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Review

Application of plant extracts to improve the shelf-life, nutritional and health-related properties of ready-to-eat meat products

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ABSTRACT

Plant extracts are increasingly becoming important additives in food industry due to their antimicrobial and antioxidant abilities that delay the development of off-flavors and improve the color stability in ready-to-eat (RTE) meat products. Due to their natural origin, they are excellent candidates to replace synthetic molecules, which are generally considered to have toxicological and carcinogenic effects. The efficient extraction of these antioxidant molecules from their natural sources, along with the determination of their activity in the commercialized products, have been a great challenge for researchers and food chain contributors. The objective of this review is to highlight the application of plant extracts to improve the shelf-life, nutritional and health-related properties of RTE meat products. The sensory effects of these extracts on RTE meat products as well as the possible synergistic effects of a combination of extracts are discussed.

1. Introduction

With the increasing demand for easily prepared ready-to-eat (RTE) foods and globalization, concerns for food safety and quality are also increasing. Perishable food products, especially meat products are subjected to bacterial and fungal contamination causing undesirable reactions that deteriorate flavor, odor, color, sensory, and textural properties. Lipid oxidation is the other major issue concerning meat that deteriorates the quality of products during processing and storage. Lipid oxidation is the process where an unsaturated fatty acid fraction of membrane phospholipids is oxidized. Membrane phospholipids are sensitive to oxidation in meat due to their more unsaturated fatty acids in comparison with other lipids. However, lipid oxidation is also affected by the degree of unsaturation of the fatty acids in the phospholipid and triglyceride fractions (Igene et al., 1980). As a result, the formation of hydroperoxides and their secondary products (*e.g.* short-chain aldehydes and ketones) causes undesirable flavors in the meat products (Maqsood & Benjakul, 2011). To inhibit the growth of undesirable microorganisms and reduce lipid oxidation in RTE meat-based foods, antioxidant bioactive compounds can be incorporated into product formulation, coated on its surface, or incorporated into the packaging material (Horita et al., 2018; Granato, Nunes, & Barba, 2017; Nikmaram et al., 2017; Lorenzo et al., 2018; Lorenzo, Batlle, & Gómez, 2014). In this regard, synthetic antioxidants such as butylated hydroxytoluene (BHT), are extensively used to delay or prevent lipid oxidation by either scavenging the chain-carrying peroxyl radicals or avoiding the formation of free radicals. With increasing concern over the safety of these synthetic compounds, research is being carried out to find novel and naturally occurring compounds that preserve the sensory and microbial quality of meat products Roohinejad, Mousavi Khaneghah, et al., 2017; Ciriano et al., 2009; Johnston, Sepe, Miano, Brannan, & Alderton, 2005). Consumers do not prefer synthetic antioxidants because of their carcinogenicity (EFSA, 2011; EFSA 2012) and have resulted in the development of “clean label” products. Moreover, consumer's preference for natural food additives and concern regarding the safety of synthetic preservatives prompted the food industry to look for natural alternatives (Roohinejad, Nikmaram, et al., 2017; Aziz & Karboune, 2018). Therefore, natural antioxidants have greater

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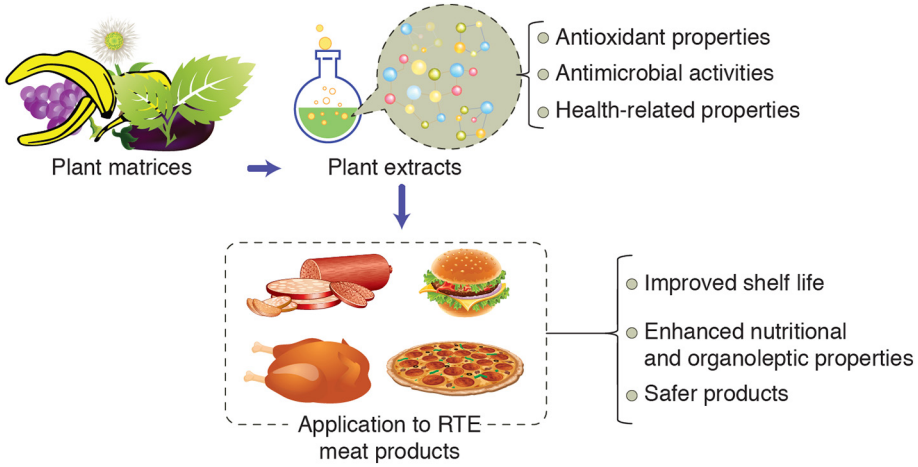

Fig. 1. Schematic of application of plant extracts to control the microbiological activity as well as to increase the nutritional and sensory properties in RTE meat-based products.

application potential in the meat industry because of the consumer's acceptability over the synthetic antioxidants (Fernandes, Trindade, Lorenzo, et al., 2016; Munekata et al., 2017; Pateiro, Lorenzo, Amado, & Franco, 2014). In this context, plant extracts are gaining a wide interest in the food industry for their potential as antimicrobials and antioxidants since they are also Generally Recognized as Safe (GRAS) (Vinceković et al., 2017; Kim, Cho, & Han, 2013) and should not negatively influence sensory properties (*e.g.* color, odor or flavor); be efficient at low concentrations (0.001–0.01%); be compatible with the foods and have the ease of application; be stable during processing and shelf-life; and economic. Most importantly, these components and their metabolites must be nontoxic at larger doses than those normally ingested by regular diets (Lorenzo et al., 2018). The current review focuses on the use of natural plant extracts to control the microbiological activity as well as to increase the nutritional and sensory properties of RTE meat-based products (Fig. 1).

