extract from ginger (*Zingiber officinales*) also showed effectiveness against *P. aeruginosa* and *Klebsiella pneumonia* while thyme (*Thymus kotschyana*) extract showed effectiveness against *S. aureus* and *E. coli*. Soković, Glamočlija, Marin, Brkić, and van Griensven (2010) reported that thyme (*T. vulgaris*) extract exhibited a broad antibacterial activity against several microorganisms.

Peppermint (*Mentha piperita*) extracts exhibit broad spectrum antimicrobial properties and are very effective against several microorganisms including bacteria, yeasts, and molds (Carretto, Almeida, Furlan, Jorge, & Junqueira, 2010; Singh, Shushni, & Belkheir, 2015). It has been reported that the mint extracts showed activity against *S. aureus* and *S. pyogenes* (Singh et al., 2015). The ethanolic extract from mint exhibited antifungal activity against several *Candida spp*., but its infusion lacked such properties (Carretto et al., 2010).

Cinnamon (*Cinnamomum zeylanicum* and *C. cassia*) extracts possess strong antimicrobial properties against a broad range of pathogenic and spoilage microorganisms. These extract show inhibit the growth of *B. cereus*, *B. coaguiaris*, *B. subtilis*, *P. aeruginosa*, *L. monocytogenes*, *Acinetobacter baumannii*, *E. cloacae*, *S. aureus*, *E. coli* and *A. lannensis* and *A. bogorensis* (Antolak, Czyzowska, & Kregiel, 2017; Bayoub, Baibai, Mountassif, Retmane, & Soukri, 2010; Hosseininejad et al., 2011; Khan et al., 2009; Ranasinghe et al., 2013; Tekwu et al., 2012)

Nettle (*Urtica dioica*) extract obtained using water as a solvent showed antimicrobial effect against *M. luteus*, *Proteus mirabilis*, *Citrobacter koseri*, *S. aureus*, *S. pyogenes*, *S. epidermidis*, *S. pneumoniae*, *E. aerogenes*, *E. coli*, and *C. albicans* (Gülçin, Küfrevioğlu, Oktay, & Büyükokuroğluc, 2004; Gülçin, Küfrevioglu, & Oktay, 2005; Modarresi-Chahardehi, Ibrahim, Fariza-Sulaiman, & Mousavi, 2012; Turker & Usta, 2008). Nettle extracts were effective against *Acinetobacter calcoaceticus*, *B. cereus*, *B. spizizenii*, *V. parahaemolyticus* and *K. pneumonia*. The antimicrobial properties of nettle extract were comparable to miconazole, amoxicillin and ofloxacin (Modarresi-Chahardehi et al., 2012). In another study, it was reported that the nettle extract showed inhibitory activity against *Asaia* spp. This bacterium is responsible for spoilage in several types of beverages (Antolak et al., 2017).

Sun et al. (2020) reported that the extract prepared from blueberry showed antimicrobial activity against *V. parahaemolyticus* present in salmon samples. This extract disrupts gene transcription, cell membrane structure, and energy transport in the microbial cells. Ahn, Grun, and Mustapha (2004) used extracts from grape seed and pine bark as antimicrobial agents in ground beef and reported that these extracts were effective against *E. coli* O157:H7, *S. typhimurium*, and *L. monocytogenes*. Aliakbarlu and Mohammadi (2015) reported that the sumac (*Rhus coraria* L.) and barberry (*Barberis vulgaris* L.) extracts reduced the microbial populations in ground sheep meat. Abdulla, Abdel Samie, and Zaki (2016) studied the effect of ziziphus leaf extract on microbial quality of sausages and reported that the extract reduced the microbial count in sausages during cold storage. Nowak, Czyzowska, Efenberger, and Krala (2016) used cherry and blackcurrant leaf extracts in vacuum-packed pork sausages and reported that these extracts were effective against *Pseudomonas*. Piskernik, Klancnik, Riedel, Brøndsted, and Smole Mozina (2011) reported that rosemary extract showed antimicrobial activity against *Campylobacter jejuni*-chicken meat.

Wei, Wolf-Hall, and Hall (2009) reported that raisin extracts showed inhibitory activity against the *Bacillus* species responsible for ropy-bread and also resulted in a decrease in the *B. licheniformis B. subtilis, A. flavus* and *P. chrysogenum* counts in liquid bread and bread systems. Degirmenci and Erkurt (2020) investigated the effect of cyprus (*Citrus aurantium* L.) flower extract on the pathogens in rice pudding and reported that the extract prepared in methanol exhibited the strongest antimicrobial effect against *E. coli* O157:H7, *S. typhimurium*, *L. monocytogenes*, and *B. cereus*. The use of this extract reduced the growth rate of all these pathogens and other natural flora in product.

