Chapter 8

Phytochemicals in Fruits and Vegetables

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Abstract

Fruits and vegetables are the most important sources of phytochemicals. Phytochemicals use for both human diets and natural antimicrobial agents in food preservation. Their benefits for health are mainly due to high antioxidant activity. Antimicrobials of plant origin are known as secondary metabolites that could play a role not only individually or jointly against food-borne pathogens but also contribute to food flavor. Phytochemicals have a strong effect on control and prevention of natural spoilage processes and growth of microorganisms, including pathogens causing food safety issues. Microorganisms are always associated with harvested plants and slaughtered animals, the basic unprocessed materials of the food industry. Since foods consumed by humans undergo several processing treatments, it is important to understand the effect of such treatments on the phytochemical composition of foods.

Keywords: phytochemicals, food preservatives, food spoilage, food phenolics

1. Introduction

Fruits and vegetables are consumed as fresh or processed and known to be among the most important sources of phytochemicals for the human diet. About 200,000 phytochemicals are known so far and 20,000 of them have been identified as originating from fruits, vegetables and grains [1]. Phytochemicals has many health effects as antioxidants against many diseases or antibacterial, antifungal, antiviral, cholesterol-lowering, antithrombotic, or anti-inflammatory effects [2]. Phytochemicals are used for various purposes such as pharmaceuticals, agrochemicals, flavors, fragrances, coloring agents, biopesticides and food additives [1]. Their chemical structures composed of phytochemicals such as phenolics, alkaloids, saponins and terpenoids [1]. These compounds are known as secondary metabolites having various identifiable structures, although a benzene ring with one or more hydroxyl groups is a common feature. They are commonly classified as flavonoids (anthocyanins, flavan-3-ols, flavonols, proanthocyanidins or flavones, non-hydrolyzable tannins, isoflavones and flavanones) and non-flavonoids (hydroxycinnamic, hydroxybenzoic acid, hydrolyzable tannins, benzoic acids and stilbenes) [3]. Sugars, acids and polysaccharides are an important source of phytochemicals, secondary metabolites of plants also known as their antioxidant activity and other properties [4]. Lately, there are many investigations on plant "antimicrobial," "antiviral," or "antibacterial" effects [1]. In addition, phytochemicals are some of the most important natural preservation structures to reduce and inhibit pathogenic microorganism growth and preserve the overall quality of food products [5]. These antimicrobials can protect food products, extending the shelf life naturally [5]. Chilling, fermentation, freezing, acidification, nutrient restriction, water activity reduction, synthetic antimicrobials and pasteurization have been used in food preservation technology and phytochemicals such as flavonoids, polyphenols, anthocyanins and carotenoids are also used to preserve and control microbial spoilage in foods traditionally [6]. In general, food antimicrobials can be classified as natural and synthetic substances depending on their origin. Synthetic antimicrobials are found in fruits naturally such as benzoic acid in cranberries, tartaric acid in grapes, sorbic acid in rowanberries, malic acid in apples and citric acid in lemons [6]. Secondary metabolites are in close contact through sophisticated communication involving metabolic attacks by plants on their pathogens [7]. Fruits and vegetables have phenolics which are biologically active compounds. Fruits and vegetables have a special phytochemical group which protect plants from their environment stress such as pollution, pathogens, or various abiotic stresses [2]. Even if secondary metabolites having different structures, they can have similar functions. First, plant-defensive metabolites include phytoalexins biosynthesized to respond to biotic and abiotic stresses with the effect of both protecting the plant and controlling the pathogen growth [7]. Secondly, most of these metabolites are responsible for the organoleptic and qualitative properties of foods originating from such plants. For example, anthocyanins constitute a pigment group responsible for the color of a great variety of fruits, flowers and leaves [8] and flavan-3-ols are polyphenols involved in the bitterness and astringency of tea, grapes and wine [9, 10]. Thirdly, these compounds are unique sources of industrial material in the form of food additives, pharmaceuticals and flavors [11]. Finally, they are considered to be beneficial for health, mainly due to their antioxidant activity. Many studies have suggested that a high intake of polyphenol-rich foods may have cardiovascular benefits and provides some level of cancer chemopreventive activities and beneficial effects against other less prevalent but devastating illnesses, such as urinary bladder dysfunctions and Alzheimer's disease [12]. Furthermore, food scientists and nutrition specialists suggest that phytochemicals offer many health benefits when consumed as part of the usual human diet [13].

