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Identification of Antioxidant Additives in Food Products Sold in Dakar Markets

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Abstract

The use of food additives in industrial production has the advantage of improving sensory properties, technological quality and extending the shelf life of foods. Among the most widely used additives are antioxidants, which prevent oxidation, browning and rancidity reactions in foods. However, the strong presence of these additives on the market is not without risks for human health, and should be controlled to guarantee food safety. Analysis of the risks associated with consumption of foods containing these additives requires, among other things, information on the frequency of use of these additives in various consumer products. The aim of this study is therefore to identify the antioxidants present in industrial food products distributed in Dakar. The methodology adopted consists of a qualitative analysis based on the identification of additives from food labels. Investigations were carried out in 9 stores, 4 superettes and 2 supermarkets located in different districts of Dakar. The results revealed the presence of 12 antioxidant additives, dominated by citric acid (53%) and ascorbic acid (29%). These studies have also highlighted the simultaneous use of several antioxidants in the same food product. Moreover, for some artificial antioxidants identified antioxydant such as BHA and BHT, health risks are associated with their consumption. The results of this study open up prospects for the development of information databases on food additives.

Keywords

Additives, Antioxidant, Food Products, Market, Risk

1. Introduction

Foodstuffs can be degraded through a variety of physical, chemical, enzymatic and microbiological reactions. These reactions contribute to high food losses during production, processing, storage and distribution [1]. In addition, they can lead to the production of toxic substances such as free radicals and microbial toxins, which are responsible for serious food-related illnesses [2]. For centuries, man has used processes such as drying, salting, sugaring and fermenting to preserve foodstuffs. Moreover, in recent decades, with the rapid industrialization of the agri-food sector and scientific advances, natural and artificial substances known as additives have been widely used to preserve food stability. Among these additives are the antioxydant used in foods to avoid chemical and enzymatical alternatives. In fact, antioxidants help extend shelf life by inhibiting reactions such as enzymatic activity, browning and, above all, rancidity [3]. Indeed, one of the main obstacles to food preservation is rancidity, which is linked to the oxidation of unsaturated fatty acids, a process that occurs through the formation of free radicals by oxygen, leading to a series of chain reactions [4]. Food antioxidants, added to foodstuffs, have the same mission as endogenous antioxidants in the human body, namely to protect foodstuffs against these attacks, while preserving their organoleptic quality, texture and safety for consumption [5]. Today, the use of antioxidants is increasingly contested by consumers due to the many negative effects attributed to them. Indeed, artificial antioxidants may have carcinogenic effects and must therefore be strictly controlled [3]. So, although artificial additives dominate the market, new consumer trends are forcing manufacturers to find alternatives to their natural equivalents [5]. What's more, food regulatory authorities, in conjunction with industry and the scientific community, are regularly tightening regulations on the use of these substances to ensure consumer health safety. With this in mind, the EFSA, the FDA and the Codex Alimentarius Commission, through JECFA, regularly undertake studies to assess and re-evaluate the toxicity of certain food addtives [6] [7]. These assessments, which follow well-defined procedures [8], require, among other things, access to data relating to frequency in foods and their level of consumption by populations. However, in Senegal, few data on the presence of antioxidants additives are available in the scientific literature. It is in this context that this study set itself the objective of completing the profile and frequency of antioxidant addtives in industrial food products marketed in Dakar.

2. Materials and Methods

The study concerned samples of labels of industrial foodstuffs marketed in Dakar over the period from October to December 2022 Data collection was carried out in Dakar, with the owners' approval, at 9 stores, 2 wholesalers, 4 petrol station minimarkets and one supermarket, in order to obtain a diverse range of products. The data collection process involved checking whether the product contained at least one food additive of any type, in order to determine the profile of antioxidants and the proportion of all food additives in the listed products. To this end, a photo of the ingredients and the product name on the packaging was taken to avoid duplication. The samples were made up of various food products covering most of the food products commonly distributed on the national market. These samples were grouped into 16 food categories based on the Codex classification of foods [9]. The number of samples for each category depended on the availability of the products concerned on the market and the presence of information on food additives.