6.5 Plant extracts as antioxidants

Lipid oxidation is one of the important types of chemical spoilage of foods. It leads to the production of several compounds that degrade the quality of foods with respect to sensory and nutritional aspects. These changes can be inhibited or minimized by the application of antioxidants.

Antioxidants prevent lipid oxidation in several ways. These compounds inhibit chain reaction by removing initiating radicals, break chain reaction, decompose peroxides, decrease localized oxygen concentrations, and bind the chain initiating catalysts during the lipid oxidation process (Dorman, Peltoketo, Hiltunen, & Tikkanen, 2003). A large number of substances have been found to act as antioxidants, but only a small number has been used in food. The application of antioxidants in food varies according to the regulatory laws of a country and international standards (Karre, Lopez, & Getty, 2013).

The antioxidants may be grouped into two categories: synthetic and natural. Synthetic antioxidants include butylated hydroxyanisole, butylated hydroxytoluene, tert-butylhydroquinone, and propyl gallate, and have been extensively used in different food products. These synthetic antioxidants have been associated with several negative impacts on health of consumers and thus consumers demand safer food and that too with an extended shelf life. This has forced the scientific community to evaluate the natural sources for the preservative potential, especially from plant sources (Shah et al., 2014).

The antioxidant potential of plant extracts can be evaluated by several assays such as diphenyl-1-picrylhydrazyl, superoxide anion scavenging assay, hydrogen radical scavenging assay, hydrogen peroxide scavenging assay, 2,2-azinobis-3-ethylbenzthiazoline-6-sulfonic acid radical scavenging activity and reducing power assay. The antioxidant capacity of the extract is influenced by the extraction procedure and the type of solvent used (Brewer, 2011; Shah et al., 2014).

Plant extracts have been applied to various food systems for the prevention of various deteriorative changes occurring due to the oxidation of various food components. Several authors have reviewed the use of plant extracts in meat and poultry products (Alirezalu et al., 2020; Karre et al., 2013; Nikmaram et al., 2018; Shah et al., 2014).

Mansour and Khalil (2000) used the extracts prepared from potato peels, ginger rhizomes, and fenugreek seeds in beef patties and reported that the extracts from ginger rhizome and fenugreek seed effectively reduced the lipid oxidation during cold storage. Fernandez-Lopez et al. (2003) studied the effect of extracts from rosemary and hyssop in cooked pork meat and reported that these extracts prevented the lipid oxidation as well as heme pigment degradation during cooking and storage. Ahn, Grun, and Mustapha (2007) applied Pycnogenol, ActiVin and Herbalox in cooked ground beef and reported that these antioxidants reduced lipid oxidation by 94%, 92% and 92% respectively compared to control. Also, these additives reduced the hexanal content of beef samples throughout the storage period.

Many researchers have used grape seed extract (GSE) in various types of meat products. Brannan and Mah (2007) evaluated the effect of GSE in raw and cooked ground meat and reported that GSE reduced the lipid oxidation more effectively than gallic acid. GSE inhibited the formation of primary and secondary oxidation compounds in different types of meat. Rojas and Brewer (2007) reported that GSE reduced the lipid oxidation and the off-odors associated with it in cooked beef and pork patties. Also, these authors reported a concentration dependent effect of antioxidant activity in GSE. In another study, Rojas and Brewer (2008) evaluated the effect GSE in vacuum packaged raw beef and pork patties kept under frozen conditions for 4 months and reported that the GSE prevented lipid oxidation in both types of meat. Similar reports on the application of GSE in various meat products have been reported by Shan, Cai, Brooks, and Corke (2009), Colindres and Brewer (2011), Ozvural and Vural (2012), and Reddy et al. (2013).

Kanatt, Chander, and Sharma (2007) evaluated the effect of mint leaf extract in lamb meat processed by irradiation and stored at chilled temperatures. They reported that the antioxidant properties of extract were equivalent to BHT. The extract lowered the TBARS values significantly in treated samples in comparison to the samples without any antioxidant.

Drumstick leaf extract was applied in cooked goat meat patties stored at refrigerated conditions by Das, Rajkumar, Verma, and Swarup (2012). They reported that the treated samples showed a reduction in lipid oxidation during refrigerated storage. The antioxidant properties of the extract were comparable to BHT. Furthermore, it had no adverse effect on the sensory parameters of patties. Similar results on the application of *Moringa* leaf extract were reported by Muthukumar, Naveena, Vaithiyanathan, Sen, and Sureshkumar (2014) for raw and cooked pork patties stored at refrigerated conditions. Shah, Bosco, and Mir (2015) reported that the *Moringa* leaf extract reduced the lipid oxidation in raw beef stored in high oxygen modified atmosphere packaging.