2. Commonly used methods of treating plant foods

Many fresh fruits especially small berries and vegetables are highly perishable after harvest. During the harvest, bruising can reduce shelf life, influencing both color and texture of fresh products. The freshness of fruits and vegetables can be maintained in storage through reduction of temperature and/or oxygen levels, increase in carbon dioxide levels, use of modified atmosphere packaging or edible coatings, or treatment with gamma irradiation or high pressure. These can also be combined with treatments of 1-MCP, ozone and ultraviolet (UV) irradiation to further prevent losses. One of the most basic treatments used to lengthen the shelf life of fresh commodities during storage is to store in a low temperature and high relative humidity conditions. It has been known and used to extend the shelf life of fruits and vegetables since antiquity [14]. Moreover, exposure to low temperature during storage optimizes produce appearance and has the additional benefit of protecting nonappearance quality attributes, such as texture, nutrition, aroma and flavor [14]. There are many chemical and natural preservative treatments used to reduce postharvest losses and extend the shelf life of fresh commodities. Using plant extracts with known antimicrobial properties can be of great importance in food preservation. There are some chemical substances in plants that produce a definite action on the microbiological, chemical and sensory quality of foods and these phytochemicals have been grouped in several categories including polyphenols, flavonoids, tannins, alkaloids, terpenoids, isothiocyanates, lectins, polypeptides, or their oxygen-substituted derivatives [6]. On the other hand, alternative sources of natural products, such as plant extracts, either as pure compounds or as standardized extracts, provide unlimited opportunities for control of microbial growth owing to their chemical diversity. The use of natural antimicrobials as phytochemicals is organic acids, essential oils, or plant extracts and could be a good alternative to ensure food safety [6]. To inactivate or inhibit the growth of spoilage and pathogenic microorganisms during preservation of food, there are several processing techniques used including the use of chemical preservatives and synthetic antimicrobials [5]. However, these techniques have not been considered natural antimicrobial agents in food preservation. But, naturally derived compounds in plant extracts can be good control agents for pathogenic microorganisms. The use of synthetic chemicals is increasingly restricted in many countries. Nowadays, the recent trend has been for the use of natural preservatives due to the adverse health effects of synthetic ones. The alternative methods preserve foods and reduce pest and pathogen injury, with the use of resistant varieties or integrated cropping strategies in which plant secondary metabolites may improve crop protection [6]. The major goals of such natural antimicrobials are to protect the food from food poisoning and spoilage microorganisms that cause off-odors, off-flavors and discoloration quality losses [6]. Antimicrobials are called traditional when they have been used for many years and many countries approve them for inclusion in foods. Although many synthetic antimicrobials are found naturally (benzoic acid, sorbic acid, citric acid, malic acid, tartaric acid), the perception of natural has become important for many consumers. The safety and shelf life of food ingredients can also be improved by application of novel technologies to avoid or delay microbial growth like packaging in modified atmosphere, nonthermal treatments, activated films, irradiation, etc. [6]. The use of fruits and vegetables as a source of certain phytochemicals, such as ascorbic acid (AA), carotenoids, phenols and flavonoids, has not only health-promoting effects but also widely used to restrict oxidation-induced degenerative changes in cell physiology and aging [15] and is well known due to their significant impact on the food industry [16]. Both glucosinolates and leaf surface waxes are important phytochemicals that also play an important role in protecting plants from pest and pathogen injury [17]. These factors that positively affect plant protection also minimize crop damage by pests and pathogens. Β-Carotene, lycopene, lutein and zeaxanthin are known to exhibit antioxidant activity. Increasing oxidative stress results in produce losing keeping quality, not only in terms of microbial contamination, excessive softening and browning but also in terms of significant depletion of phytochemicals, such as phenolics, flavonoids, ascorbic acid and carotenoids. The addition of AA minimizes oxidative deterioration in processed fruits and vegetables. Exogenous treatment of AA in minimally processed fruits and vegetables reduces or stops enzymatic browning and oxidation-susceptible degenerative changes such as the deterioration of carotenoids, phenolics and flavonoids [16].