The approach consisted in collecting this information from food product labels at randomly selected sales outlets, *i.e.* local stores, mini-markets, markets and supermarkets. The methodology applied is based on the identification of food additives from information on food packaging, as adopted in several studies [10] [11]. Indeed, standards and regulations governing the development of food products require information that objectively informs the consumers about food additives. Regulation (EU) No. 1169/2011 of the European Parliament on the provision of food information to consumers was published in the Official Journal of the European Union on November 22, 2011. Similarly, the General Standard on the Labeling of Prepackaged Foods specifies that the full list of ingredients is a mandatory label statement [12].

The survey was carried out using a smartphone equipped with a digital camera for photographing product labels and a computer for data recording. Statistical data processing is carried out using Microsoft Excel version 2016). A qualitative approach was applied to identify additives in food products. The names of the substances on the labels and, above all, the indication of the function sought by the manufacturers made it possible to identify the additives in question by reference to the Codex standard [13]. The frequency of antioxidant additives in the samples was calculated using the following formula:

$$\text{Fao} = \frac{\text{Tao}}{\text{Tadd}} \times 100$$

Fao: Frequency of antioxidant additives;

Tadd: Total number of antioxidant additives on food labels;

Tadd: Total number of food additives on food labels.

For determination antioxydants frequency in a food category, the calculation takes into account the food additives present in this category. For the overall frequency (preponderance) of antioxidant additives, the sum total of food additives identified in all samples was considered.

3. Results

A total of 399 industrial food product labels (N) were collected from retail outlets in Dakar. These samples consisted of milk and milk products (6.3%; N = 25), fats (1.5%; N = 6), fruit and vegetables (10.8%; N = 43), confectionery (10%; N = 40), cereals and cereal-based products (8.2%; N = 30), bakery products (8.5%; 34), meat and meat products (6%; N = 24), bouillons, sauces and soups (18.3%;

N = 73), beverages (18.5%; N = 74) and miscellaneous products (2.2%; N = 9). The latter products include savoury snacks, infant formula and ready meals.

In the samples surveyed, the frequency of antioxidant additives in the various food product categories varied (Figure 1). Compared with other additives, these substances are most prevalent in fruit and vegetables (52% of additives identified), fats and oils (28%) and beverage (26%). They are also very common in meat, meat products and poultry (21%) and broths, sauces and condiments (18%). In other food categories such as milk and confectionery, their frequency is relatively low.

There are 12 substances declared as antioxidants by manufacturers (Figure 2). In terms of representativeness, these antioxidant additives are largely dominated

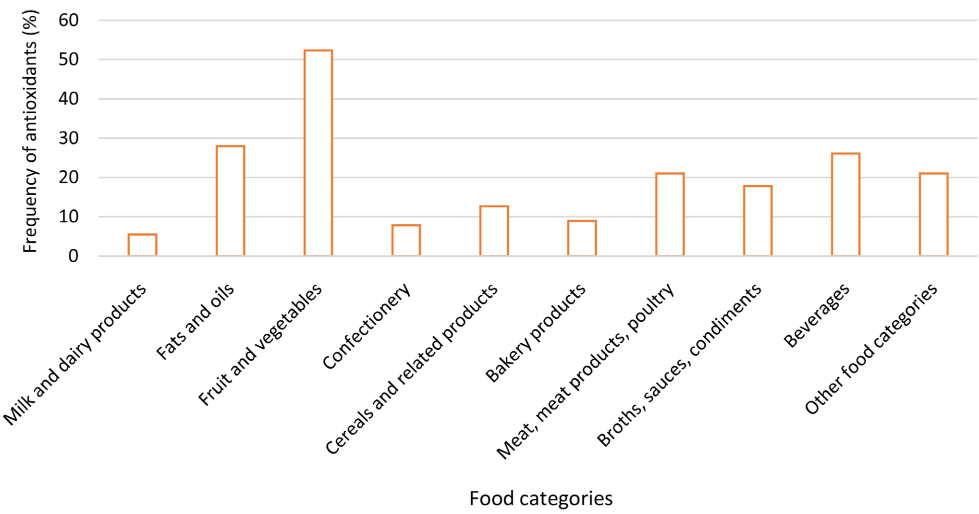

Figure 1. Frequency of antioxidants in relation to additives identified in different food categories.

