established in 2016

MAS JOURNAL of Applied Sciences

ISSN 2757-5675

DOI: http://dx.doi.org/10.52520/masjaps.183

Derleme Makalesi

Plant-Based Food Preservatives: An Overview of Some Essential Oils, Spices and Fruit Extracts

Halenur YILDIZ[1], Buket ER DEMİRHAN[2*], Burak DEMİRHAN[2]

[1]Department of Food Analysis and Nutrition, Graduate School of Health Sciences, Gazi University, Ankara

[2]Department of Pharmaceutical Basic Sciences, Faculty of Pharmacy, Gazi University, Ankara

*Corresponding author: erbuket@gazi.edu.tr

Geliş Tarihi: 28.09.2021 **Kabul Tarihi**: 29.10.2021

Abstract

Synthetic food additives are widely used to prevent microbial growth in foods and to extend their shelf life. However, in recent years, natural alternatives have been preferred for the use of synthetic preservatives. Some spices, herbs, plant extracts, and essential oils have antimicrobial and antioxidant effects owing to their important bioactive compounds. There are studies on adding natural preservatives directly to foods or incorporating them into packaging systems. Within this context, a remarkable antimicrobial effect of essential oils, spices, and fruit extracts has been recently highlighted. Finally, it is important to carry out further researches to explain the antimicrobial and antioxidant effects of the use of natural preservatives in foods, their interactions with other additives, and their effects on sensory properties. In this review, it is aimed to give general information about some plant-based food preservatives such as essential oils, spices and fruit extracts, their effects and use in foods.

Keywords: Plant extracts, food preservatives, antimicrobial, antioxidant

INTRODUCTION

Food additives such as antioxidants and antimicrobials are widely used to prevent microbial growth and to extend shelf life. Antioxidants, which are synthetic or natural compounds, are added to foods to stabilize the color and to avoid lipid oxidation and undesirable tastes. Butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are among the most common added synthetic antioxidants in the food industry. Antimicrobials are used to control foodborne pathogens (García-García & Searle 2015; Nair et al., 2019). Microorganisms such as *Salmonella* spp., *Staphylococcus aureus, Listeria monocytogenes, Escherichia coli* O157:H7 and *Bacillus cereus* affect food quality as well as pose a risk to human health. Foodborne diseases are a worldwide public health problem (Gutiérrez-del-Río et al., 2018). Commonly used antimicrobials include nitrite and nitrates, organic acids and sulfides (García-García & Searle, 2015). However, as a result of increased health awareness of consumers against the use of synthetic antimicrobial compounds due to the toxicity risks of synthetic antimicrobial compounds, the use of natural preservatives has been conceived as an alternative and has led to extensive research (García-García & Searle, 2015; Pisoschi et al., 2018). It has an antimicrobial and antioxidant effect owing to important bioactive compounds (aldehydes, flavonoids, phenolic acids and terpenes) contained in some herbal extracts, spices and essential oils. There are studies to add these natural preservatives directly to meat and meat products, fruits and vegetables or incorporate them into packaging systems (Aziz & Karboune, 2018). It is important to develop quantitative and qualitative innovations in the agricultural sector, which is responsible for plant food production (Özel & Maesaroh, 2021). Plant-derived bioactive compounds show antimicrobial effects by changing cell membrane permeability. As a result of changes in membrane functions, activities such as nutrient uptake, enzyme activity, electron transport, synthesis of protein and nucleic acids are affected in the cell. The activity of natural antimicrobials depends on concentration, microbial enzyme activity is inhibited at low concentrations while denaturation of proteins is induced at high concentrations (Pisoschi et al., 2018). The antioxidant activity of these compounds is realized by neutralizing free radicals owing to their redox properties and chemical structures. Besides, the antioxidant properties of plants protect the body from oxidative stress caused by free radicals and prevent many diseases related to oxidative stress such as diabetes, Alzheimer's, cardiovascular diseases and cancer (Martínez-Graciá et al., 2015). In this review, it is aimed to give general information about some plant-based food preservatives such as essential oils, spices and fruit extracts, their effects and use in foods.