Phenolics and their metabolites are common constituents of fruits and vegetables that play an important role as to provide astringency and aroma constituents [15]. Polyphenolic compounds are important as food preservatives that inactivate free radicals giving them an important role fighting against pathogenicity, infestation and photooxidation [1, 15]. In general, antibacterial activity of phenolic acids is stronger against Gram-positive bacteria than Gram-negative bacteria [1]. The main problems for such antimicrobials are food-poisoning microorganisms and spoilage microorganisms that are metabolic end products causing off-odors, off-flavors, texture problems and discoloration of food [1]. Phytochemicals, such as phenolic compounds, are of great importance as antithrombotic, anticarcinogenic and anti-inflammatory agents. However, due to the possible negative effects of synthetic antioxidants, food industries prefer natural ones and can be used as food additives or pharmaceutical supplements [13]. First of all, they protect plants from biotic and abiotic stress factors. Indeed, such phenolic compounds are only induced when stress factors are present and so-called phytoalexins are specifically involved in defense mechanisms and are synthesized after pathogen or predator attack or injury [18].

3. Phytochemical and secondary metabolites present in plant foods

Secondary metabolites present in plant foods, such as alkaloids, phenolic compounds (flavonoids, isoflavonoids and anthocyanins) and terpenoids, have gained importance because of their antioxidant, antiviral, antibacterial and anticancer effects [19]. These phytochemicals are mixtures of several components, including phytophenolics in herbs and spices, phenolics, flavonoids and acids in fruits and glucosinolates in cruciferous vegetables (mustard) [5]. As shown in **Table 1**, *Rubus* (cloudberry and raspberry) extracts have antimicrobial effects against food spoilage and poisoning bacteria [21]. In general, antioxidant compounds have important protection effects from fruit insects and microbial organisms during storage [23]. Secondary metabolites are very important in medicine and agricultural science due to the activity of chemotherapeutic compounds or pesticides. Phenolics and flavonoids provide very important defense mechanisms against postharvest diseases [23]. For example, walnut seed coats contain gallic acid which is a phenolic compound that prevents aflatoxin biosynthesis by *Aspergillus flavus* (**Table 1**) [23]. Therefore, polyphenol compounds have antiviral activities to some various types of viruses [23]. One of the other very important phytochemical groups are flavonoids which have antiallergenic, antiviral, antifungal and anti-inflammatory activity. It is abundant in most of the fruits and vegetables such as apples, grapes, lemons, tomatoes, onions, lettuce, broccoli, etc. [23]. Flavonoids are also known as one of the largest groups of natural phenolic compounds in plants [27]. These natural compounds have important effects against a variety of microorganisms [27]. In addition, flavonoids either have protective effects from microbial attacks or respond as phytoalexins against them. Volatiles are phytochemicals that are either inhibitory or stimulatory to fungal growth. Acetaldehyde, a volatile compound that occurs in fruit during ripening, has a fungicidal effect on postharvest pathogens [23]. As shown in **Table 1**, "Isabella" (*Vitis labrusca* L.) grape variety volatiles have a strong effect on *B. cinerea* development [19].

Name plant	Effects	References
The cranberry juice	Inhibition of *E. coli*	Howell et al. [20]
Some berry extracts (*Rubus*)	Food spoilage and poisoning bacteria	Rauha et al. [21]
Grape seed or rosemary extracts	Food preservatives	Blasa et al. [22]
Riesling grape	Gram-positive food-borne pathogens	Tajkarimi and Ibrahim [5]
Flavonoids in plant tissue	Antimicrobial	Saxena et al. [15]
Flavonoids	Antiallergenic, antiviral, and antifungal	Ippolito and Nigro [23]
Bergamot fruit extract	*Saccharomyces cerevisiae*	Mandalari et al. [24]
Citrus species and grape	*Fusarium oxysporum*	Okwu et al. [25]
Glucosinolates and leaf surface	Pest and pathogen injury	Björkman et al. [17]
The "Isabella" (*Vitis labrusca* L.) grape	(*B. cinerea*)	Makkar et al. [19]
The walnut seed coats (gallic acid)	Aflatoxin	Ippolito and Nigro [23]
Pomegranate fruit	*P. italicum*, *R. stolonifer* and *B. cinerea*	Tehranifar et al. [26]

Table 1. The effects of fruit and vegetable extracts on food pathogens.