Akarpat, Turhan, and Ustun (2008) studied the effect of myrtle, rosemary, nettle, and lemon balm leaf extracts on beef patties kept at −20°C ± 2°C for 120 days and reported that these extracts had reduced the lipid oxidation in the patties. The highest antioxidant effect was shown by myrtle and rosemary extracts compared to nettle and lemon balm extracts. Also, the application of the extract from myrtle leaf (10% extract) to patties prevented the damage in lipids due to oxidation in beef patties during frozen storage. Alp and Aksu (2010) studied the effect of nettle (*U. dioica*) extract on the quality of ground beef kept under modified atmosphere and reported that the extract reduced the lipid oxidation in the beef samples.

Hayes, Stepanyan, Allen, O'Grady, and Kerry (2010a) evaluated the effect of extract from olive leaf in raw and cooked pork patties kept under aerobic and modified atmospheres for 8 and 12 days, respectively. Lipid oxidation was minimized by the olive leaf extract treatment. Also, it did not affect the sensory parameters but had changed the instrumental textural attributes. In another study, Hayes, Stepanyan, Allen, O'Grady, and Kerry (2010b) reported that the same leaf extract reduced the oxidation of lipid and oxymyoglobin in raw beef patties. Furthermore, Hayes, Stepanyan, Allen, O'Grady, and Kerry (2011) observed a reduction in lipid oxidation of fresh and cooked pork sausages packaged under aerobic and modified atmospheres by using olive leaf extract. Also, it did not affect the other physicochemical and sensory parameters of the sausages.

Vegetable oils are rich in several unsaturated compounds and thus are susceptible to various oxidative processes. Some studies have reported the use of plant extracts to prevent the oxidative damage in these oils. Potato peel extract was used to preserve vegetable oil from sunflower and soybean by Mohdaly, Sarhan, Mahmoud, Ramadan, and Smetanska (2010). The results showed that the peroxide value of these oils was reduced by the application of the potato peel extract. In another study, rosemary extract was used in preservation of soybean oil (Casarotti & Jorge, 2014). They reported that the extract improved the oxidative stability and other quality parameters of the oil. Wang, Fu, Wang, Yang, and Wu (2018) reported that the rosemary extracts used in omega-3 fatty-acid rich flaxseed oil reduced the lipid oxidation of the oil.

Milk and its products are rich source of lipids, and these lipids undergo several adverse changes during processing or storage. Literature shows that some studies have been carried out to preserve milk and milk products. Mango seed kernels extracts have been used to preserve pasteurized cow milk (Abdalla & El-Hamahmy, 2007) and ghee (Puravankara, Bohgra, & Sharma, 2000). Similarly, *Moringa* leaf extracts were used to preserve and increase the shelf life of ghee as it is rich in various natural antioxidant compounds (Siddhuraju & Becker, 2003).

Plant extracts have been investigated in several bakery products such as bread (Peng et al., 2010) and biscuits (Reddy, Urooj, & Kumar, 2005). GSE was used to enrich and preserve bread. It was reported that the antioxidant activity of the extract added was reduced due to the thermal degradation during baking process. However, the extract enriched the bread with antioxidant compounds (Peng et al., 2010). Amla (*Emblica officianalis*) and *Moringa* leaf extract were used as preservatives in cookies. The results revealed that these extracts showed the antioxidant effect comparable to BHT. The antioxidant potential of these extracts increased with the increase in extract concentration. The peroxide values also decreased in the treated samples (Reddy et al., 2005).

6.6 Plant extracts as antibrowning agents

Browning is a process, which results in color change of foods to brown or dark brown with the passage of time. It has a positive or negative impact on the quality of a food product (Martinez &Whitaker, 1995). In case of fruit and vegetable products, browning is not desirable but in case of certain foods it produces unique color and flavor for example, bread, coffee, cocoa, raisins, etc. Browning may proceed through enzymatic or nonenzymatic routes. The enzymatic browning requires enzymes to produce brown colored compounds while the nonenzymatic browning does not require any enzyme. Enzymatic browning occurs due to the polyphenol oxidase (PPO), a copper-containing enzyme present in food. Enzymatic browning in food products occurs during various processing procedures such as cutting, peeling, slicing, etc. The nonenzymatic browning occurs through a series of chemical reactions and can be categorized into the Maillard reaction, carameli-zation, and ascorbic acid oxidation. These changes affect the sensory and nutritional quality of the food products (Moon, Kwon, Lee, & Kim, 2020).

