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Challenges and approaches in the use of natural antioxidants of plant origin as food additives in meat and meat products

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Abstract

The purpose of this work is to review several studies focused on the use of natural antioxidants of plant origin as food additives in meat industry. This study is motivated by consumers' preference for meat and meat products with an improved composition, without addition of synthetic antioxidants. The reducing the content of fats, cholesterol, salt and nitrites, as well as improving the profile of fatty acids and the incorporation of bioactive compounds are growing worldwide. Also, the negative health consequences or beliefs regarding the utilization of synthetic antioxidants in meat and meat products, causes the industry to include the natural antioxidants in foods, a good alternative being the plant sources. Some natural sources of antioxidants are spices, herbs and fruit which can be added to meat products in various forms: whole, ground, powder or as isolates from their extracts. These plant materials are rich in bioactive compounds that contribute to the reducing of microbial growth and inhibit the lipid oxidation during storage, improving the quality of fresh and processed meat and meat products. Compounds such as phenolic acids, phenolic diterpenes, flavonoids and volatile oils, often have strong H-donating activity, making them extremely effective antioxidants; some compounds can chelate metals and donate H to oxygen radicals, slowing down oxidation. Thus, it can be said that the natural antioxidants are used in meat industry in order to delay or prevent the lipid oxidation, delay the development of off-flavors, improve color stability and microbiological quality and extend the shelf-life, without affecting the sensory or nutritional properties.

Keywords: natural antioxidants of plant origin, meat and meat products, lipid oxidation, sensory and nutritional properties

1. Introduction

It is known that meat and all meat products are the main source of proteins as well as amino acids, fats, vitamins, minerals and many more vital nutrients, as a result they are an essential part of human nutrition [1].

The meat industry has been evolving internationally and has been driven by the customer, consumers preferences and lifestyle as well as by the economics, geographical, political, cultural and religious factors and this evolution is a consequence of the increase in the demand for extended meat preservation.

The extended meat preservation has become the foundation, the pier of the international meat trade and it has been directly associated with meat safety and biosecurity assurance. In order to extend the meat shelf life, tradition techniques have been used such as salting, smoking, drying, fermentation and canning [2].

As it is known, the meat products are foods resulting from processing fresh meat originated from different animals, through one or more types of processes as

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cooking, drying, smoking, salting, fractionation, fermentation and the addition of seasonings or other additives [3].

By processing the fresh meat will result a reduced perishability and an incresed shelf life, minimizing the transport and storage costs and also adding value to wastes and to pieces of meat that are less valuable or which would not be usually used fresh, taking into account the commercial alternatives. Only the process of meat itself does not have significant impact on the nutritional quality of the product, but it gives however characteristics as colour and flavour that are typical for each process [3].

Due to a high level of manipulation during the meat processing the oxidative process takes place and oxidation will affect the characteristics of the product such as colour, flavour, nutritional value and texture. This happens due to the attack of the free radicals on proteins, lipids, pigments and vitamins, so the oxidation becomes a limiting factor for the meat and meat products quality and accetability [4-6].

Lipid and protein oxidation in meat products is the second most important cause of meat spoilage, following microbial spoilage [7]. It is associated with intrinsic and extrinsic quality degradation, reduced nutritional value and a general deterioration in meat palatability and other organoleptic properties [8, 9].

Meat oxidation is related to its increased content of proteins, fats, carbohydrates and water,and results in the formation of chemical compounds with cytotoxic, mutagenic and oxidative effects on body tissues, thereby promoting cancer, atherosclerosis, inflammation and aging processes [10].

Following the microbial spoilage, the second most important cause of meat spoilage is the lipid and protein oxidation [7]. This is being correlated with intrinsic and extrinsic quality degradation, diminished nutritional value, a general degenaration in meat palatability and other organoleptic properties [8-10].

2. Oxidative processes developed in meat and meat products

The oxidation of meat is linked to the high content of carbohydrates, water, protein and fat and leads to the formation of chemical compounds with cytotoxic, mutagenic and oxidative effects on body tissues, thus promoting cancer, atherosclerosis, inflammation and aging [10].

The appearance of the oxidation process is also due to the high level of handling of the meat so that it can be processed [11].

The formation of free radicals and the spread of oxidative reactions due to excessive manipulation occur either by decompartmentalizing cellular structures, which allows the interaction of previously isolated compounds, or by exposing these molecules to oxygen and light [11].

Food loses its quality due to oxidation, causing changes in texture, aroma, color, taste which lead to nutritional losses of proteins, lipids and pigments, in addition to the production of potentially toxic compounds. The most researched is the oxidation of lipids due to the significant loss of quality caused by it, but we can not ignore the oxidation of other compounds [12].