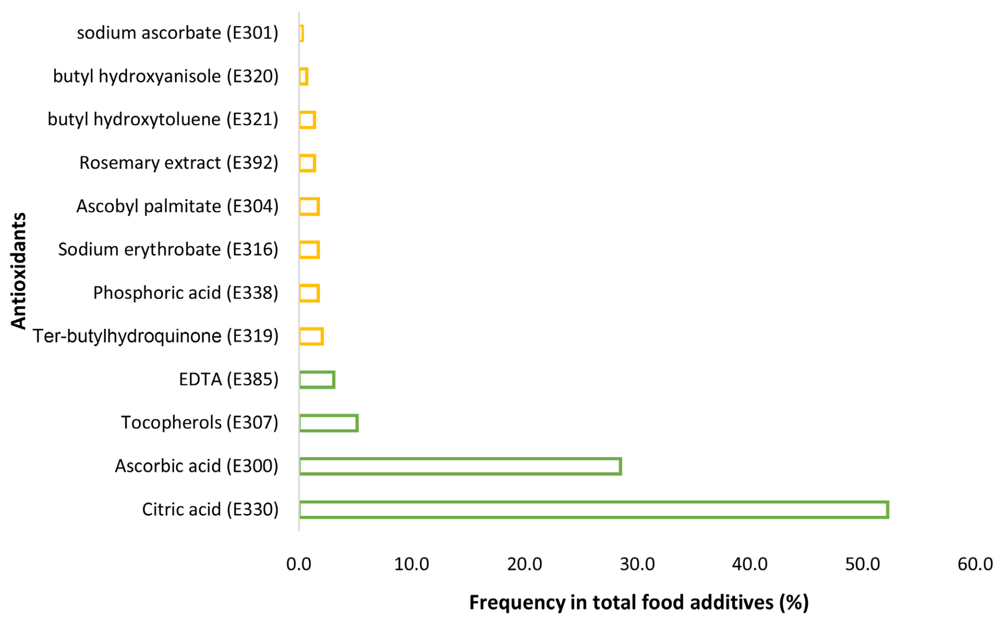

Figure 2. Frequency of the different types of antioxidants identified on food labels.

by citric acid (52.2%) and ascorbic acid (28.5%). Tocopherols, Calcium disodium ethylenediaminetetraacetate (EDTA) and Ter-butylhydroquinone or TBHQ follow with 5.2%, 3.1% and 2.1% respectively. Other identified additives are present at frequencies of less than 2%. These include phosphoric acid (1.7%), sodium erythrobate (1.7%), ascobyl palmitate (1.7%), rosemary extract (1.4%), butyl hydroxytoluene or BHT (1.4%), butyl hydroxyanisole or BHA (0.7%) and sodium ascorbate (0.3%).

The results of this study revealed a wide dispersion of antioxidant additives in foods (**Table 1**). Some of them are widely distributed across food categories. Such is the case with citric acid (E330), found in all food categories with the exception of meat products and infant formula. Citric acid is used in the production of mustard condiments, soups, broths and sauces. It is also widely found in soft drinks and fruit juices. Ascorbic acid (E300) is also found in many food products, particularly beverages, where it is the main antioxidant. Ascorbic acid is also widely used in meat, fruit and vegetable processing. Tocopherols (E307), well represented in cereals and cereal-based products, are also found in dairy products, confectionery, bakery products and beverages. The use of EDTA (E385) was particularly noted in sauces and mayonnaises. TBHQ (E319) was identified on samples of cookies, margarine and cereals. Ascobyl palmitate (E304) is present in margarine, cakes and mashed potatoes. Phosphoric acid (E338) is found in soft drinks, mayonnaises and sauces. Sodium erythrobate (E316) is particularly used in processed meats. Rosemary extract (E392) is found on bouillon cubes and infant formula. BHT (E321) is found on ketchup sauce and mayonnaise, while BHA (E320) is found on soft drinks. Sodium ascorbate (E301), the least frequent antioxidant in the samples analyzed, was only identified on processed meat.

These studies have also highlighted the simultaneous use of several antioxidants in the same food product (**Table 2**). In fact, among foods containing antioxidant additives, 36% present combinations of substances ranging from 2 to 4 substances.