4. Phytochemicals as natural preservatives and antimicrobials

Natural preservatives derived from plant extracts such as phytochemicals and essential oils are used against fungal development in many fruits and vegetables after harvest [28]. The efficiency of an antimicrobial treatment depends on many factors, such as type, genus, species and strain of the main microorganism, in addition to environmental factors such as pH, water activity, temperature, atmospheric composition and an initial microbial load of the food materials [6]. Therefore, other important subject to know is type of the microorganism(s) owing to usually combinations of antimicrobials are more effective than adding just one. The natural antimicrobial preservative activity is not clear since there are many influencing factors, one of the most important being the interaction between phytochemicals and growth of microorganisms [6]. Processing of foods containing phytochemicals is expected to result in some changes in their phytochemical content. Phytochemicals present in many food stuffs are lost by heat processing such as sterilization, pasteurization and dehydration [6].

Many investigations have evaluated phytochemical effects on antifungal activity. The potential use of plant extracts as natural antimicrobial agents in food preservation forms the basis for many applications such as grape seed or rosemary extracts that have been used as food preservatives [22]. Researchers reported that grape extracts of Riesling *Vitis vinifera* L. grapes showed strong preservative effects against some of the Gram-positive food-borne pathogens [5]. The alkaloids, steroids, tannins, flavonoids, saponins and glycosides which were secondary metabolites showed various biological activities and act in plant defense mechanisms. Flavonoids usually occur as glycosides and aglycones in plant tissue which have significant antioxidant properties and antimicrobial and insect-repellent properties as well [15]. Flavonoids and their antimicrobial effect are useful as a food preservative to extend the shelf life and safety of foods. Flavonoids play important roles in biological activities, including antiallergenic, antiviral and antifungal effects [23]. It is also present in various common fruits and vegetables (apples, grapes, lemons, tomatoes, onions, lettuce and broccoli). The following flavonoids are antifungal agents in plants: isoflavonoids, flavans flavanones. However, the antifungal activity of flavonoid compounds plays an important role between plant-microorganism and host plant's defensive systems [8]. Saponin and flavonoids are found in fruits and vegetables and in general they form a soapy lather after extracted from parts of plants [5]. Mandalari et al. [24] reported that Bergamot fruit extract which is rich in flavonoid has an effective on the yeast *Saccharomyces cerevisiae* (**Table 1**).

Okwu et al. [25] also showed that the antifungal activity of both citrus species and grape has an important effect against *Fusarium oxysporum* (**Table 1**). Thiosulfinates come from hydrolysis products of garlic and onion. They have a strong potential of producing antimicrobial effects against pathogenic microorganisms [5]. Broccoli, Brussels' sprouts, cabbage mustard and horseradish have glucosinolates that also have a wide range of antibacterial effects. Moreover, olive leaves (*Olea europaea*) are rich in phenolic compounds, with demonstrated strong antimicrobial effects and can be potentially used in food processing [5]. Al-Zoreky [29] reported that phenolics and flavonoids present in pomegranate fruit peels demonstrated strong antimicrobial activity against some food pathogen microorganisms. In addition, *Psidium guajava* has phenolic, flavonoid, carotenoid, terpenoid and triterpenes that demonstrated strong antimicrobial activity [30]. Salas et al. [31] reported that flavonoids extracted from citrus species, not only naringin, hesperidin and neohesperidin but also enzymatically modified derivatives of these compounds, have strong antifungal activity [31]. The limonoid compounds have important antibacterial and antiviral activity as shown in **Table 1** [1]. Vikram et al. [32] reported that seeds of grapefruits have significant inhibitory effect on pathogenic *Escherichia coli* O157:H7. Black raspberry and Chardonnay seed extracts have also antibacterial activity to inhibiting growth of some food pathogen microorganisms [33]. Tehranifar et al. [26] reported that high percentage of phenolic content in the peel and seed of pomegranate fruit has high antifungal activity especially on postharvest fungi (*Penicillium italicum*, *Rhizopus stolonifer* and *Botrytis cinerea*). Another study showed that berry extracts exhibit selective inhibitory properties against intestinal bacteria [1]. Recently, antifungal activity has been found in all tissue types of strawberry fruit due to the phenolic compounds that inhibit the growth of fungi [23].