Lipid oxidation is presented as an oxygen-dependent, oxidative damage of saturated and unsaturated fatty acids.

This fatty acid change is mainly achieved by an autocatalytic mechanism of free radicals, called self-oxidation and involve 3 steps: initiation, propagation and termination, Figure 1 [13].

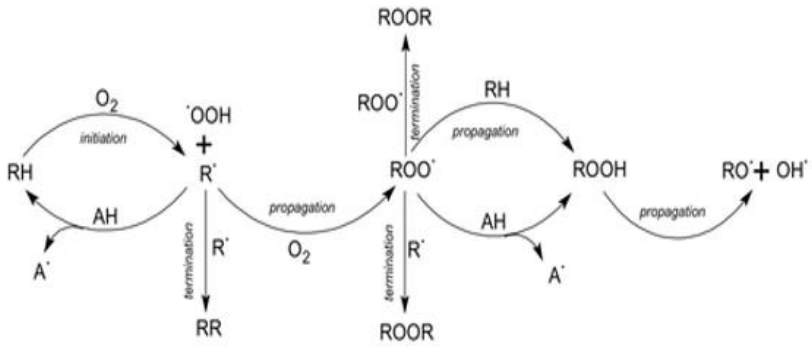

Figure 1. Mechanism of lipid oxidation process AH - antioxidant (free radical scavenger; chain breaking inhibitor); A˙ - free radical, relatively very stable [13].

Protein carbonylation happens when the protein oxidation is initiated by myoglobin, metallic catalysts or oxidizing lipids, which react with chains of amino acids leading to the generation of the protein and carbonyl derivates [14].

The result of the oxidative process is determined by three major factors, such as: (i) the profile and content of the fatty acids; (ii) the type of the antioxidants compounds (enzymes or peptide, vitamins) and (iii) the contents of the pro-oxidant compounds (metals and enzymes, hemeproteins) [10, 15].

The colour of meat is determined by the the content and shape of the myoglobin, a protein which is present in the muscle cells and it is responsible for the transport and storage of the oxygen. This metalloprotein has a polypeptide chain linked to a prosthetic group, called heme group formed by a porphyrin ring containing an iron atom. The iron present in this heme group binds to the oxygen and can take various forms which are reversible with each other. So, depending on the oxidation state of the iron contained in this molecule, the colour of the myoglobin can considerably change [16].

The process of lipid peroxidation developed in raw and processed meat has three major effects: (i) in term of sensory quality: flavour and colour, juiciness (dripping losses) and altered texture; (ii) in terms of bioavailability: decresed nutritional value due to essential fatty acids oxidation and (iii) in terms of food safety: products that suffer a secondary lipid peroxidation are considered to be toxic to humans [17].

The lipid hydroperoxides which are the initial products of the lipid oxidation process are actually odorless and their effect is a decresed nutritional value when they are resulted from the fatty acids oxidation (e.g., linoleic and arachidonic). Additionaly, they will furthrt decompose to different volatile and nonvolatile secondary products which are responsible for off-odor, off-taste, changed colour and the loss of the protein stability [18-20].

A significant number of studies have shown a close connection between the food end products of lipid peroxidation and the various damaging health issues, including neurodegenerative diseases, atherosclerosis and cancer [21, 22].

A high carcinogenic factor in food is the malonaldehyde (MDA) which is a degradation product of lipid oxidation and cholesterol oxidation products [23].

3. Approaches to inhibiting oxidation in meat and meat products

3.1. Substances that inhibit food oxidation

In a biological matrix such as food, an antioxidant is a substance that at low concentration will delay, prevent or remove the oxidative damage process on the targeted molecules by removing the reactive oxygen species (ROS), enhancing the biological antioxidant defenses or inhibiting the ROS production [24].

Many studies have been conducted on this highly important matter. Pokorny [25] underlined the difference between the substances that protect the foods against oxidation, which would be called oxidation inhibitors and those that will actually inhibit the oxidation process by reacting with the free radicals, which would be called the ”true” antioxidants.

In parallel, Shahidi & Zhong [26] and Kumar [27] seperated between the primary antioxidants also called chain-breaking antioxidants which will break the oxidation chain reaction, mainly by hydrogen or electron donation and secondary antioxidants, also called preventive inhibitors which will act by slowing the oxidation process by other types of mechanisms.

The free radicals like peroxyl radicals are removed by the primary antioxidants, leading to the completion of the free-radical chain oxidation reactions and therefore, canceling the oxidation cycle at the begining step [28], becoming the most effective antioxidants. On this note, a few examples include powerful antioxidants synthesized in plants such as carotenoids and phenolic compounds thymol, quercetin, carvacrol, etc) and α-tocopherols.