Properties and effects of some essential oils and spices

Essential oils have been known and used since ancient times for their medicinal properties and antimicrobial effects (Chen et al., 2021; Buchbauer & Wallner 2015). Essential oils synthesized by aromatic plants constitute a very small part of the plant composition and are generally liquid, colorless and volatile at ambient temperature. They are well soluble in organic solvents and alcohol but slightly soluble in water (Falleh et al., 2020). They are extracted from plants by several extraction methods such as steam distillation, solvent extraction,

microwave-assisted extraction and supercritical liquid extraction (Chen et al., 2021). Bioactive components found in the structure of essential oils are very sensitive to environmental factors such as heat, light and oxygen. Encapsulation application is considered as an alternative method used to minimize the loss of bioactive compounds. Also, since essential oils have poor solubility in water, solutions such as nanoemulsions are needed (Ni et al., 2021). Essential oils have a specific aroma, taste and odor (Falleh et al., 2020). It contains many bioactive components, such as terpenes, alcohols, aldehydes, ketones, lactones, carboxylic acids and sulfides (Pisoschi et al., 2018). It is known that they have antimicrobial and antioxidant effects, depending on the phytochemical components it contains. Due to these properties, it is used as a natural ingredient in many pharmaceuticals and cosmetic products (Falleh et al., 2020). Spices are known to have strong antimicrobial effects include rosemary, thyme, cinnamon, clove, turmeric and ginger. Also, these spices are widely used all over the world (Aziz & Karboune, 2018). Clove (*Syzygium aromaticum*) is one of the spices widely used all over the world. It has a strong aroma. Phenylpropanoids, sesquiterpenoids, tannins and triterpenoids are classified as the main chemical constituents of cloves. Eugenol is known as the main ingredient in cloves. Extracts from cloves exhibit a variety of biological activities such as antibacterial, antioxidant, antifungal, anticarcinogenic, antiviral, anticonvulsant, histamine release inhibitor and tyrosinase inhibitory activities (Devkota & Adhikari-Devkota, 2020). Cinnamon (*Cinnamomum zeylanicum*) is one of the oldest and most popular spices used by people. Cinnamon essential oil; consists of monoterpene hydrocarbons, oxygenated monoterpenes, oxygenated diterpenes, oxygenated hydrocarbons, diterpene hydrocarbons and sesquiterpene hydrocarbons. Cinnamaldehyde is the main ingredient responsible for the antimicrobial effect (Cardoso-Ugarte et al., 2016). The antioxidant compounds found in cinnamon are photochatechuic, p-coumaric, p-hydroxybenzoic, vanillic, caffeic, gallic, ferulic acids and p-hydroxybenzaldehyde (Brewer, 2011). For many years, cinnamon essential oil has entered the composition of many different medicinal preparations. Cinnamon essential oil has beneficial effects in the treatment of itching, dry mouth, bronchitis, diarrhea, gall bladder, urinary system and heart diseases. As a result of the researches, it has been shown that cinnamon essential oil and its components also have insecticidal, acaricidal and antimutagenic activities (Cardoso-Ugarte et al., 2016). Thyme (*Thymus vulgaris* L.), belonging to the Lamiaceae family is one of the spices commonly used in the Mediterranean region. It is generally considered safe and has positive health effects. Thymol, carvacrol, y-terpinene and p-cymene are reported to be present in thyme essential oil, which contains about 20 compounds (Fasseas et al., 2008). The main components responsible for its antibacterial, antioxidant and antifungal effects are thymol and carvacrol (Mandal & DebMandal, 2016). Turmeric (*Curcuma longa*) has been widely used in Asia for centuries and has an important role in Indian medicine. Its main components are curcumin, bis-dimethoxycurcumin,dimethoxycurcumin and 2.5-xylenol. It is known that the free radical scavenging ability of turmeric oil is very close to vitamin E and BHT. The α- and β-turmerone, curlone and α-terpineol found in turmeric oil are the main components

that have antioxidant activity (Brewer, 2011). Turmeric is important as a food coloring, spice and natural food preservative (Yıldız et al., 2021). Turmeric can be used in some food products, including dairy products, cereals, biscuits, baked goods, pastry creams, salad dressings, sauces, popcorn, desserts, gelatins, and beverages (Bhowmik et al., 2009; Prasad & Aggarwal, 2011; Yıldız et al., 2021). It is known that fresh and dried ginger also contains compounds with antimicrobial and antioxidant effects (camphene, p-cineol, α-terpineol, zingiberene and pentadecanoic acid). Ginger extract is reported to exhibit nearly equal antioxidant activity to BHA and BHT (Brewer, 2011). Although spices and essential oils are effective and safe as a food preservative, their use may be limited due to their intense flavor (Carpena et al., 2021). Optimization of essential oils combinations and applications is important in order to obtain effective antimicrobial activity at low concentrations that will not adversely affect the organoleptic acceptability of foods (Macwan et al., 2016).