4. Discussion

In several studies, it has been reported that ascorbic acid and its salts are widely used to protect foods against oxidation [14]. Indeed, ascorbic acid (E300) is a powerful antioxidant used in most countries [15]. Ascorbic acid acts primarily as a donor of single hydrogen atoms, while the radical anion monodehydroascorbate reacts primarily with radicals. Together, these properties explain ascorbic acid's remarkable antioxidant action [16]. Ascorbic acid has the ability to significantly inhibit tyrosinase, a polyphenol oxidase (PPO), the main browning enzyme in fruit and vegetables. This explains its widespread use for preserving fruit and vegetables by preventing oxidation of phenolic compounds [9]. Ascorbyl palmitate found in products is a fat-soluble ascorbic acid derivative. This substance ascorbyl is used as an antioxidant for its heat stability in thermal processes such as frying potato chips in oil [17]. The effectiveness of sodium ascorbate

Table 1. Main antioxidant additives identified in food products collected at Dakar markets.

Food categories Products collected	**Antioxidants**
Dairy products and similar Liquid milk, cheese, powdered milk, flavoured milk, condensed milk	Citric Acid (E330) Tocopherols (E307)
Fats and oils Butter, margarine	Citric acid (E330) Ascorbic acid (E300) TBHQ (E319) Tocopherols (E307) Ascobyl palmitate (E304)
Fruits and vegetables Tinned fruit, mushrooms, jams, tinned vegetables, mashed potatoes	Ascorbic acid (E330) Ascorbic acid (E300) EDTA (E385) Rosemary extract (E392) Ascobyl palmitate (E304)
Confectionery Chocolate, hard confectionery, soft confectionery, spreads, chewing gum	Citric acid (E330) Tocopherol (E307) Ascorbic acid (E300)
G6 Cereals and cereal products Cereals, desserts, wheat cakes	Citric acid (E330) Tocopherol (E307) TBHQ (E319) Ascorbic acid (E300) Ascobyl palmitate (E304)
Bakery products Cookie, cake	Citric acid (E330) TBHQ (E319) Ascorbic acid (E300) Tocopherols (E307) Rosemary extract (E392) Ascobyl palmitate (E304)
G8 Meat, meat products, poultry Processed chicken, processed meat, processed poultry	Ascorbic acid (E300) Sodium erythrobate (E316) Sodium ascorbate (E301)
Salts, spices, soups, sauces, salads and protein products Broth, condiment, mayonnaise, mustard, sauce, vinegar, vinaigrette	Citric acid (E330) EDTA (E385) Ascorbic acid (E300) Phosphoric acid (E338) TBHQ (E319) Rosemary extract (E392)
Foods for special dietary uses Infant formulas	Ascorbic acid (E300) Ascobyl palmitate (E304)
Beverages, excluding dairy products Soft drinks, hot drinks, sweet drinks, vegetable concentrates, fruit juice concentrates, fruit nectars	Ascorbic acid (E300) Phosphoric acid (E338) Tocopherols (E307) BHA (E320) EDTA (E385)
Prepared foods Prepared dishes	Citric acid (E330) Ascorbic acid (E300) Sodium erythrobate (E316) Rosemary extract (E392)

Table 2. Antioxidant combinations found in industrial food products.

Types of antioxidant additives combinations	Food products
Citric acid/ascorbic acid	Soft drinks, Fruit juices, Canned vegetables, Concentrated fruit juices, Canned fruit, Mashed potatoes with milk, Mushrooms, Powdered drinks, Mustard, Fruit nectars, Jam, Biscuits.
Citric acid/phosphoric acid/EDTA/BHT	Ketchup sauce
Citric acid/phosphoric acid	Soft drink
Citric acid/ascorbic acid/EDTA	Sweetened beverage
Citric acid/Butylated hydroxytoluene/EDTA	Mayonnaise
Citric acid/rosemary extract	Cookie
Citric acid/ascorbic acid/tocopherol	Fruit juice
Citric acid/tocopherol/ascobyl palmitate	Cereal
Citric acid/EDTA	Fried apple sauce
Citric acid/Tocopherol	Milk powder
Citric acid/tocopherol/ascobyl palmitate	Margarine
Citric acid/BHA	Soft drinks
Citric acid/Butylated hydroanisole	Soft drinks
Citric acid/Sodium erythrobate	Prepared dishes (carbonara twists)
Ascorbic acid/Tocopherol	Chocolate, Cereal
Ascorbic acid/Sodium erythrobate	Processed poultry
Ascorbic acid/ascobyl palmitate	Infant formula
Phosphoric acid/EDTA	Mayonnaise