The enzymatic browning is responsible for economic losses in food industry and the main factor involved is the PPO. This enzyme catalyzes the oxidation of phenolic compounds in food products thus, leads to the antioxidant degradation and color alteration in them. Several synthetic compounds have been used to control the browning reactions in foods but the recent studies have shown that new antibrowning strategies are being developed to replace synthetic additives (sulfites) with natural extracts derived from plants (Tinello, Mihaylova, & Lante, 2020; Zocca, Lomolino, & Lante, 2011).

Plant extracts have been used to prevent the browning reactions in several food products as they are regarded as safe and fulfill the consumer demand of more natural additives in food. The extracts from onion have been used to prevent the browning in many food products. These extracts applied to potatoes cause inhibition of the PPO activity and thus suppressed the browning in them (Lee et al., 2002). Onion extract has been also used to reduce the browning in pear (Kim, Kim, & Park, 2005). In another study, this extract resulted in reduced browning in fresh apple juice (Lee, Seo, Rhee, & Kim, 2016).

Several fruits have shown promising results in the prevention of browning reactions in food products. Lozano-de-Gonzalez, Barrett, Wrolstad, and Durst (1993) used pineapple juice has been used to prevent the browning in fresh and dried apples. This extract has also been used as an antibrowning agent in banana slices by Chaisakdanugull, Theerakulkait, and Wrolstad (2007). Lemon and grape juice have been investigated on dough samples used for pastry production and the results revealed that these juices reduced the browning reactions in the dough (Brütsch et al., 2018).

Liu et al. (2019) investigated the effect of purslane (*Portulaca oleracea* L.) extract on potato slices and reported that the extract inhibited the activity of PPO in the potato slices and thus reduced the browning reaction during storage.

Tyrosinase is a copper-containing enzyme and is responsible for enzymatic browning in several foods such as button mushrooms. Fattahifar, Barzegar, Ahmadi Gavlighi, and Sahari (2018) investigated the effect of pistachio (*Pistacia vera* L.) green hull extract on the browning of button mushrooms and reported that this extract inhibited the activity of tyrosinase and thus reduced the browning reactions involving the role of tyrosinase.

6.7 Conclusion

Plants are rich sources of natural ingredients used in food preservation. Different plant parts have been used in the form of extracts and used as preservatives in many food products. As these preservatives are obtained from edible plant sources, they are generally regarded as safe and are preferred by consumers over the synthetic preservatives. These preservative are categorized into antimicrobials, antioxidants, and antibrowning agents according to their function in the food. These extracts show antimicrobial properties against food spoilage as well as foodborne pathogenic microorganisms. These extracts applied to various food systems help in preventing various deteriorative changes occurring due to the oxidation of various food components. Furthermore, these extracts effectively reduced the browning reactions in several food products.

References

Abdalla, A. E. M., & El-Hamahmy, S. M. (2007). Egyptian mango by-product 2: Antioxidant and antimicrobial activities of extract and oil from mango seed kernel. *Food Chemistry*, *103*, 1141−1152.

Abdulla, G., Abdel Samie, M. A.-S., & Zaki, D. (2016). Evaluation of the antioxidant and antimicrobial effects of ziziphus leaves extract in sausage during cold storage. *Pakistan Journal of Food Science*, *26*, 10−20.

Ahn, J., Grun, I. U., & Mustapha, A. (2004). Antimicrobial and antioxidant activities of natural extracts in vitro and in ground beef. *Journal of Food Protection*, *67*, 148−155.

Ahn, J., Grun, I. U., & Mustapha, A. (2007). Effects of plant extracts on microbial growth, color change, and lipid oxidation in cooked beef. *Food Microbiology*, *24*, 7−14.

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*, 117−132.

Aliakbarlu, J., & Mohammadi, S. (2015). Effect of sumac *(Rhus coraria* L.) and barberry *(Barberis vulgaris* L.) water extracts on microbial growth and chemical changes in ground sheep meat. *Journal of Food Processing and Preservation*, *39*, 1859−1866.

Alirezalu, K., Pateiro, M., Yaghoubi, M., Alirezalu, A., Peighambardoust, S. H., & Lorenzo, J. M. (2020). Phytochemical constituents, advanced extraction technologies and techno-functional properties of selected Mediterranean plants for use in meat products. A comprehensive review. *Trends in Food Science & Technology*, *100*, 292−306.

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

Alzoreky, N. S. (2009). Antimicrobial activity of pomegranate (*Punica granatum* L.) fruit peels. *International Journal of Food Microbiology*, *134*, 244−248.

Antolak, H., Czyzowska, A., & Kregiel, D. (2017). Antibacterial and antiadhesive activities of extracts from edible plants against soft drink spoilage by *Asaia* spp. *Journal of Food Protection*, *80*(1), 25−34.

