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Mini Review

Natural products in food preservation

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Abstract

The production of safe, high-quality and shelf-stable food has become a challenge to the food industry. That is why chemical additives are often used in order to ensure that throughout the shelf life the food remains suitable for consumption with all desirable sensory characteristics, thereby ensuring its preference at the time of purchase. However, some chemical additives when ingested in high amounts may provide undesirable reactions to the consumers. Therefore, consumers, food industry and the health authority are beginning to urge that these chemical preservatives be replaced with natural products with properties that preserve the food throughout its shelf life. The present review thus addresses the main mechanisms of food deterioration and the most common natural products used as preservatives, exposing their main components, modes of action and applications.

Introduction

Fruits, vegetables, seafood and meats generally have a very short shelf life, thus requiring appropriate preservation technologies to extend their shelf life (Krishnan *et al*., 2015; Martínez-Graciá *et al*., 2015). In view of this, the food industry has invested more and more in preservation methods. Many of them have made use of chemical and synthetic preservatives because they are low cost and easy to obtain. However, nowadays, the requirement of consumers is that these preservatives be replaced by products as close to the natural ones as possible due to the adverse effects that synthetic chemical preservatives can cause to consumers' health, even though these products have their use allowed in some countries (Govaris *et al*., 2010).

Currently, researchers have been intensively looking for preservative agents considered natural, those that are derived preferentially from plants. These preservatives should act at extending the shelf life and ensuring safety, as well as providing the benefit of replacing the synthetic preservatives conventionally used by the food industries (Thielmann *et al*., 2017).

Among the most widely used synthetic preservatives are nitrates, benzoates, sulphites, sorbates and formaldehyde which despite the benefits conferred on food, such as the safety and quality of products that reach the consumers, pose risks to the consumers due to the adverse effects that their consumption can cause (Sultana *et al*., 2014). Many chemical preservatives, such as butylhydroxyanisole (BHA) and butylhydroxytoluene (BHT) have been used successfully to prevent food deterioration caused by lipid oxidation. In contrast, synthetic compounds have significant disadvantages, such as the risks of manipulation and increase of chemical residues disposed in the food and in the environment.

In addition, these preservatives might have negative consequences for the health of the consumers, being associated with possible carcinogenic effects (Kim *et al*., 2013). Therefore, the perception of the consumers regarding the intake of foods containing high levels of chemical compounds, together with the development of diseases, such as cancer and cardiovascular diseases, has promoted the search for natural preservatives, among them, the derivatives from plants (Krishnan *et al*., 2014).

The use of herbs, spices and essential oils in foods has been documented over the years. In the food sector, the herbs and spices began to be used in order to aromatise beverages and foods, in addition to masking undesirable properties, especially in meat products. As a result, it was found that in addition to masking organoleptic characteristics, herbs and spices were also able to conserve food. Therefore, nowadays, plant products have been used and studied in food, mainly due to its antimicrobial

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and antioxidant properties to replace the synthetic preservatives (Cattelan *et al*., 2012) for example oregano extracts in the preparation of hamburger, to reduce oxidative action (Fernandes *et al*., 2017), extracts and compounds derived from olive (*Olea europaea* L.) as potential antimicrobial in food matrices (Thielmann *et al*., 2017), essential oils of coriander (*Coriandrum sativum* L.) and hyssop (*Hyssopus officinalis* L.) on the shelf life of ground beef (Michalczyk *et al*., 2012).

Even though natural antimicrobials derived from plants have been used for centuries, but their actions have only been confirmed scientifically in the last 30 years (Saeed *et al*., 2013). According to Tajkarimi *et al*. (2010), the first reports of scientific studies with herbs and spices on food preservation took place in the 1880's when the antimicrobial activity of cinnamon oil was verified against spores of *Bacillus anthracis*.

Natural products have been used to prevent changes in food, especially those related to microbial development and the occurrence of oxidative reactions (Krishnan *et al*., 2014). Plants have the ability to synthesise, through the secondary metabolism, several compounds that have, among other functions, antimicrobial and antioxidant actions, varying according to their constituents, which have complex structures. These components are naturally produced by stimulating the defence system of a plant during adverse conditions (Gracia *et al*., 2015).