Fruit Extracts as some potential food preservatives

The fruits contain important bioactive compounds, mostly polyphenols. These compounds are distributed in different parts of the fruit such as the peel and seed (Pisoschi et al., 2018). Phytochemicals found naturally in fruits prevent the negative effects of free radicals and microorganisms on food safety and health. Also they give color, aroma and texture to various parts of the plant (Dubreuil, 2020). Fruit extracts that are potential food preservatives include grapes, cranberries and pomegranates (Betanzos-Cabrera et al., 2015). Cranberry is a fruit that contains significant amounts of anthocyanins. The structure of anthocyanins contains many phenolic hydroxyl groups. Owing to this chemical structure, they have positive health effects (anti-cancer, anti-inflammatory, preventing lipid peroxidation and platelet aggregation, preventing diabetes and facilitating weight loss). Cranberry has an antibacterial effect against foodborne pathogens thanks to its rich anthocyanin content (Ma et al., 2019). One of the natural preservatives accepted as an alternative to the use of synthetic additives in recent years is grape seed extract. Grape, one of the most widely grown fruits in the world; has a rich content in terms of polyphenols, tocopherols, other macro and micronutrients. It is a good source of phytochemical components, especially with antioxidant and antimicrobial properties. These components, which are spread over every part of the fruit, are mostly in the seeds (Gómez-Mejía et al., 2021). The grape seed includes significant amounts of catechin, epicatechin, proanthocyanidins, quercetin, gallic acid, epicatechin gallate, rosmarinic acid and oxalic acid (Unusan 2020; Gómez-Mejía et al., 2021). The number of bioactive components contained in grape seed extract is depending on the variety of the grape and the agricultural practices. It is known to show antifungal and antiviral activity in addition to its antibacterial properties (Gómez-Mejía et al., 2021). Grape seed extract reduces lipid oxidation and maintains color stability in cooked and raw meats. Therefore, it has the effect of increasing the shelf life and quality. It is also stated that it does not affect sensory properties such as taste and smell (Aziz & Karboune, 2018). As a result, grapes are one of the most widely grown fruits in the world, making them easy to access. Re-evaluation of grape seed, which is a waste of wine,

molasses, fruit juice and vinegar industries, as a natural preservative in the food industry is also important in terms of sustainable practices (Chen et al., 2020). Besides, grape seed extract can show anti-inflammatory, antioxidant, antihypertensive, anticarcinogenic, neuroprotection and lipid-lowering effects with its proanthocyanidins and phenolic compounds (Unusan, 2020). Pomegranate (*Punica granatum* L.) is among the fruits rich in polyphenols such as tannins. It is mostly found in Asia and belongs to the Punicaceae family. Its antibacterial, antifungal and antioxidant activities have been tested in various studies. Half of the pomegranate fruit consists of the rind. Also, the rind is rich in bioactive components. It consists of flavonoids, anthocyanins, catechins, epicatechin, and epigallocatechin. It also contains tannins such as peduncalagin, punicalin, punicalagin, ellagic acid and gallic acid. It also has positive effects on cardiovascular health and wound healing, reducing the risk of cancer and mutagen formation. (Tanveer et al., 2015).