Bayoub, K., Baibai, T., Mountassif, D., Retmane, A., & Soukri, A. (2010). Antibacterial activities of the crude ethanol extracts of medicinal plants against *Listeria monocytogenes* and some other pathogenic strains. *African Journal of Biotechnology*, *9*, 4251−4258.

Branen, A. L., Davidson, P. M., Salminen, S., & Thorngate, J. H., III (2002). *Food additives* (2nd Edition). New York: Marcel and Dekker Inc.

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*, 540−546.

Brewer, M. S. (2011). Natural antioxidants: Sources, compounds, mechanisms of action, and potential applications. *Comprehensive Reviews in Food Science and Food Safety*, *10*, 221−247.

Brütsch, L., Rugiero, S., Serrano, S., Städeli, C., Windhab, E., Fischer, P., & Kuster, S. (2018). Targeted inhibition of enzymatic browning in wheat pastry dough. *Journal of Agricultural and Food Chemistry*, *66*, 12353−12360.

Carretto, C. F. P., Almeida, R. B. A., Furlan, M. R., Jorge, A. O. C., & Junqueira, J. C. (2010). Antimicrobial activity of *Mentha piperita* L. against *Candida* spp. *Brazilian Dental Journal*, *13*(1), 4−9.

Casarotti, S., & Jorge, N. (2014). Antioxidant activity of rosemary extract in soybean oil under thermoxidation. *Journal of Food Processing and Preservation*, *38*(1), 136−145.

Chaisakdanugull, C., Theerakulkait, C., & Wrolstad, R. E. (2007). Pineapple juice and its fractions in enzymatic browning inhibition of banana [*Musa* (AAA Group) Gros Michel]. *Journal of Agricultural and Food Chemistry*, *55*, 4252−4257.

Chan, E. W. C., Lim, Y. Y., & Omar, M. (2007). Antioxidant and antibacterial activity of leaves of *Etlingera* species (Zingiberaceae) in Peninsular Malaysia. *Food Chemistry*, *104*, 1586−1593.

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

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

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 - Food Science and Technology*, *126*, 109273. Available from https://doi.org/10.1016/j.lwt.2020.109273.

Devi, K. P., Nisha, S. A., Sakthivel, R., & Pandian, S. K. (2010). Eugenol (an essential oil of clove) acts as an antibacterial agent against *Salmonella typhi* by disrupting the cellular membrane. *Journal of Ethnopharmacology*, *130*(1), 107−115.

Dey, D., Debnath, S., Hazra, S., Ghosh, S., Ray, R., & Hazra, B. (2012). Pomegranate pericarp extract enhances the antibacterial activity of ciprofloxacin against extended spectrum b-lactamase (ESBL) and metallo-b-lactamase (MBL) producing Gram-negative bacilli. *Food and Chemical Toxicology: An International Journal Published for the British Industrial Biological Research Association*, *50*, 4302−4309.

Ding, S. H., An, K. J., Zhao, C. P., Li, Y., Guo, Y. H., & Wang, Z. F. (2012). Effect of drying methods on volatiles of Chinese ginger (*Zingiber officinale* Roscoe). *Food and Bioproducts Processing*, *90*, 515−524.

Dorman, H. J. D., Peltoketo, A., Hiltunen, R., & Tikkanen, M. J. (2003). Characterisation of the antioxidant properties of deodourised aqueous extracts from selected Lamiaceae herbs. *Food Chemistry*, *83*, 255−262.

Dua, A., Gaurav, G., Balkar, S., & Mahajan, R. (2013). Antimicrobial properties of methanolic extract of cumin (*Cuminum cyminum*). *seeds. International Journal of Research in Ayurveda and Pharmacy*, *4*(1), 104–107.

Duman, A. D., Ozgen, S. K. M., Dayisoylu, K. S., Eribl, N., & Durgac, C. (2009). Antimicrobial activity of six Pomegranate (*Punica granatum* L.) varieties and their relation to some of their pomological and phytonutrient characteristics. *Molecules (Basel, Switzerland)*, *14*, 1808–1817.

Fattahifar, E., Barzegar, M., Ahmadi Gavlighi, H., & Sahari, M. A. (2018). Evaluation of the inhibitory effect of pistachio (*Pistacia vera* L.) green hull aqueous extract on mushroom tyrosinase activity and its application as a button mushroom postharvest anti-browning agent. *Postharvest Biology and Technology*, *145*, 157–165.

Fernandez-Lopez, J., Sevilla, L., Sayas-Barbera, E., Navarro, C., Marin, F., & Perez-Alvarez, J. A. (2003). Evaluation of the antioxidant potential of hyssop (*Hyssopus officinalis* L.) and rosemary (*Rosmarinus officinalis* L.) extracts in cooked pork meat. *Journal of Food Science*, *68*, 660–664.