(E301) in preventing oxidation of both lipids and proteins has been tested in fermented dry sausages [15]. Citric acid is a natural substance whose antioxidant properties have been proven in numerous food matrices [18]. Citric acid and its salts have long been known to play a role in controlling the oxidative alteration of flavour and color in a wide range of food products [19]. The industrial use of this organic acid as an antioxidant is applied in products such as beverages, jams and jellies, sauces, cheese and canned vegetables, but also bakery products, dry soup or cake [20]. Tocopherols, which form the vitamin E group, are antioxidants produced either photosynthetically or chemically [21]. As well as being among the most widely used antioxidants in industry [22], tocopherols are reputed (suggested) to reduce the risk of cancer [23]. Erythorbates (E315 - E316) are antioxidants involved in reducing the formation of nitrosamines during curing and cooking processes. They are widely added to meats, frozen fruits, vegetables, oils, fats, seafood and fish [15]. Rosemary extracts extracted from the dried leaves of rosemary (*Rosmarinus officinalis* L.) have aromatic properties. In addition, the presence of phenolic diterpenes, carnosic acid and carnosol in these extracts is thought to be responsible for their excellent antioxidant properties [24]. One study suggested that rosemary extract, used in the preservation of sunflower oil at 60˚C, showed greater antioxidant activity than α-tocopherol, ascorbyl palmitate and even citric acid under the same conditions [25]. In addition, rosemary extracts are used in phytotherapy for anti-inflammatory and antimicrobial applications, as well as for the prevention and treatment of diabetic and cardiovascular diseases [26]. Phosphoric acid is a synergistic antioxidant and acidity regulator, particularly in beverages, dairy products and certain types of potato chips [27]. Artificial antioxidants identified in industrial products include BHA (E320), BHT (E321) and TBHQ (E319). These are fat-soluble phenolic compounds often added to foodstuffs for their ability to react with free radicals and delay the propagation stage in the oxidation reaction [28]. The use of any of these 3 artificial antioxidants depends on the food and the processing techniques applied. For example, TBHQ is the most widely used in thermal processes, due to its high heat stability [28]. BHA, on the other hand, is stable to pH variations [28]. However, consumption of the latter three artificial antioxidants is associated with negative health effects. BHA has been implicated in thyroid damage, metabolic and growth disorders, neurotoxicity and carcinogenesis [29]. BHT is said to have toxic effects on motor and neurobehavioral activity, as well as implications for histopathological changes in the brain, heart and lungs [30]. Furthermore, one study found that TBHQ led to activation of inflammatory pathways, generation of reactive species, induction of CYP1A1, activation of caspases, reduced GSH/ATP levels and triggering of progressive cancer development [31]. In industrial food production, EDTA, another artificial antioxidant, has demonstrated its effectiveness in food protection. One study, for example, suggested its protective effect against lipid oxidation in mayonnaises enriched with fish oils [32]. In addition, EDTA, used in food dehydration processes, inhibits the enzymes responsible for browning and discoloration of vegetables [33]. The use of EDTA has also shown satisfactory results in the inhibition of polyphenol oxidases responsible for enzymatic browning of pigments in banana extracts [34]. However, the excessive presence of EDTA in foods may cause abdominal cramps, diarrhoea, vomiting, urinary disorders and blood in the urine [3].