Plant-based antimicrobials and antioxidants in food preservation

The food industry is becoming more specialized in food processing in order to meet consumer needs. Plant-based food preservatives are important applications in terms of both public health and food safety. There are many studies on the use of essential oils, spices and fruit extracts as antimicrobials and antioxidants in foods (Table 1). Foodborne pathogens threaten health and cause economic losses. For example *Escherichia coli* O157:H7, which is among the foodborne pathogens, can cause hemolytic uremic syndrome, hemorrhagic colitis and thrombocytopenic purpura. *Listeria monocytogenes* is an important pathogen that can cause listeriosis in especially pregnant women, immunosuppressed individuals, and the elderly. Staphylococcal food poisoning is caused by *Staphylococcus aureus* exotoxin and *S.* Typhimurium causes salmonellosis. Therefore, it is great importance for public health to control foodborne pathogens (Harich et al., 2017). Fresh meat is susceptible to microbial spoilage due to its high moisture content. The factors affecting the shelf life of meat during storage are lipid oxidation and microbiological activity. If suitable conditions are not provided, it causes significant economic losses and health problems (Hussain et al., 2021; Khaleque et al., 2016). In recent years, the interest in ready-to-eat foods and the consumption of ready-to-eat meat products have increased. However, even if cooked meats are stored at 4 °C, some pathogens (*Staphylococcus aureus*) can multiply rapidly (Gong et al., 2021). Also, cooked meats are more susceptible to lipid oxidation during storage than raw meat (Reddy et al., 2013). Fish meat is a very important food for human consumption due to its high protein content and other nutritional benefits such as omega-3 and omega-6 fatty acids. However, the nutritional and sensory properties of the product are affected due to lipid oxidation, microbial growth and enzymatic oxidation during storage. Some herbal extracts and spices (sage, grape seed, thyme, clove, kiwi peel) are known to significantly reduce lipid and protein oxidation, inhibit microbial growth and preserve sensory properties in fish meats (Abdel-Wahab et al., 2020; Guan et al., 2019). Fresh fruits and vegetables, which have a very important place in a healthy diet, spoil rapidly because they contain 80-90% water by weight. Since these foods are not processed before consumption, the risk of foodborne illness should be taken into account. Plant-based preservatives

are effective against mold, yeast, *Escherichia coli* O157: H7, *Salmonella* spp. and *Listeria monocytogenes* in fresh fruits and vegetables. (Harich et al., 2017; Paudel et al., 2019).

Table 1. The use of plant-based antimicrobials and antioxidants in foods

Plant-Based Preservatives	Foods	Functions	References
Clove oil	Ground beef	Antimicrobial *(Listeria monocytogenes)*	(Khaleque et al., 2016)
	Chicken frankfurters	Antimicrobial *(Listeria monocytogenes)*	(Mytle et al., 2006)
Clove, sage and kiwifruit peel extracts	Fish fingers	Antimicrobial and antioxidant	(Abdel-Wahab et al., 2020)
Cinnamon oil	Ground lamb	Antimicrobial (Lactic acid bacteria, and Enterobacteriaceae) and antioxidant	(Hussain et al., 2021)
	Melon	Antimicrobial (*Listeria monocytogenes and Salmonella* spp.*)*	(Paudel et al., 2019)
Thyme oil	Cake	Antimicrobial (aerobic mesophilic bacteria, coliforms, yeasts and molds)	(Gonçalves et al., 2017)
	Smoked horse meat sausage	Antimicrobial (total bacterial count and biogenic amines)	(Huang et al., 2021)
Turmeric	Meatballs	Antimicrobial (total aerobic bacteria, total coliform bacteria)	(Demirhan 2020)
	Cuttlefish	Antimicrobial (mesophilic, psychrophilic, biogenic amine-forming bacteria and *Pseudomonas*)	(Arulkumar et al., 2017)
Cranberry	Pre-cut red peppers	Antimicrobial (*Escherichia coli* O157:H7, *Listeria monocytogenes and Salmonella* Typhimurium)	(Harich et al., 2017)
	Cooked meat	Antimicrobial (*Staphylococcus aureus)*	(Gong et al., 2021)
Grape seed extract	*sous vide* cooked ground beef	Antimicrobial (*Clostridium perfringens*)	(Cosansu & Juneja 2018)
	Buffalo veal slices	Antimicrobial (psychrotrophic and yeast and mold) and antioxidant	(Singh et al., 2018)
	Minced beef	Antimicrobial and antioxidant	(Amin & Edris 2017)
	Mutton slices	Antimicrobial (psychrophilic and coliform) and antioxidant	(Reddy et al., 2013)
	Roast chicken	Antimicrobial (total aerobic bacteria, *Pseudomonas spp.*, mold and yeast) and antioxidant	(Guo et al., 2020)
Grape Seed, Sage and Oregano Extracts	Fishballs	Antimicrobial and antioxidant	(Guan et al., 2019)
Pomegranate seed powder, grape seed extract and tomato powder	Chicken nuggets	Antimicrobial (total bacteria, yeast and mold) and antioxidant	(Kaur et al., 2015)
Pomegranate rind extract	Cheese	Antimicrobial (total bacteria, yeast and mold) and antioxidant	(Mahajan et al., 2015)

Application of essential oils in food is a greatly developing area for the food industry. Spices have long been used as food additives. The effects of spices, which are generally added to foods in terms of flavor and color, on food safety and preservation are also investigated (Gottardi et al., 2016).