Gülçin, I., Küfrevioglu, Ö. I., & Oktay, M. (2005). Purification and characterization of polyphenol oxidase from nettle (*Uritca dioica* L.) and inhibitory effects of some chemicals on enzyme activity. *Journal of Enzyme Inhibition and Medicinal Chemistry*, *20*, 297–302.

Gülçin, I., Küfrevioğlu, Ö. I., Oktay, M., & Büyükokuroğluc, M. E. (2004).). Antioxidant, antimicrobial, antiulcer and analgesic activities of nettle (*Urtica dioica* L.). *Journal of Ethnopharmacology*, *90*, 205–215.

Hayes, J. E., Stepanyan, V., Allen, P., O'Grady, M. N., & Kerry, J. P. (2010a). Effect of lutein, sesamol, ellagic acid and olive leaf extract on the quality and shelf-life stability of packaged raw minced beef patties. *Meat Science*, *84*, 613–620.

Hayes, J. E., Stepanyan, V., Allen, P., O'Grady, M. N., & Kerry, J. P. (2010b). 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*, 289–296.

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*, 164–172.

Hill, L. E., Gomes, C., & Taylor, T. M. (2013). Characterization of beta-cyclodextrin inclusion complexes containing essential oils (trans-cinnamaldehyde, eugenol, cinnamon bark, and clove bud extracts) for antimicrobial delivery applications. *LWT—Food Science and Technology*, *51*(1), 86–93.

Hosseininejad, Z., Moghadam, S. D., Ebrahimi, F., Abdollahi, M., Zahedi, M. J., Nazari, M., ... Sharififar, F. (2011). In vitro screening of selected Iranian medicinal plants against *Helicobacter pylori*. *International Journal of Green Pharmacy*, *5*, 282–285.

Kanatt, S. R., Chander, R., & Sharma, A. (2007). Antioxidant potential of mint (*Mentha spicata* L.) in radiation-processed lamb meat. *Food Chemistry*, *100*, 451–458.

Karre, L., Lopez, K., & Getty, K. J. K. (2013). Natural antioxidants in meat and poultry products. *Meat Science*, *94*, 220–227.

Khan, R., Islam, B., Akram, M., Shakil, S., Ahmad, A., Ali, S. M., ... Khan, A. U. (2009). Antimicrobial activity of five herbal extracts against multi drug resistant (MDR) strains of bacteria and fungus of clinical origin. *Molecules (Basel, Switzerland)*, *14*, 586–597.

Kim, M. J., Kim, C. Y., & Park, I. (2005). Prevention of enzymatic browning of pear by onion extract. *Food Chemistry*, *89*, 181–184.

Kothari, V. (2011). In vitro antibacterial activity in Seed extracts of *Phoenix sylvestris* Roxb (Palmae), and *Tricosanthes dioica* L (Cucurbitaceae). *Current Trends in Biotechnology and Pharmacy*, *5*(1), 993–997.

Kothari, V., Pathan, S., & Seshadri, S. (2010). Antioxidant activity of *M. zapota* and *C. limon* seeds. *Journal of Natural Remedies*, *10*(2), 175–180.

Lee, B., Seo, J. D., Rhee, J. K., & Kim, C. Y. (2016). Heated apple juice supplemented with onion has greatly improved nutritional quality and browning index. *Food Chemistry*, *201*, 315−319.

Lee, M. K., Kim, Y. M., Kim, N. Y., Kim, G. N., Kim, S. H., Bang, K. S., & Park, I. (2002). Prevention of browning in potato with a heat-treated onion extract. *Bioscience, Biotechnology, and Biochemistry*, *66*, 856−858.

Liu, X., Yang, Q., Lu, Y., Li, Y., Li, T., Zhou, B., & Qiao, L. (2019). Effect of purslane (*Portulaca oleracea* L.) extract on anti-browning of freshcut potato slices during storage. *Food Chemistry*, *283*, 445−453.

Lozano-de-Gonzalez, P. G., Barrett, D. M., Wrolstad, R. E., & Durst, R. W. (1993). Enzymatic browning inhibited in fresh and dried apple rings by pineapple juice. *Journal of Food Science*, *58*, 399−404.

Mahboubi, A., Asgarpanah, J., Sadaghiqani, P. N., & Faizi, M. (2015). Total phenolic and flavonoid content and antibacterial activity of *Punica granatum* L. Var. pleniflora flower (Golnar) against bacterial strains causing food borne diseases. *BMC Complementary and Alternative Medicine*, *15*, 366−373.

Mahfuzul_Hoque, M., Bari, M. L., Juneja, V. K., & Kawamoto, S. (2007). Antimicrobial activity of cloves and cinnamon extracts against food borne pathogens and spoilage bacteria and inactivation of *Listeria monocytogenes* in ground chicken meat with their essential oils. *Journal of Food Science and Technology*, *72*, 9−21.