Antioxidants are often combined in foods for a variety of reasons. These substances may interact synergistically, antagonistically or simply additively. Synergistic effects of antioxidants are combined effects that are more enhanced than the sum of the individual effects of the compounds, whereas antagonistic effects refer to combined effects that are inferior to the effects of additives [35]. The synergistic effect of ascorbic acid and citric acid has been demonstrated in the inhibition of browning reactions and food oxidation, particularly in fruit and vegetables [36]. Furthermore, one study suggested that, combined with citric acid and ascorbyl palmitate, rosemary extract presents an additive antioxidant effect in the preservation of sunflower oil [25]. One study also demonstrated the synergistic antioxidant effect of ascorbic acid and EDTA in improving the color stability of betacyanins in the presence of polysaccharides [37]. Combining antioxidants has the advantage not only of increasing their efficacy through a synergistic effect, but also of reducing the quantity of additives to avoid exceeding the maximum permitted quantities.

5. Conclusion

This study highlighted the profile of antioxydants in industrial food products distributed in the Dakar market. The results showed that the antioxidant additives present in these products are dominated by two natural organic substances, citric acid and ascorbic acid. Other antioxidants of artificial origin such as BHA and BHA are also indicated on the food labels of industrial products. Some of these artificial products raise concerns among consumers because of the many negative effects associated with them. As a result, a quantitative analysis of certain antioxidants is required to assess compliance with the maximum concentrations authorized by manufacturers. What's more, in addition to the need to tighten controls and regulations on these additives, there is an urgent need to exploit the potential of safer, natural substances in the preservation of food products.

Contributions of the Authors

AK and PAD had the original idea for the study and, with all co-authors carried out the design, sampling and the analyses and drafted the manuscript, SN, MD, AD and MC participated in writing the manuscript. All authors read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare that they have no competing interests.

References

[1] Ishangulyyev, R., Kim, S. and Lee, S.H. (2019) Understanding Food Loss and Waste—Why Are We Losing and Wasting Food? *Foods*, **8**, Article 297. https://doi.org/10.3390/foods8080297

[2] Garden-Robinson, J. (2022) Foodborne Infections and Intoxications. *Journal of Nutrition Education and Behavior*, **54**, 283-284. https://doi.org/10.1016/j.jneb.2021.09.013

[3] Bensid, A., El Abed, N., Houicher, A., *et al.* (2022) Antioxidant and Antimicrobial Preservatives: Properties, Mechanism of Action and Applications in Food—A Review. *Critical Reviews in Food Science and Nutrition*, **62**, 2985-3001. https://doi.org/10.1080/10408398.2020.1862046

[4] Choe, E. and Min, D.B. (2009) Mechanisms of Antioxidants in the Oxidation of Foods. *Comprehensive Reviews in Food Science and Food Safety*, **8**, 345-358. https://doi.org/10.1111/j.1541-4337.2009.00085.x

[5] Carocho, M., Morales, P. and Ferreira, I.C.F.R. (2018) Antioxidants: Reviewing the Chemistry, Food Applications, Legislation and Role as Preservatives. *Trends in Food Science & Technology*, **71**, 107-120. https://doi.org/10.1016/j.tifs.2017.11.008

[6] IPCS INCHEM (2023) Joint Expert Committee on Food Additives (JECFA) Monographs & Evaluations. https://www.inchem.org/pages/jecfa.html

[7] U.S. Food and Drug Administration (2023) Food Additive Status List. https://www.fda.gov/food/food-additives-petitions/food-additive-status-list

[8] EFSA Panel on Additives and Products or Substances Used in Animal Feed (FEEDAP), Rychen, G., Aquilina, G., *et al.* (2017) Guidance on the Assessment of the Safety of Feed Additives for the Consumer. *EFSA Journal*, **15**, e05022.

[9] Codex (2021) General Standard for Food Additives. https://www.fao.org/fao-who-codexalimentarius/committees/committee/related-standards/en/?committee=CCFA

[10] Badora, A., Bawolska, K., Kozłowska-Strawska, J. and Domańska, J. (2019) Food Additives in Food Products: A Case Study. Intech Open, London. https://doi.org/10.5772/intechopen.85723

[11] Anses—Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (2019) Rapport Oqali : Bilan et évolution de l'utilisation des additifs dans les produits transformés. https://www.anses.fr/fr/content/rapport-oqali-bilan-et-%C3%A9volution-de-lutilisation-des-additifs-dans-les-produits-transform%C3%A9s