CONCLUSION

When existing studies are examined, it has been seen that natural preservatives are preferable in terms of food safety and quality. Some spices, plant extracts and essential oils act as antimicrobial and antioxidants owing to bioactive compounds such as terpenes and flavonoids. Although plant-based natural preservatives are attractive to consumers in terms of being sustainable and healthy, the sensory acceptability of food is also an important factor. Foods with intense aromas such as clove oil affect the taste and acceptability, so the amount used is very important. The solution for food preservatives that have intense flavor may be to use them in combination with other preservatives and treatments. Further research is needed to better understand natural antimicrobials in terms of physical, chemical and sensory aspects.

REFERENCES

Abdel-Wahab, M., El-Sohaimy, S.A., Ibrahim, H.A. & Abo El-Makarem, H.S. (2020). Evaluation the efficacy of clove, sage and kiwifruit peels extracts as natural preservatives for fish fingers. Annals of Agricultural Sciences, 65: 98–106.

Amin, R.A. & Edris, S.N. (2017). Grape Seed Extract as Natural Antioxidant and Antibacterial in Minced Beef. *PSM Biological Research*, 2: 89–96.

Arulkumar, A., Ramanchandran, K., Paramasivam, S., Palanivel, R. & Miranda, J.M. (2017). Effects of turmeric (*Curcuma longa*) on shelf life extension and biogenic amine control of cuttlefish (*Sepia brevimana*) during chilled storage. *CyTA* - Journal of Food, 15: 441–447.

Aziz, M. & Karboune, S. (2018). Natural antimicrobial/antioxidant agents in meat and poultry products as well as fruits and vegetables: A review. Critical Reviews in Food Science and Nutrition, 58: 486–511.

Betanzos-Cabrera, G., Montes-Rubio, P. Y., Fabela-Illescas, H. E., Belefant-Miller, H., & Cancino-Diaz, J. C. (2015). Antibacterial activity of fresh pomegranate juice against clinical strains of Staphylococcus epidermidis. Food & Nutrition Research, 59(1): 27620.

Bhowmik, D.C., Kumar, K.S., Chandira, M., & Jayakar, B. (2009). Turmeric: A herbal and traditional medicine. Archives of Applied Science Research, 1(2): 86-108.

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.

Buchbauer, G. & Wallner, I.M. (2015). Essential Oils: Properties, Composition and Health Effects. In: Caballero, B., Toldra, F. & Finglas, P.M. (Ed.). Encyclopedia of Food and Health. Cambridge, Massachusetts, USA: Academic Press. p. 558–562.

Cardoso-Ugarte, G.A., López-Malo, A. & Sosa-Morales, M.E. (2016). Cinnamon (*Cinnamomum zeylanicum*) essential oils. In: Preddy, V. (Ed.). Essential Oils in Food Preservation, Flavor and Safety. Cambridge, Massachusetts, USA: Academic Press. p. 339–347.

Carpena, M., Nuñez-Estevez, B., Soria-Lopez, A., Garcia-Oliveira, P., & Prieto, M. A. (2021). Essential oils and their application on active packaging systems: a review. Resources, 10(1), 7.

Chen, K., Zhang, M., Bhandari, B. & Mujumdar, A.S. (2021). Edible flower essential oils: A review of chemical compositions, bioactivities, safety and applications in food preservation. Food Research International, 139: 109809.

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.

Cosansu, S. & Juneja, V.K. (2018). Growth of *Clostridium perfringens* in sous vide cooked ground beef with added grape seed extract. Meat Science, 143: 252–256.

Demirhan, B. (2020). The effect of turmeric on microbial quality in meatballs. Harran Journal of Food Science, 24: 9–16.

Devkota, H.P. & Adhikari-Devkota, A. (2020). Cold pressed clove (*Syzygium aromaticum*) oil. In: Ramadan, M.F. (Ed.). Cold Pressed Oils. Cambridge, Massachusetts, USA: Academic Press. p. 273–276.