Mansour, E. H., & Khalil, A. H. (2000). Evaluation of antioxidant activity of some plant extracts and their application to ground beef patties. *Food Chemistry*, *69*, 135−141.

Martinez, M. V., & Whitaker, J. R. (1995). The biochemistry and control of enzymatic browning. *Trends Food Science and Technology*, *6*, 195−200.

Modarresi-Chahardehi, A., Ibrahim, D., Fariza-Sulaiman, S., & Mousavi, L. (2012). Screening antimicrobial activity of various extracts of *Urtica dioica*. *Revista de Biologia Tropical*, *60*(4), 1567−1576.

Mohdaly, A., Sarhan, M., Mahmoud, A., Ramadan, M., & Smetanska, I. (2010). Antioxidant efficacy of potato peels and sugar beet pulp extracts in vegetable oils protection. *Food Chemistry*, *123*(4), 1019−1026.

Moon, K. M., Kwon, E. B., Lee, B., & Kim, C. Y. (2020). Recent trends in controlling the enzymatic browning of fruit and vegetable products. *Molecules (Basel, Switzerland)*, *25*, 2754. Available from https://doi.org/10.3390/molecules25122754.

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*, 3172−3180.

Nazir, F., Salim, R., Yousf, N., Bashir, M., Naik, H. R., & Hussain, S. Z. (2017). Natural antimicrobials for food preservation. *Journal of Pharmacognosy and Phytochemistry*, *6*(6), 2078−2082.

Nikmaram, N., Budaraju, S., Barba, F. J., Lorenzo, J. M., Cox, R. B., Mallikarjunan, K., & Roohinejad, S. (2018). Application of plant extracts to improve the shelf-life, nutritional and health-related properties of ready-to-eat meat products. *Meat Science*, *145*, 245−255.

Nowak, A., Czyzowska, A., Efenberger, M., & Krala, L. (2016). Polyphenolic extracts of cherry (*Prunus cerasus* L.) and blackcurrant (*Ribes nigrum* L.) leaves as natural preservatives in meat products. *Food Microbiology*, *59*, 142−149.

Othman, M., Loh, H. S., Wiart, C., Khoo, T. J., Lim, K. H., & Ting, K. N. (2011). Optimal methods for evaluating antimicrobial activities from plant extracts. *Journal of Microbiological Methods*, *84*(2), 161−166.

Ozvural, E. B., & Vural, H. (2012). The effects of grape seed extract on quality characteristics of frankfurters. *Journal of Food Processing and Preservation*, *36*, 291−297.

Pandey, A., & Singh, P. (2011). Antibacterial activity of *Syzygium aromaticum* (Clove) with metal ion effect against food borne pathogens. *Asian Journal of Plant Science and Research*, *1*(2), 69−80.

Peng, X., Ma, J., Cheng, K. W., Jiang, Y., Chen, F., & Wang, M. (2010). The effects of grape seed extract fortification on the antioxidant activity and quality attributes of bread. *Food Chemistry*, *119*(1), 49−53.

Piskernik, S., Klancnik, A., Riedel, Ch. T., Brøndsted, L., & Smole Mozina, S. (2011). Reduction of *Campylobacter jejuni* by natural antimicrobials in chicken meat-related conditions. *Food Control*, *22*, 718−724.

Puravankara, D., Bohgra, V., & Sharma, R. S. (2000). Effect of antioxidant principles isolated from mango (*Mangifera indica* L.) seed kernels on oxidative stability of buffalo ghee (butter-fat). *Journal of the Science of Food and Agriculture*, *80*, 522−526.

Qader, M. K., Khalid, N. S., & Abdullah, A. M. (2013). Antibacterial activity of some plant extracts against clinical pathogens. *International Journal of Microbiology and Immunology Research.*, *1*(5), 53−56.

Ranasinghe, P., Pigera, S., Premakumara, G. A. S., Galappaththy, P., Constantine, G. R., & Katulanda, P. (2013). Medicinal properties of 'true' cinnamon (*Cinnamomum zeylanicum*): A systematic review. *BMC Complementary and Alternative Medicine*, *13*, 275. Available from https://doi.org/10.1186/1472-688213-275.

Reddy, G. V. 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*, 288−294.

Reddy, V., Urooj, A., & Kumar, A. (2005). Evaluation of antioxidant activity of some plant extracts and their application in biscuits. *Food Chemistry*, *90*(1), 317−321.

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*, 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*, 173−188.

Sadeghian, A., Ghorbani, A., Mohamadi_Nejad, A., & Rakhshandeh, H. (2011). Antimicrobial activity of aqueous and methanolic extracts of pomegranate fruit skin. *Avicenna Journal of Phytomedicine.*, *1*(2), 67−73.

