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Lipid Oxidation in Meat

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Abstract

Lipids are primarily responsible for both desirable and undesirable flavors and aromas in meat. However, lipid oxidation in most cases deteriorates the quality of meat and causes unacceptable flavor for consumers. Lipids can be oxidized by enzymatic and non-enzymatic reactions and there are many mechanisms to explain these complex reactions in meat. Autoxidation is a continuous free-radical chain reaction and is the most important mechanism of lipid oxidation in meat. The three basic phases of this mechanism consists of initiation, propagation, and termination and these steps are usually used to explain the autoxidation system. Antioxidants are classified as (1) free radical scavengers (2) oxygen scavengers (3) chelators.

Keywords: Chelators; Oxygen; Scavengers; Antioxidants

Introduction

Lipids are primarily responsible for both desirable and undesirable flavors and aromas in meat. Basically, Nawar [1] indicated that the desirable flavor of cheese is caused by lipid oxidation. However, lipid oxidation in most cases deteriorates the quality of meat and causes unacceptable flavor for consumers. Buckley et al. [2] reported that an increase of lipid oxidation would cause a decrease of flavor, color, texture, nutritional value and acceptability in meat. There are also some other detrimental effects regarding lipid oxidation, including decrease of shelf life, increase of off-flavor, change of the functional and sensory characteristics, and sometimes formation of carcinogenic substances [3,4]. Malonaldehyde, which is a degradation product of lipid oxidation, has been criticized as a carcinogenic factor in food [5].

Lipids can be oxidized by enzymatic and non-enzymatic reactions and there are many mechanisms to explain these complex reactions in meat. However, autoxidation is a continuous free-radical chain reaction and is the most important mechanism of lipid oxidation in meat [6]. The definition of a "free radical" is an atom or molecule with an unpaired electron; therefore, they are very unstable and reactive. After free radicals attract electrons from stable compounds, the previously stable materials become free radicals. These newly formed free radicals then react with other compounds that become free radicals to react with other compounds. Therefore, these free-radical reactions work like a chain reaction [7]. It is also indicated that oxygen free radicals usually cause biological damage of lipids, nucleic acids, enzymes, and proteins. Especially, oxygen free radicals react with polyunsaturated fatty acids to produce lipid peroxides in cell membranes.

The three basic phases of this mechanism consists of initiation, propagation, and termination and these steps are usually used to explain the autoxidation system. Min [8] also outlined these three major chemical reactions of autoxidation. It is called a triplet oxygen oxidation: initiation is the formation of free alkyl radicals; propagation is the chain reaction of free alkyl radicals and peroxy radicals; and termination is the formation of nonradical products. These reactions can be illustrated as follows:

Initiation:

RH ---------> R. + H.

Propagation:

R. + O_2 ---------> ROO.

ROO. + RH ----------> ROOH + R.

Termination:

ROO. + R. ----------> ROOR

R. + R. ----------> R-R

ROO. + ROO. ----------> ROOR + O_2

RO. + R. ----------> ROR

2RO. +2ROO. ----------> 2ROOR +O_2

RH=Unsaturated fatty acid; R.=Alkyl radical; ROO.=Peroxy radical; RO.=Alkoxy radical; ROOH=Hydroperoxide (Figure 1).

Hsieh and Kinsella [9] proposed that the reactions that cause decomposition of hydroperoxides to form secondary oxidative substances are very complex. Hydroperoxides, the primary products formed from autoxidation, are very unstable. It is, therefore, easy to break these products down into secondary oxidative products, such as aldehydes, alkenes, ketones and alcohols that cause off-flavors and off-odors in meat. Lillard [10] indicated that hydroperoxides, which are odorless and tasteless, do not contribute directly to flavor. Moreover, Ho and Chen [11] reported that aldehydes were the largest contributors to volatile flavors by cleavage of hydroperoxides formed from unsaturated fatty acids.

There are many factors associated with lipid oxidation in meat; for example, heat and light; catalysts; oxygen content and types of oxygen; phospholipids; unsaturated fatty acids; condition of pre-slaughter; processes that destroy muscle membranes; and pH [3,12-14]. Preventing these factors from causing oxidation is very important when making nitrite-free meat products.

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Phospholipids, which are located in the cell membranes, are sensitive to oxidation in meat due to their more unsaturated fatty acids compared to other lipids. Lean meat contains a high percentage of phospholipids that makes it sensitive to oxidation [15]. Therefore, phospholipids act as the major contributors to oxidative rancidity in lean meat. However, lipid oxidation is also influenced by the degree of unsaturation of the fatty acids in the phospholipid and triglyceride fractions.