Dubreuil, J. D. (2020). Fruit extracts to control pathogenic *Escherichia coli*: A sweet solution. Heliyon, 6: e03410.

Falleh, H., Ben Jemaa, M., Saada, M. & Ksouri, R. (2020) Essential oils: A promising eco-friendly food preservative. Food Chemistry, 330: 127268.

Fasseas, M.K., Mountzouris, K.C., Tarantilis, P.A., Polissiou, M. & Zervas, G. (2008). Antioxidant activity in meat treated with oregano and sage essential oils. Food Chemistry, 106: 1188–1194.

García-García, R. & Searle, S.S. (2015). Preservatives: Food Use. In: Caballero, B., Toldra, F. & Finglas, P.M. (Ed.). Encyclopedia of Food and Health. Cambridge, Massachusetts, USA: Academic Press. p. 505–509.

Gómez-Mejía, E., Roriz, C.L., Heleno, S.A., Calhelha, R., Dias, M.I., Pinela, J., Rosales-Conrado, N., León-Gonzalez, M.E., Ferreira I.C.F.R. & Barros, L. (2021). Valorisation of black mulberry and grape seeds: Chemical characterization and bioactive potential. Food Chemistry, 337: 127998.

Gonçalves, N.D., de Lima Pena, F., Sartoratto, A., Derlamelina, C., Duarte, M.C.T., Antunes, A.E.C. & Prata, A.S. (2017). Encapsulated thyme (*Thymus vulgaris*) essential oil used as a natural preservative in bakery product. Food Research International, 96: 154–160.

Gong, S., Fei, P., Sun, Q., Guo, L., Jiang, L., Duo, K., Bi, X. & Yun, X. (2021). Action mode of cranberry anthocyanin on physiological and morphological properties of *Staphylococcus aureus* and its application in cooked meat. Food Microbiology, 94: 103632.

Gottardi, D., Bukvicki, D., Prasad, S., & Tyagi, A. K. (2016). Beneficial effects of spices in food preservation and safety. Frontiers in Microbiology, 7, 1394.

Guan, W., Ren, X., Li, Y. & Mao, L. (2019). The beneficial effects of grape seed, sage and oregano extracts on the quality and volatile flavor component of hairtail fish balls during cold storage at 4 °C. *LWT*-Food Science and Technology, 101: 25–31.

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: 1598–1605.

Gutiérrez-del-Río, I., Fernández, J. & Lombó, F. (2018). Plant nutraceuticals as antimicrobial agents in food preservation: Terpenoids, polyphenols and thiols. International Journal of Antimicrobial Agents, 52: 309–315.

Harich, M., Maherani, B., Salmieri, S. & Lacroix, M. (2017). Antibacterial activity of cranberry juice concentrate on freshness and

sensory quality of ready to eat (RTE) foods. Food Control, 75: 134–144.

Huang, L., Wang, Y., Li, R., Wang, Q., Dong, J., Wang, J. & Lu, S. (2021). Thyme essential oil and sausage diameter effects on biogenic amine formation and microbiological load in smoked horse meat sausage. Food Bioscience, 40: 100885.

Hussain, Z., Li, X., Zhang, D., Hou, C., Ijaz, M., Bai, Y., Xiao, X. & Zheng, X. (2021). Influence of adding cinnamon bark oil on meat quality of ground lamb during storage at 4 °C. Meat Science, 171: 108269.

Kaur, S., Kumar, S., Bhat, Z.F. & Kumar, A. (2015). Effect of pomegranate seed powder, grape seed extract and tomato powder on the quality characteristics of chicken nuggets. Nutrition and Food Science, 45: 583–594.

Khaleque, M.A., Keya, C.A., Hasan, K.N., Hoque, M.M., Inatsu, Y. & Bari, M.L. (2016). Use of cloves and cinnamon essential oil to inactivate *Listeria monocytogenes* in ground beef at freezing and refrigeration temperatures. *LWT* - Food Science and Technology, 74: 219–223.

Ma, Y., Ding, S., Fei, Y., Liu, G., Jang, H. & Fang, J. (2019). Antimicrobial activity of anthocyanins and catechins against foodborne pathogens *Escherichia coli* and *Salmonella*. Food Control, 106: 106712.