Shah, M. A., Bosco, S. J. D., & Mir, S. A. (2014). Plant extracts as natural antioxidants in meat and meat products. *Meat Science*, *98*, 21−33.

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*, 1879−1885.

Siddhuraju, P., & Becker, K. (2003). Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (*Moringa oleifera* Lam.) leaves. *Journal of Agricultural and Food Chemistry*, *51*, 2144−2155.

Sikora, E., Cieslik, E., Leszcznska, T., Filipiak-Florkiewicz, A., & Pisulewski, P. M. (2008). The antioxidant activity of selected cruciferous vegetables subjected to aquathermal processing. *Food Chemistry*, *107*, 55−59.

Singh, R., Shushni, M. A. M., & Belkheir, A. (2015). Antibacterial and antioxidant activities of *Mentha piperita* L. *Arabian Journal of Chemistry*, *8*(3), 322−328.

Sofia, K., Prasad, R., Vijay, V. K., & Srivastava, A. K. (2007). Evaluation of antibacterial activity of Indian spices against common foodborne pathogens. *International Journal of Food Science and Technology*, *42* (8), 910−915.

Soković, M., Glamočlija, J., Marin, P. D., Brkić, D., & van Griensven, L. J. L. D. (2010). Antibacterial effects of the essential oils of commonly consumed medicinal herbs using an in vitro model. *Molecules (Basel, Switzerland)*, *15*, 7532−7546.

Stalikas, C. D. (2007). Extraction, separation, and detection methods for phenolic acids and flavonoids. *Journal of Separation Science*, *30*, 3268−3295.

Sun, X. H., Hao, L. R., Xie, Q. C., Lan, W. Q., Zhao, Y., Pan, Y. J., & Wu, V. C. H. (2020). Antimicrobial effects and membrane damage mechanism of blueberry (*Vaccinium corymbosum* L.) extract against *Vibrio parahaemolyticus*. *Food Control*, *111*, 107020. Available from https://doi.org/10.1016/j.foodcont.2019.107020.

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*, 115−121.

Tekwu, E. M., Askun, T., Kuete, V., Nkengfack, A. E., Nyasse, B., Etoa, F. X., & Beng, V. P. (2012). Antibacterial activity of selected Cameroonian dietary spices ethno-medically used against strains of mycobacterium tuberculosis. *Journal of Ethnopharmacology*, *142*, 374−382.

Tinello, F., Mihaylova, D., & Lante, A. (2020). Valorization of onion extracts as anti-browning agents. *Food Science and Applied Biotechnology*, *3*(1), 16−21.

Turker, A. U., & Usta, C. (2008). Biological screening of some Turkish medicinal plant extracts for antimicrobial and toxicity activities. *Natural Product Research*, *22*, 136−146.

Turkmen, N., Sari, F., & Velioglu, Y. S. (2006). Effects of extraction solvents on concentration and antioxidant activity of black and black mate tea polyphenols determined by ferrous tartrate and Folin−Ciocalteu methods. *Food Chemistry*, *99*, 835−841.

Upadhyay, R., Ramalakshmi, K., & Rao, L. J. M. (2012). Microwave-assisted extraction of chlorogenic acids from green coffee beans. *Food Chemistry*, *130*(1), 184−188.

Verma, V., Singh, R., Tiwari, R. K., Srivastava, N., & Verma, S. (2012). Antibacterial activity of extracts of Citrus, Allium and Punica against food borne spoilage. *Asian Journal of Plant Science and Research.*, *2*(4), 503−509.

Wang, Y. Z., Fu, S. G., Wang, S. Y., Yang, D. J., & Wu, Y. H. S. (2018). Effects of a natural antioxidant, polyphenol-rich rosemary (*Rosmarinus officinalis* L.) extract, on lipid stability of plant-derived omega-3 fatty-acid rich oil. *LWT—Food Science and Technology*, *89*, 210−216.

Wei, Q., Wolf-Hall, C., & Hall, C. A. (2009). Application of raisin extracts as preservatives in liquid bread and bread system. *Journal of Food Science*, *74*, M177−M184.

Yeh, H. Y., Chuang, C. H., Chen, H. C., Wan, C. J., Chen, T. L., & Lin, L. Y. (2014). Bioactive components analysis of two various gingers (*Zingiber officinale* Roscoe) and antioxidant effect of ginger extracts. *LWT—Food Science and Technology*, *55*, 329−334.

Zocca, F., Lomolino, G., & Lante, A. (2011). Dog rose and pomegranate extracts as agents to control enzymatic browning. *Food Research International*, *44*(4), 957−963.