[12] Codex (2018) General Standard for the Labelling of Prepackaged Foods. https://www.fao.org/fao-who-codexalimentarius/committees/committee/related-standards/en/?committee=CCFA

[13] Codex (2021) Class Names and the International Numbering System for Food Additives. https://www.fao.org/fao-who-codexalimentarius/committees/committee/related-standards/en/?committee=CCFA

[14] Davidson, P.M., Sofos, J.N. and Branen, A.L. (2005) Antimicrobials in Food. CRC Press, Boca Raton. https://doi.org/10.1201/9781420028737

[15] Novais, C., Molina, A.K., Abreu, R.M.V., *et al.* (2022) Natural Food Colorants and Preservatives: A Review, a Demand, and a Challenge. *Journal of Agricultural and Food Chemistry*, **70**, 2789-2805. https://doi.org/10.1021/acs.jafc.1c07533

[16] Njus, D., Kelley, P.M., Tu, Y.J. and Schlegel, H.B. (2020) Ascorbic Acid: The Chemistry Underlying Its Antioxidant Properties. *Free Radical Biology and Medicine*, **159**, 37-43. https://doi.org/10.1016/j.freeradbiomed.2020.07.013

[17] Satyanarayana, A., Giridhar, N., Joshi, G.J. and Rao, D.G. (2000) Ascorbyl Palmitate as an Antioxidant for Deep Fat Frying of Potato Chips in Peanut Oil. *Journal of Food Lipids*, **7**, 1-10. https://doi.org/10.1111/j.1745-4522.2000.tb00155.x

[18] Gülçin, İ. (2012) Antioxidant Activity of Food Constituents: An Overview. *Archives of Toxicology*, **86**, 345-391. https://doi.org/10.1007/s00204-011-0774-2

[19] Milsom, P.E. (1987) Organic Acids by Fermentation, Especially Citric Acid. In: King, R.D. and Cheetham, P.S.J., Eds., *Food Biotechnology*—1, Springer, Dordrecht, 273-307. https://doi.org/10.1007/978-94-009-3411-5_7

[20] García-García, R. and Searle, S.S. (2016) Preservatives: Food Use. In: Caballero, B., Finglas, P.M. and Toldrá, F., Eds., *Encyclopedia of Food and Health*, Academic Press, Cambridge, 505-509. https://doi.org/10.1016/B978-0-12-384947-2.00568-7

[21] Bora, J., Tongbram, T., Mahnot, N., *et al.* (2022) Chapter 14—Tocopherol. In: Kour, J. and Nayik, G.A., Eds., *Nutraceuticals and Health Care*, Academic Press, Cambridge, 259-278. https://doi.org/10.1016/B978-0-323-89779-2.00008-9

[22] Barouh, N., Bourlieu-Lacanal, C., Figueroa-Espinoza, M.C., *et al.* (2022) Tocophe-

rols as Antioxidants in Lipid-Based Systems: The Combination of Chemical and Physicochemical Interactions Determines Their Efficiency. *Comprehensive Reviews in Food Science and Food Safety*, **21**, 642-688. https://doi.org/10.1111/1541-4337.12867

[23] Das Gupta, S. and Suh, N. (2016) Tocopherols in Cancer: An Update. *Molecular Nutrition & Food Research*, **60**, 1354-1363. https://doi.org/10.1002/mnfr.201500847

[24] Mira-Sánchez, M.D., Castillo-Sánchez, J. and Morillas-Ruiz, J.M. (2020) Comparative Study of Rosemary Extracts and Several Synthetic and Natural Food Antioxidants. Relevance of Carnosic Acid/Carnosol Ratio. *Food Chemistry*, **309**, Article ID: 125688. https://doi.org/10.1016/j.foodchem.2019.125688

[25] Hraš, A.R., Hadolin, M., Knez, Ž. and Bauman, D. (2000) Comparison of Antioxidative and Synergistic Effects of Rosemary Extract with *α*-Tocopherol, Ascorbyl Palmitate and Citric Acid in Sunflower Oil. *Food Chemistry*, **71**, 229-233. https://doi.org/10.1016/S0308-8146(00)00161-8