The secondary antioxidants inhibit the oxidation by removing ROS, which are chain-initiating catalysts, or oxygen, or binding transition metal cations to stabilize them in inactive or insoluble forms, thus limiting the radical initiation step in the oxidation process [21].

These antioxidant compounds operate following certain mechanisms: (i) inducing the peroxides decomposition, removing oxygen and reducing the redox potential (i.e. sulphites, ascorbate erythorbate, ascorbyl palmitate, sulphur and sulphur compound such as thiols, allicin, bisulphides, selenium and selenium compounds); (ii) preventing the hydroperoxides metal-assisted hemolytic degradation by chelating prooxidant metal ions, for example, organic acids as phytic, citric, ascorbic acid and their salts, amino acids and peptides, especially those containing histidine or ethylenediaminetetraacetic acid (EDTA), poly-phosphates; (iii) quenching the singlet oxygen, for example, carnosine and anserine, carotenoid pigments; (iv) removing oxygen or ROS (e.g. superoxide dismutase, catalase, glutathione peroxidase, etc); (v) Inhibiting oxidative enzymes such as lipoxygenases, peroxidases or polyphenol oxidases, for example, sulfites; (vi) regenerating primary oxidants by showing a synergistic action other oxidation inhibitors, for example, a very high recognized synergism is between ascorbic acid or carotenoids and tocopherols. A single compound can operate following different mechanisms [17].

The chemical antioxidants are being considerably used to prevent and avoid the effects of lipid oxidation developed in meat and meat products.

They have been a lot of consumer requests supporting the use of natural antioxidants compounds due to the population awareness of the possible health issues implications of the widespread use of the synthetic antioxidants (i.e allergies and allergis reactions, disorders suffered by pregnant women and children, potential carcinogenic effects, etc) [29, 30].

An agreed alternative to the syntethic additives is the use of natural antioxidants in the meat products. Since they have been globally consumed by the general population without signs of allergies, toxicity and also providing beneficial effects to human health, most sources of natural antioxidants compounds have shown their safety in using them in the meat processsing [31, 32].

Because they are easily obtained from natural sources, the natural antioxidants have a great potential to be used instead of the synthetic ones. The synthetic antioxidants have been used and are still used in the food industry, especially due to their low costs and high availability as well as their stability and high performance [33].

Even though these synthetic antioxidants have been extensively used, over time a lot of safety issues have been raised.

Therefore, there are now a lot of available studies that have been shown a close connection between the long-term used of synthetic antioxidants and several health issues (i.e gastrointestinal problems, skin allergies , increased risk of cancer) [33].

3.2. Plant-derived antioxidants used in meat systems

Compounds with antioxidant activity are used in order to reduce the effects of free radicals. These compounds acre called ”antioxidants”, a term used to define any substances that delay or prevent the food biomolecules oxidation, even when added in low concentration [34].

The antioxidants exploited by the meat industry are either natural or synthetic. The natural antioxidants can be further classified based on their origin (plants, animals or bacteria) and their chemical structure (e.g., phenols, tocopherols or vitamin C). Plant-derived natural antioxidants originate from fruits, teas and herbs, seeds, spices, vegetables, cereals and trees [35].

Nowadays, both natural or synthetic antioxidants are used in the meat industry. The natural antioxidants are being classed upon their origin (animal, bacteria or plants) and their chemical structure (e.g., tochopherols, phenols). The plant-originated natural oxidants come from spices, fruits, trees, teas seeds, and herbs, vegetables and cereals [35].

High concentration of antioxidants are found in a variety of plant organs such as flowers, stems, fruits, leaves or roots and the concentration varies based on the plant species and on the actual antioxidant substance. The above-mentioned plant parts can be used in the food products directly (e.g., fruit puree or juice) or after extracting and purifying the content of antioxidant substances (e.g., rosemary extract) [36, 37].

The main mode of action of antioxidants and their properties are directly related to their chemical structure. Therefore, the major group of antioxidants based on their chemical structure are phenols, tannins, flavonids and isoflavonoids, anthocyanins, lignans, stilbenes, tocopherols, carotenoids and vitamin C [38].

Phenolic compounds can be categorizated based on their carbon chains, therefore, the phenols and benzoquinones with the basic skeleton C6 come from natural sources such as berries, olive oil, fruit wines. Phenolic acids with the carbon chains C6-C1 can be found in apple juice, cider, oranges, blueberries and blackberries. Phenolic compounds like acetophenones and phenylacetic acids derived from cocoa powder, nicotiana, pine, pisum, avena and balsamic vinegar have in their chemical structure the C6-C2 combination. The carbon chains C6-C3 are present in hydroxycinnamic acids, phenylpropenes, coumarins-isocoumarins and chromones, these phenolic compounds can be extract from plant sources like herbs, pomes, leafy greens, asparagus, cinnamon, cloves and potatoes [38].