5. Other beneficial properties of plant phytochemicals

In the last decade, the results of many research have shown the positive effects of phytochemicals in human health. There is a strong correlation of antioxidant consumption with lower risk of many diseases such as cardiovascular cancer, diabetes and hypertension diseases as well as other medical conditions [34, 35]. Fruits and vegetables have phenolic compounds, pigments and natural antioxidants; these compounds protect many diseases like cancer and heart disease [36]. The importance of antioxidant effects on cardiovascular diseases and cancer is especially important [23] and these antioxidants can be found in various fruits, vegetables and herbs. Phenolics as flavonoids have an important effects such as antimicrobial, anti-inflammatory, antioxidant, antiviral, antiallergic, anticancer, antiulcer, antidiabetic, antiplasmodial, antihypertensive, anticonvulsant and all reducing risks for severe human diseases [27]. Antioxidants in fruits and vegetables have defensive effects and are three main groups: vitamins, phenolics and carotenoids [35]. Vitamin C (L-ascorbic acid, AA) and the oxidized form (dehydroascorbic acid, DHAA), carotenoids and phenolic compounds prevent cardiovascular disease, cancer and cataracts which are associated with the oxidative damage of lipids, DNA and proteins [4]. Moreover, some carotenoids also have antioxidant activity (AOA) and shown beneficial effects on the reduction of cardiovascular diseases [4]. The fruits and vegetables that have phytochemicals are also not only low in fat and saturated fat, cholesterol and calories but also are rich in potassium and sodium, fiber, folic acid and AA [34]. One of the most important flavonols is quercetin, which is higher in onion (red and yellow), broccoli, kale, French beans, apple, red grapes and cherries. Quercetin is anticarcinogenic and inhibits low-density lipoprotein (LDL) oxidation activities [34].

6. Conclusion

In a conclusion, potentially a great number of phytochemicals including some of the vitamins, flavonoids, terpenoids, carotenoids, phenolics, phytoestrogens, minerals and antioxidants in plant materials are used as alternative preservative agents for controlling postharvest physiological disorders or microbial pathogen injuries of both fresh fruit and vegetables in the food industry. Many publications have focused on the potential protective nature of these natural phytochemical compounds against fungal and bacterial attacks. Moreover, these natural compounds have become interesting candidates not only for plant protection but also human and animal health protection from fungal and bacterial diseases because of their lower toxicity or absence of toxicity.

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References

[1] Patra AK. Dietary Phytochemicals and Microbes. ISBN 978-94-007-3925-3 ISBN 978-94-007-3926-0 (eBook). 2012; DOI 10.1007/978-94-007-3926-0 Springer Dordrecht Heidelberg New York London.

[2] Schreiner M, Huyskens-Keil S. Phytochemicals in Fruit and Vegetables. Crit. Rev. Plant Sci. 2006;25:267–278.

[3] Waterhouse AL. Wine Phenolics. Ann. N. Y. Acad. Sci.. 2002;957:21–36.

[4] Escobedo-Avellaneda Z, Janet G.-U., Aurora Valdez-Fragosoa J, Antonio T., Welti-Chanesa J. Phytochemicals and antioxidant activity of juice, flavedo, albedo and comminuted orange. J. Funct. Foods. 2014;6:470–481.

[5] Tajkarimi M, Ibrahim SA. Phytochemicals as Anti-microbial Food Preservatives. Chapter 2012;7:207–225. In: Patra AK. Dietary Phytochemicals and Microbes. ISBN 978-94-007-3925-3 ISBN 978-94-007-3926-0 (eBook). DOI 10.1007/978-94-007-3926-0 Springer Dordrecht Heidelberg New York London.