[26] Degner, S.C., Papoutsis, A.J. and Romagnolo, D.F. (2009) Chapter 26—Health Benefits of Traditional Culinary and Medicinal Mediterranean Plants. In: Watson, R.R., Ed., *Complementary and Alternative Therapies and the Aging Population*, Academic Press, San Diego, 541-562. https://doi.org/10.1016/B978-0-12-374228-5.00026-3

[27] Silva, M. and Lidon, F. (2016) An Overview on Applications and Side Effects of Antioxidant Food Additives. *Emirates Journal of Food and Agriculture*, **28**, 823-832. https://doi.org/10.9755/ejfa.2016-07-806

[28] Cacho, J.I., Campillo, N., Viñas, P. and Hernández-Córdoba, M. (2016) Determination of Synthetic Phenolic Antioxidants in Edible Oils Using Microvial Insert Large Volume Injection Gas-Chromatography. *Food Chemistry*, **200**, 249-254. https://doi.org/10.1016/j.foodchem.2016.01.026

[29] Zhang, X.J., Diao, M. and Zhang, Y.F. (2023) A Review of the Occurrence, Metabolites and Health Risks of Butylated Hydroxyanisole (BHA). *Journal of the Science of Food and Agriculture*, **103**, 6150-6166. https://doi.org/10.1002/jsfa.12676

[30] Alabdaly, Y.Z., Al-Hamdany, E.K. and Abed, E.R. (2021) Toxic Effects of Butylated Hydroxytoluene in Rats. *Iraqi Journal of Veterinary Sciences*, **35**, 121-128. https://doi.org/10.33899/ijvs.2020.126435.1322

[31] Khezerlou, A., Akhlaghi, A., Alizadeh, A.M., Dehghan, P. and Maleki, P. (2022) Alarming Impact of the Excessive Use of Tert-Butylhydroquinone in Food Products: A Narrative Review. *Toxicology Reports*, **9**, 1066-1075. https://doi.org/10.1016/j.toxrep.2022.04.027

[32] Thomsen, M.K., Jacobsen, C. and Skibsted, L.H. (2000) Mechanism of Initiation of Oxidation in Mayonnaise Enriched with Fish Oil as Studied by Electron Spin Resonance Spectroscopy. *European Food Research and Technology*, **211**, 381-386. https://doi.org/10.1007/s002170000199

[33] Bhat, T.A., Rather, A.H., Hussain, S.Z., *et al.* (2021) Efficacy of Ascorbic Acid, Citric Acid, Ethylenediaminetetraacetic Acid, and 4-Hexylresorcinol as Inhibitors of Enzymatic Browning in Osmo-Dehydrated Fresh Cut Kiwis. *Food Measure*, **15**, 4354-4370. https://doi.org/10.1007/s11694-021-01017-2

[34] Vhangani, L.N., Mogashoa, L. and Wyk, J.V. (2021) Enhancing the Enzymatic Browning Inhibition Capacity of *Moringa oleifera* Seed Extract via the Maillard Reaction. *African Journal of Food, Agriculture, Nutrition and Development*, **21**, 18518-18532. https://www.ajol.info/index.php/ajfand/article/view/231642 https://doi.org/10.18697/ajfand.103.20065

[35] Chen, X., Li, H., Zhang, B. and Deng, Z. (2022) The Synergistic and Antagonistic Antioxidant Interactions of Dietary Phytochemical Combinations. *Critical Reviews in Food Science and Nutrition*, **62**, 5658-5677. https://doi.org/10.1080/10408398.2021.1888693

[36] Suttirak, W. and Manurakchinakorn, S. (2010) Potential Application of Ascorbic Acid, Citric Acid and Oxalic Acid for Browning Inhibition in Fresh-Cut Fruits and Vegetables. *Walailak Journal of Science and Technology*, **7**, 5-14. https://wjst.wu.ac.th/index.php/wjst/article/view/47

[37] Guo, Q., Zhang, Z., Dadmohammadi, Y., *et al.* (2021) Synergistic Effects of Ascorbic Acid, Low Methoxy Pectin, and EDTA on Stabilizing the Natural Red Colors in Acidified Beverages. *Current Research in Food Science*, **4**, 873-881. https://doi.org/10.1016/j.crfs.2021.11.005