Meat from various livestock species has different sensitivity to lipid oxidation because the different species contain various proportions of unsaturated fatty acids; for example, chicken contains a higher percentage of unsaturated fatty acids and therefore has a faster rate of lipid oxidation than pork. Because pork contains more unsaturated fatty acids than beef, pork is more sensitive to lipid oxidation compared to beef. Therefore, the development of lipid oxidation varies due to the specie [16]. The processes of grinding, chopping, flaking, emulsification and cooking also accelerate lipid oxidation. The major reason is that processing liberates the membrane-bound phospholipids so they can be more easily oxidized. These processing steps disrupt muscle structures, causing unsaturated fatty acids to react with oxygen that is incorporated with the air, and to increase contact with enzymes, and heme pigments which contain metal ions such as irons that promote autoxidation in the meat systems [17]. There are, thus, many factors to influence lipid oxidation and off-flavor in muscle foods. Control of these factors is the best way to retard lipid oxidation and off-flavor in meat products.

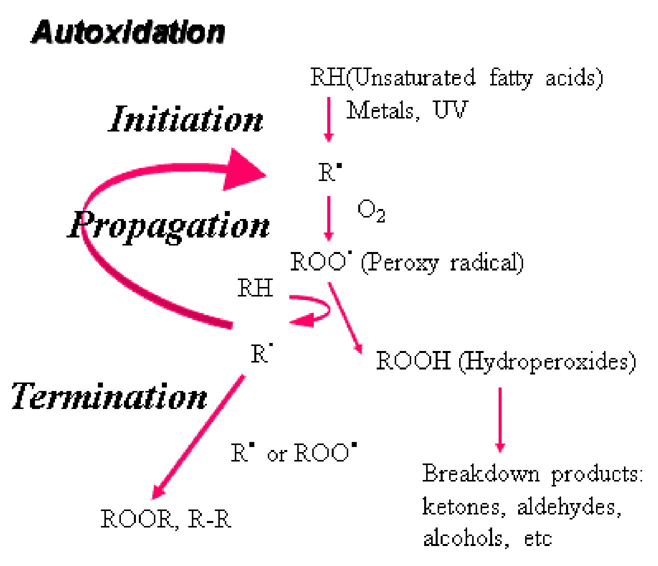

Figure 1: Autoxidation in meat.

The chemical compounds used to delay the initiation step or slow the speed of lipid oxidation are called antioxidants [8]. However, antioxidants do not reverse autoxidation, if it occurs. On the other hand, Decker [18] indicated that antioxidants could have prooxidant activity to promote lipid oxidation under different conditions. According to their functions of inhibiting lipid oxidation, the classification of antioxidants could be primary antioxidants such as free radical scavengers or synergists that contain oxygen scavengers and chelators. The mechanism of primary antioxidants is to stabilize the free radicals by donating hydrogen's to the free radicals or accepting electrons from the free radicals with the formation of a complex. These reactions of the mechanism are as follows:

Hydrogen donation:

R. + AH →□ RH + A.

RO. + AH →□ ROH + A.

ROO. + AH →□ ROOH + A.

Formation of a complex (electron acceptation)

R. + A. →□ RA

RO. + A. →□ ROA

ROO. + A. →□ ROOA

R.=Alkyl radical; ROO.=Peroxy radical; RO.=Alkoxy radical; AH=Antioxidant [8].

Synergistic antioxidants are the compounds used to improve the function of primary antioxidant and improve lipid stability in food. The functions of synergists are to regenerate the primary antioxidants, to react with oxygen (oxygen scavengers), and to chelate prooxidant metals (chelators) such as iron and copper [19]. Therefore, antioxidants are classified as (1) free radical scavengers (2) oxygen scavengers (3) chelators.

Consumers are demanding "label friendly" food products. Use of synthetic antioxidants could be related to health concerns; however, natural antioxidants have limited used in food systems due to special color, flavor and high cost [20]. Natural antioxidants are usually made from seed, grains, nuts, and vegetable oil; therefore, it is very important for processor to prevent the original flavor, aroma and color from the raw material of natural antioxidants that makes them unacceptable in meat products.

The ability of antioxidants for maintaining oxidative stability is influenced by the food system in which they are used. The first of practical difficulties encountered is to make a uniform dispersion at low concentration required by regulation of the antioxidants. Hydrophilic and hydrophobic characteristics of the antioxidants also affect distribution of antioxidants in meat systems. Therefore, the delivery of antioxidants in meat product becomes very important for antioxidative efficacy.

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