2. Ready-to-eat meat products

RTE meat is defined as a meat or poultry product that is edible without additional preparation to achieve food safety (9 Code of Federal Regulations, Part 430). It may receive additional preparation to make the product more palatable (*e.g.*, frozen and/or refrigerated meat and poultry products). These are mainly (but not exclusively) grouped into two categories, deli meats, and hot dogs. Deli meats are sold at the delicatessen counter or pre-packaged, which include but are not limited to: baked or boiled ham, turkey ham, chicken roll, roast beef, corned beef, bologna, and salamis. These products could be in various forms such as pre-sliced, intact as a loaf, sandwich, mixed into a salad or simply cut into pieces. RTE meat products have become increasingly popular due to the convenience in preparation, time-saving and good taste. RTE products are manufactured at intermediate temperatures with the final product temperatures typically in the range of 65–75 °C. They are different from canned products that are processed at high temperatures for sterility/total microbial lethality (Horita et al., 2018). Thus, RTE foods and especially muscle foods require refrigeration and are generally referred to as cold cuts. Despite the popularity, RTE meat and poultry are vulnerable to the foodborne outbreak associated with the pathogens such as *Listeria monocytogenes* and spoilage microorganism such as lactic acid bacteria. The contamination by microorganisms in RTE products occurs mostly after the cooking step and it continues further during the shelf life of the product causing foodborne diseases (Horita et al., 2018). *Listeria monocytogenes* can grow at refrigeration temperatures and tolerate salts and nitrites (Ivy, Wiedmann, & Boor, 2012; McClure, Beaumont, Sutherland, & Roberts, 1997). Since 1983, the United States Department of Agriculture (USDA) - Food Safety and Inspection Service (FSIS) has been conducting regular microbiological testing on RTE meats to ensure product safety. The risk of RTE meat and poultry products to L. *monocytogenes* outbreaks proves to be a global concern. In order to increase the microbial safety, meat and meat products are subjected to various treatments during processing. High-pressure processing is one of these technologies. When meat samples are subjected to > 30 0Mpa pressure, it results in the formation of secondary lipid oxidation products which affects on the quality and shelf life attributes of RTE meat products (Kumar et al., 2015). Tremendous efforts have been made in the food industry on developing technologies to minimize microbial contamination and to increase the quality of RTE meat products. The incorporation of plant extracts in the product formulation has been receiving attention in the meat industry due to their beneficiary natural antimicrobial and antioxidant properties. The following sections focus on the application of various plant extracts as antimicrobial agents and their role in enhancing sensory properties.

3. Plant extract properties

3.1. Antioxidant potential of plant extracts

Due to potential negative health effects (*e.g.* toxicological and nutritional) of synthetic antioxidant compounds at high concentrations, application of natural plant antioxidants has gained attention (Omidizadeh et al., 2011; Bouaziz, Koubaa, Barba, Roohinejad, & Chaabouni, 2016; Fernandes et al., 2016; Roohinejad et al., 2016; Taghvaei & Jafari, 2015; Roohinejad, Everett, & Oey, 2014). Several compounds with antioxidant activity have been identified in plant extracts, in which phenolic compounds are considered as the major active group (Roohinejad et al., 2017; Zhu et al., 2017; Lu, Kelly, & Miao, 2016; Roselló-Soto et al., 2015; Barba, Esteve, & Frígola, 2014). The highly effective antioxidant properties of phenolic compounds have been associated with their free radical scavenging capability, their potential chelation of pro-oxidant metals, their role as reducing agents, and quenchers of singlet oxygen (Mohajer, Taha, Ramli, & Mohajer, 2016; Roohinejad et al., 2014). Phenolic compounds are categorized into 4 general groups including phenolic acids (*e.g.* gallic, protochatechuic, caffeic, and rosmarinic acids), phenolic diterpenes (*e.g.* carnosol and carnosic acid), flavonoids (*e.g.* quercetin and catechin), and volatile oils (*e.g.* eugenol, carvacrol, thymol, and menthol) (Şahin et al., 2018; Barba, Esteve, & Frígola, 2014; Shan, Cai, Sun, & Corke, 2005).

It has been reported that plant pigments such as anthocyanin and