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Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects – A review

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ABSTRACT

This review reports on the latest research results and applications of phenolic and polyphenolic compounds. Phenolic compounds, ubiquitous in plants, are an essential part of the human diet and are of considerable interest due to their antioxidant properties and potential beneficial health effects. These compounds range structurally from a simple phenolic molecule to complex high-molecular-weight polymers. There is increasing evidence that consumption of a variety of phenolic compounds present in foods may lower the risk of health disorders because of their antioxidant activity. When added to foods, antioxidants control rancidity development, retard the formation of toxic oxidation products, maintain nutritional quality, and extend the shelf-life of products. Due to safety concerns and limitation on the use of synthetic antioxidants, natural antioxidants obtained from edible materials, edible by-products and residual sources have been of increasing interest. This contribution summarizes both the synthetic and natural phenolic antioxidants, emphasizing their mode of action, health effects, degradation products and toxicology. In addition, sources of phenolic antioxidants are discussed in detail.

1. Introduction

Lipid oxidation is a major cause for food quality deterioration and generation of off odours and off flavours, decreasing shelf-life, altering texture and colour, and decreasing the nutritional value of food (Alamed, Chaiyasit, McClements, & Decker, 2009). Numerous methods have been developed to control the rate and extent of lipid oxidation in foods, but addition of antioxidants is most effective. Antioxidants have become an indispensible group of food additives mainly because of their unique properties of extending the shelf-life of food products without any adverse effect on their sensory or nutritional qualities. Historically, gum guaiac was the first antioxidant approved for stabilization of animal fats especially lard in the 1930s (Nanditha & Prabhasankar, 2009). Halliwell, Aeschbacht, Loligert, and Aruoma (1995) reported that antioxidants are also of interest to biologists and clinicians because they may help to protect the human body against damage by reactive oxygen species (ROS). According to the United States Department of Agriculture (USDA) Code of Federal Regulation, "antioxidants are substances used to preserve food by retarding deterioration, rancidity or discoloration due to oxidation" (Shahidi & Wanasundara, 1992). Antioxidants for use in food system must be inexpensive, non-toxic and effective at low concentrations; highly stable and capable of surviving processing; have no odour, taste or colour of their own; easy to incorporate and have a good solubility in the product (Kiokias, Varzakas, & Oreopoulou, 2008). One of the

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primary pathways of lipid degradation is that of autoxidation. The process of autoxidation of polyunsaturated lipids in foods involves a free radical chain reaction that is generally initiated by exposure of lipids to light, heat, ionizing radiation, metal ions or metalloprotein catalysts. The enzyme lipoxygenase can also initiate oxidation (Shahidi, 2015; Shahidi & Naczk, 2004). The classic route of autoxidation includes initiation (production of lipid free radicals), propagation and termination (production of non radical products) reactions (Shahidi & Wanasundara, 1992). A general schematic pathway for autoxidation of polyunsaturated lipids is shown in Fig. 1. Antioxidants act at different levels in the oxidative sequence involving lipid molecules. They may decrease oxygen concentration, intercept singlet oxygen ($^1O_2$), prevent first-chain initiation by scavenging initial radicals such as hydroxyl radicals, bind metal ion catalysts, decompose primary products of oxidation to nonradical species and break chain reaction in order to prevent continued hydrogen abstraction from substrates (Shahidi, 2000a, 2000b, 2015; Shahidi & Naczk, 2004).

$$\text{Initiation} \quad RH \rightarrow R^{\bullet} + H^{\bullet} \tag{1}$$

$$\text{Propagation} \quad R^{\bullet} + O_2 \rightarrow ROO^{\bullet} \tag{2}$$

$$ROO^{\bullet} + RH \rightarrow R^{\bullet} + ROOH \tag{3}$$

$$\text{Termination} \quad \left.\begin{array}{l} R^{\bullet} + R^{\bullet} \\ R^{\bullet} + ROO^{\bullet} \\ ROO^{\bullet} + ROO^{\bullet} \end{array}\right\} \text{Nonradical products} \tag{4}$$