[6] Negi PS. Plant Extracts for the Control of Bacterial Growth: Efficacy, Stability and Safety Issues for Food Application. Int. J. Food Microbiol. 2012;156:7–17.

[7] Soledade M, Pedras C. Fungal Attack and Cruciferous Defenses: Tricking Plant Pathogens. Chapter. 2011;9:127 pp. in: Gang DR. The Biological Activity. of Phytochemicals. Vol. 41, DOI 10.1007/978-1-4419-7299-6. ISBN 978-1-4419-6961-3 e-ISBN 978-1-4419-7299-6. Springer New York Dordrecht Heidelberg London.

[8] Harborne JB, Williams CA. Advances in Flavonoids Research Since 1992. Phytochemistry. 2000;55:481–504.

[9] Noble AC. Bitterness in Wine. Physiol. Behav. 1994;56:1251–1255.

[10] Halsam E, Lilley TH. Natural Astringency in Foodstuffs—A Molecular Interpretation. Crit. Rev. Food Sci. Nutr. 1988;27:1–40.

[11] Zhao J, Davis LC, Verpoorte R. Elicitor Signal Transduction Leading to Production of Plant Secondary Metabolites. Biotechnol. Adv. 2005;23:283–333.

[12] De Pascual-Teresa S, Moreno DA, Garcia-Viguera C. Flavanols and Anthocyanins in Cardiovascular Health: A Review of Current Evidence. Int. J. Mol. Sci. 2010;11:1679–1703.

[13] Tlili N, Mejri H, Yahia Y, Saadaoui E, Rejeb S, Khaldi A, Nasri N. Phytochemicals and antioxidant activities of Rhus tripartitum (Ucria) fruits depending on locality and different stages of maturity.Food Chemistry, 2014;160:98–103.

[14] Paull RE. Effect of Temperature and Relative Humidity on Fresh Commodity Quality. Postharvest Biol. Technol. 1999;15:263–277.

[15] Saxena A, Bawa AS, Raju PS. Phytochemical Changes in Fresh-cut Jackfruit (*Artocarpus heterophyllus* L.) Bulbs During Modified Atmosphere Storage. Food Chem. 2009;115:1443–1449.

[16] Devi RR, Jayalekshmy A, Arumughan C. Antioxidant Efficacy of Phytochemical Extracts from Defatted Rice Bran in the Bulk Oil System. Food Chem. 2007;104:658–664.

[17] Björkman M, Klingen I, Birch ANE, Bones AM, Bruce TJA, Johansen TJ, Meadow R, Mølmann J, Seljåsen R, Smart LE, Stewart D. Phytochemicals of Brassicaceae in Plant Protection and Human Health—Influences of Climate, Environment and Agronomic Practice. Phytochemistry. 2011;72:538–556.

[18] Cantos E, Espín JC, Fernández MJ, Oliva J, Tomás-Barberán A. Postharvest UV-C-Irradiated Grapes as a Potential Source for Producing Stilbene-Enriched Red Wines. J. Agric. Food Chem. 2003;51:1208–1214.

[19] Makkar HPS, Siddhuraju P, Becker K. Plant Secondary Metabolites. Institute for Animal Production in the Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany. Humana Press Inc., a division of Springer Science+Business Media. 2007. LLC 999 Riverview Drive, Suite 208 Totowa, New Jersey 07512.

[20] Howell AB, Vorsa N, Marderosian AD, Foo LY. Inhibition of the Adherence of P-fimbriated *Escherichia coli* to Uroepithelial Surfaces by Proanthocyanidin Extracts from Cranberries. New Engl. J. Med. 1998;339:1085–1086.

[21] Rauha JP, Remes S, Heinonen M, Hopia A, Kähkönen M, Kujala T, Pihlaja K, Vuorela H, Vuorela P. Antimicrobial Effects of Finnish Plant Extracts Containing Flavonoids and Other Phenolic Compounds. Int. J. Food Microbiol. 2000;56:3–12. doi: 10.1016/S0168-1605(00)00218-X.