Macwan, S.R., Dabhi, B.K., Aparnathi, K.D., & Prajapati, J.B. (2016). Essential oils of herbs and spices: Their antimicrobial activity and application in preservation of food. International Journal of Current Microbiology and Applied Sciences, 5(5), 885-901.

Mahajan, D., Bhat, Z.F. & Kumar, S. (2015). Pomegranate (*Punica granatum*) rind extract as a novel preservative in cheese. Food Bioscience, 12: 47–53.

Mandal, S. & DebMandal, M. (2016). Thyme (*Thymus vulgaris* L.) oils. In: Preddy, V. (Ed.). Essential Oils in Food Preservation, Flavor and Safety. Cambridge, Massachusetts, USA: Academic Press. p. 825–834.

Martínez-Graciá, C., González-Bermúdez, C.A., Cabellero-Valcárcel, A.M., Santaella-Pascual, M. & Frontela-Saseta, C. (2015). Use of herbs and spices for food preservation: Advantages and limitations. *Current Opinion in Food Science*, 6: 38–43.

Mytle, N., Anderson, G.L., Doyle, M.P. & Smith, M.A. (2006). Antimicrobial activity of clove (*Syzgium aromaticum*) oil in inhibiting *Listeria monocytogenes* on chicken frankfurters. Food Control, 17: 102–107.

Nair, M.S., Nair, D.V.T., Kollanoor Johny, A. & Venkitanarayanan, K. (2019). Use of food preservatives and additives in meat and their detection techniques. In: Biswas, A.K. & Mandal K.P. (Ed.). Meat Quality Analysis: Advanced Evaluation Methods, Techniques, and Technologies. Cambridge, Massachusetts, USA: Academic Press. p. 187–213.

Ni, Z.J., Wang, X., Shen, Y., Thakur, K., Han, J., Zhang, J.G., Hu, F. & Wei, Z.J. (2021). Recent updates on the chemistry, bioactivities, mode of action, and industrial applications of plant essential oils. Trends in Food Science & Technology, 110: 78–89.

Özel, A.Ç. & Maesaroh, S. Chapter II Microgreen: A General Review, the Importance and Chance of its Development in Turkey. In Agricultural Studies on Different Subjects (Ed: Çığ, A.), 2021, 25-60. Iksad Publications ISBN: 978-625-8007-89-3

Paudel, S.K., Bhargava, K. & Kotturi, H. (2019). Antimicrobial activity of cinnamon oil nanoemulsion against *Listeria monocytogenes* and *Salmonella* spp. on melons. LWT - Food Science and Technology, 111: 682–687.

Pisoschi, A.M., Pop, A., Georgescu, C., Turcuş, V., Olah, N.K. & Mathe, E.

(2018). An overview of natural antimicrobials role in food. European Journal of Medicinal Chemistry, 143: 922–935.

Prasad, S. & Aggarwal, B.B. (2011). Turmeric, the Golden Spice: From Traditional Medicine to Modern Medicine. In: Herbal Medicine: Biomolecular and Clinical Aspects. 2nd edition. (Eds: Benzie, I.F.F.; Wachtel-Galor, S., Boca Raton (FL): CRC Press/Taylor & Francis. Chapter 13, pp. 263–288. Available from: https://www.ncbi.nlm.nih.gov /books/NBK92752/

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.

Singh, P.K., Ahlawat, S.S., Sharma, D.P., Jairath, G. & Pathera, A. (2018). Effect of grape seed extract on storage stability of buffalo veal slices at refrigeration temperature (4±1°C). Journal of Food Safety, 38: e12500.

Tanveer, A., Farooq, U., Akram, K., Hayat, Z., Shafi, A., Nazar, H. & Ahmad, Z. (2015). Pomegranate extracts: A natural preventive measure against spoilage and pathogenic microorganisms. Food Reviews International, 31: 29–51.

Unusan, N. (2020). Proanthocyanidins in grape seeds: An updated review of their health benefits and potential uses in the food industry. Journal of Functional Foods, 67: 103861

Yıldız, H., Er Demirhan, B. & Demirhan, B. An Overview of Turmeric: Properties, Chemical Composition, Health Effects and Uses in Foods, Chapter XV. In Overview on Horticulture (Ed: Çığ, A.), 2021, 373-397. Iksad Publications ISBN: 978-625-7562-92-8