Hydroperoxides are the primary products of lipid oxidation, but hydroperoxides, despite their deleterious effects on health have no effect on flavour quality of foods (Shahidi, 1998). However, these unstable molecules decompose readily to form a myriad of products such as aldehydes, ketones, alcohols and hydrocarbons, amongst others (Shahidi, 1998); these impart unpleasant flavours and odours to fats, oils and lipid containing foods. These aldehydes interact with sulphhydryl and amine groups in proteins and this may alter the functionality of proteins (McClements & Decker, 2007). Faustman, Liebler, McClure, and Sun (1999) reported the ability of unsaturated aldehydes to react with histidine in myoglobin and accelerate the oxidation of oxymyoglobin. Phenolic compounds in foods originate from one of the main classes of secondary metabolites in plants (Naczk & Shahidi, 2004). At a low concentration, phenolics act as an antioxidant and protect food from oxidative rancidity (Karakaya, 2004). Phenolic antioxidants interfere with the oxidation process as free radical terminators and sometimes also as metal chelators. Phenols have been widely studied and confirmed to possess diverse bioactivities which could be beneficial to human health. They are known to reduce the risk of cancer, heart disease, and diabetes; to inhibit plasma platelet aggregation, cyclooxygenase (COX) activity, and histamine release, as well as to exert antibacterial, antiviral, anti-inflammatory, and anti-allergenic activities (Oak, El Bedoui, & Schini-Kerth, 2005; Shetty, 2004; Yang, Landau, Huang, & Newmark, 2001; Yao et al., 2004). The benefits towards many of these conditions arise in part through the antioxidant characteristic of phenolics; therefore, it is important to quantify, identify and evaluate their antioxidant activities (Cevallos-Casals & Cisneros-Zevallos, 2010). This review summarizes both the synthetic and natural phenolic antioxidants, emphasizing their mode of action, health effects, degradation products and toxicology. In addition, sources of phenolic antioxidants are discussed in detail.

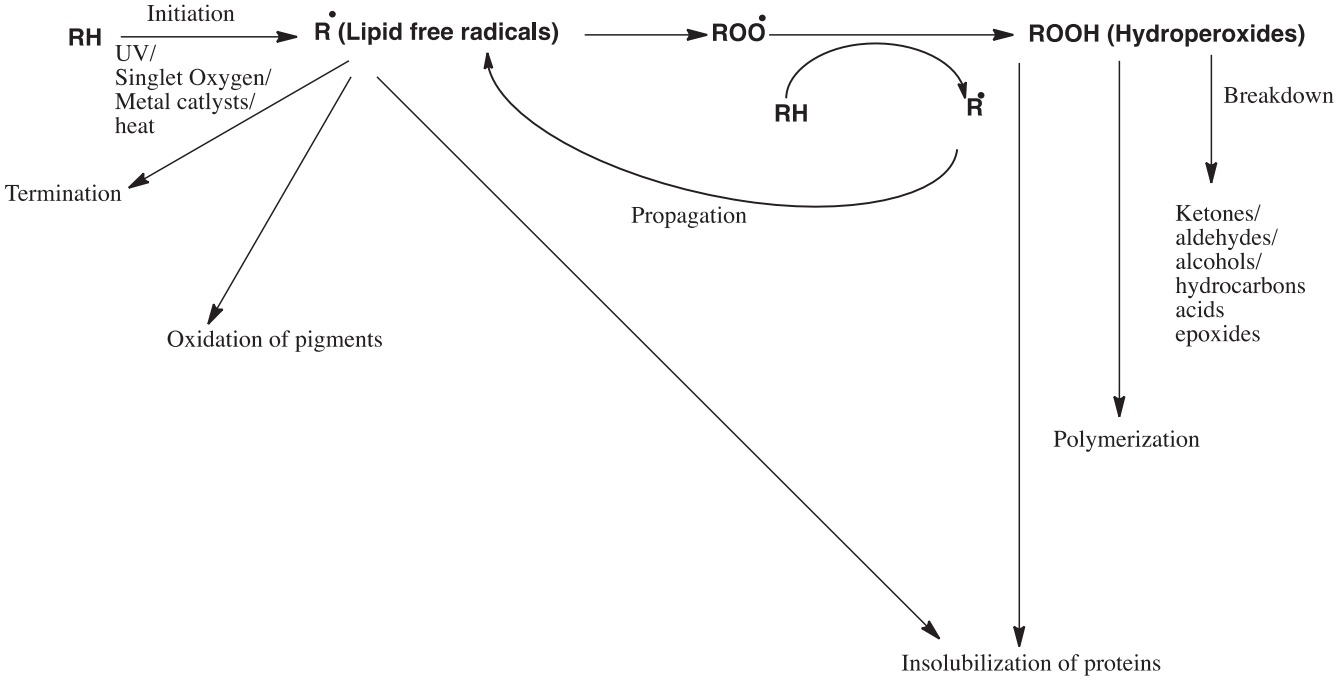

Fig. 1 – General scheme for autoxidation of lipids containing polyunsaturated fatty acids (RH) and their consequences.