[22] Blasa M, Gennari L, Angelino D, Ninfali, P. Fruit and vegetables antioxidants in health, U: Bioactive foods in promoting health (fruits and vegetables), Watson, R.R.,Preedy, V.R. (Ed.), Elsevier Inc., New York, pp. (2010); 37-58.

[23] Ippolito A, Nigro F. Natural Antimicrobials for Preserving Fresh Fruit and Vegetables. in: Wim, J. Improving the Safety of Fresh Fruit and Vegetables. 2005.

[24] Mandalari G, Bennett R, Bisignano G, Trombetta D, Saija A, Faulds C, Gasson M, Narbad A. Antimicrobial Activity of Flavonoids Extracted from Bergamot (Citrus bergamia Risso) Peel, a by Product of the Essential Oil Industry. J. Appl. Microbiol. 2007;103(6):2056–2064.

[25] Okwu DE, Awurum AN, Okoronkwo JJ. Phytochemical Composition and in vitro Antifungal Activity Screening of Extracts from Citrus Plants against Fusarium oxysporum of Okra Plant (*Hibiscus esculentus*). Afr. Crop Sci. Conf. Proc. 2007;8:1755–1758.

[26] Tehranifar A, Selahvarzi Y, Kharrazi M, Bakhsh VJ. High Potential of Agro-Industrial by Products of Pomegranate (*Punica granatum* L.) as the Powerful Antifungal and Antioxidant Substances. Ind. Crop Prod. 2011;34(3):1523–1527.

[27] De Conti Lourenço RMC, P. da Silva Melo, De Almeida ABA. Flavonoids as Antifungal Agents. Chapter 10. in: M. Razzaghi-Abyaneh and M Rai (eds.), Antifungal Metabolites from Plants. 2013; DOI: 10.1007/978-3-642-38076-1_10, Springer-Verlag Berlin Heidelberg.

[28] Sharma R. Ozone Decontamination of Fresh Fruit and Vegetables. in: Wim, J Improving the Safety of Fresh Fruit and Vegetables. 2005.

[29] Al-Zoreky NS. Antimicrobial Activity of Pomegranate (*Punica granatum* L.) Fruit Peels. Int. J. Food Microbiol.. 2009;134(3):244–248.

[30] Gutierrez RMP, Mitchell S, Solis RV. *Psidium guajava*: A Review of its Traditional Uses, Phytochemistry and Pharmacology. J. Ethnopharmacol. 2008;117(1):1–27. doi: 10.1016/j.jep. 2008.01.025.

[31] Salas MP, Celiz G, Geronazzo H, Daz M, Resnik SL. Antifungal Activity of Natural and Enzymatically-Modified Flavonoids Isolated from Citrus Species. Food Chem. 2011;124(4):1411–1415.

[32] Vikram A, Jesudhasan PR, Jayaprakasha GK, Pillai BS, Patil BS. Grapefruit Bioactive Limonoids Modulate *E. coli* O157:H7 TTSS and Biofilm. Int. J. Food Microbiol. 2010;140:109–116.

[33] Luther M, Parry J, Moore J, Meng JH, Zhang YF, Cheng ZH, Yu LL. Inhibitory Effect of Chardonnay and Black Raspberry Seed Extracts on Lipid Oxidation in Fish Oil and their Radical Scavenging and Antimicrobial Properties. Food Chem. 2007;104(3):1065–1073.

[34] Craig WJ. Phytochemicals: Guardians of our Health. J. Am. Diet. Assoc. 1997;97(10):199–204.

[35] Thaiponga K, Boonprakoba U, Crosbyb K, Cisneros-Zevallosc L, Byrnec DH. Comparison of ABTS, DPPH, FRAP and ORAC Assays for Estimating Antioxidant Activity from Guava Fruit Extracts. J. Food Compos. Anal. 2006;19:669–675.

[36] Rodríguez-Fragoso L, Osuna-Martínez U, Gonzaga-Morales AI, Reyes-Esparza J. Potential Antioxidant Benefits of Commonly Used Fruits and Vegetables around the World. in: Pereira, DAM. Medicinal Plants: Antioxidant Properties, Traditional Uses and Conservation Strategies. Nova Science Publishers, Inc., Hauppauge, NY, USA: 2013.