Fruit-derived antioxidants

The substantial phenolic content and other antioxidants in fruits make them attractive alternatives to synthetic antioxidants for food preservation. Whole, chopped or mashed fruits have been used raw (e.g., fruit purees) or processed (e.g., dried, powdered, extracts etc.) for this reason. Moreover, fruit by-products (skins, peels, seeds and pulp) have also been used to improve the antioxidant capacity of meat and meat products [39, 40].

Saha *et al.* [41] showed that strawberry fruit extract could act as a potential antioxidant source in cooked chicken patties.

García-Lomillo *et al.* [42] indicated that raw beef patties combinated with skin fraction of red wine pomace can inhibited lipid oxidation. Annatto (*Bixaorellana* L.) seeds powder is an additive who can retard lipid and protein oxidation in pork patties.

Cuong & Chin [43] used the powder as a natural coloring agent in food contains bixin and nor-bixin apocarotenoids as antimicrobial and antioxidant agents.

An excellent food source of vitamin C is acerola (*Malpighia emarginata* L.) fruit extract and Realini *et al.* [44] used acerola fruit extract to improve color and lipid stability and decrease rancid flavor of raw salted beef patties without affecting microbial load.

The skin extract of peanut is used as a natural antioxidant, Munekata *et al.* [45] indicate that in cooked chichen patties this additives can prevent lipid oxidation during regrigerated storage. Also, Munekata *et al.* [46] used peanut skin extract in raw sheep patty, it was introduced as an appropriate antioxidant instead of BHT, reducening the loss of redness and prolonging the self life of sheep patties.

Larrauri *et al.* [47] indicate that the application of peanut skin extract in salami can retarded lipid oxidationand preserved sensory proprieties of salami. The study carried out by Lee *et al.* [48] has deal with cranberries rich in phenolic compounds, who was added in mechanically separated turkey, cranberry powder reduce the thiobarbituric acid reactive substances (TBARS) value by 84% over storage period of 6 days at 2°C.

In the study performed by Kathiervel *et al.* [49] it has been investigated the cranberry powder in cooked pork, the phenolic componds reduced TBARS by 81% over a period of 7 days at 2°C.

Herbs and spices extracts

An extreme antioxidant activity has been found in herbs, spices, and extracts, so they can be used as effective natural antioxidants in meat and meat products. In the research performed by Kim *et al.* [50] it has been investigated the combined addition of soy sauce and ascorbic acid in raw beef patties, the results of this work highlighted that the use of soy sauce greatly improved color stability and retarded lipid oxidation.

DeJong & Lanari [51] used olive and wine extracts in cooked beef and pork, olive extract showed stronger antioxidant activity than wine extract. Doolaege *et al.* [52] have tracked the antioxidant effects of rosemary extract in liver pates, and the impact on product is that nitrite concentration decreases dramatically without a negative effect of color.

Rocio Teruel *et al.* [53] also investigated the antioxidant effects of rosemary extracts in chiken nuggets, the results showed an improvement of oxidative stability in frozen chicken nuggets.

De Florio Almeida *et al.* [54] conducted a study on the addition of bee pollen extract in pork sausage and the obtaine results revealed that the lyophilized bee pollen was effective in retarding the lipid oxidation.

In other study Andres *et al.* [55] investigated the combination of grape and olive pomaces extracts in raw lamb patties , the results was that could be an effective additive to replace sodium ascorbate in meat products.

4. Conclusions

One of the major problem that decrease the self life of meat and meat products is represented by lipid oxidation. To slow down lipid oxidation, to improve color stability and also to delay development of unpleasant-flavors in meat and meat products are being used antioxidants. The use of synthetic antioxidants can be considered unsafe for the health of the consumer, so, natural antioxidants are a healthy alternative.

Particular attention has been paid in recent years to natural antioxidants that improve the chemical quality of meat and meat products as well as the sensory their nutritional properties. Nowadays, the studies have made a significant progress in researching plant-based food additives and how they work in the meat industry. Plant-based natural antioxidants can be from fruits and can be used in various form whole, ground powder or isolates from their extracts Novel approaches show that the method of incorporating natural antioxidants into meat products are more effective than spraying them on their surface. In order improve the meat and meat products quality and health properties the use of bioactive compounds of plants extracts seems to be the most applied plan of action. As long as they depend on the preserving period and the manipulation, the natural antioxidants usage can be limited. The use of natural antioxidants in meat and meat products is an important goal in the meat industry. To achieve this purpose, it is necessary to improve current technologies and expand with new ones.

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