The consumers have demanded food to be microbiologically safe, closer to natural, with no chemical preservatives and with longer shelf life. Therefore, the present review discusses the main natural products used as preservatives in foods that can efficiently replace chemical additives, as well as their peculiarities as antimicrobial and antioxidant agents. Studies and researches published in the last seven years (2010-2016) were referred.

Process of food deterioration

Among the several processes that influence food deterioration, the development of deteriorating and/or pathogenic microorganisms and the increase of oxidative processes can result in a shorter shelf life of the food, as well as a reduction in the safety and quality of the product for consumption (Viuda-Martos *et al*., 2011; Krishnan *et al*., 2014).

One of the causes of food deterioration is lipid oxidation. This is more prevalent in products that are rich in lipids and polyunsaturated fatty acids. Lipid oxidation is defined as a chemical reaction responsible for the development of rancid taste and unpleasant odour in the food. In addition, this process can result in the formation of compounds harmful to the consumers' health. Oxidative rancidity is one of the main causes of the reduction of food quality, which consequently leads to the rejection of the product (Decker *et al*., 2010).

In addition to the loss of product quality due to the development of rancid flavour, significant changes in the colour, texture and nutritional quality of the food also occur as a result of the degradation of the essential fatty acids and vitamins, making the product unsuitable for consumption. Another important factor regarding the development of oxidative reactions in food is the formation of toxic compounds such as lipid peroxides and malonaldehyde, which can result in damage to the consumers such as mutagenesis and carcinogenesis (Embuscado, 2015).

After chemical deterioration, microbial deterioration of food can also lead to large losses in product quality. Additionally, during microbial deterioration, the growth of both spoilage and pathogenic microorganisms can occur which poses a risk to the consumers' health. Foodborne diseases are a major concern for consumers, the food industry and food safety authorities. Thus, the use of antimicrobial agents in foods has several objectives, among them, to eliminate or delay the action of pathogenic microorganisms, which might lead to the development of outbreaks of foodborne diseases, and to control the processes of deterioration that occur naturally in the food, which affect the organoleptic characteristics and the quality of the product (Gyawali and Ibrahim, 2014). Therefore, natural preservatives obtained from herbs and spices have been the subject of constant research to increase the shelf life and ensure the organoleptic characteristics of food. In addition, herbs and spices are considered as "Generally Recognised as Safe" (GRAS) foods and can be consumed without risk to health (Viuda-Martos *et al*., 2011).

Classification of natural preservatives

According to Graciá *et al*. (2015), natural antimicrobials can be defined as any and all substances obtained naturally or directly from a biological system without any change or modification in a laboratory environment. These can be obtained from different sources including plants, animals, bacteria, algae and fungi.

Plant extracts have the advantage of being consumed by humans for thousands of years, and in addition to the antimicrobial action, several plants are being used in different areas of human health, such as traditional medicine, functional foods, food supplements and production of recombinant protein.

However, the development of new antimicrobial strategies and systems requires a thorough knowledge of the physiological response expressed by the microorganisms to be controlled (Negi, 2012; Graciá *et al*., 2015).

Natural products obtained from plants, such as herbs, spices and essential oils, are widely used in foodstuffs as preservative of their sensory characteristics, ensuring quality and safety throughout the shelf life (Negi, 2012). Spices are characterised as products from different parts of certain plants, with the exception of leaves whereas herbs are those extracted from the leaves of the plant (Table 1). Herbs and spices can be classified based on the flavour, taxonomy or part of the plant from which they were extracted. Based on the flavour, spices and herbs can be classified into four groups: hot spices (black and white pepper, cayenne pepper, mustard), soft-flavoured spices (paprika, coriander), aromatic spices (clove, cumin, cinnamon) and herbs and vegetables (thyme, basil, bay leaves, marjoram, shallots, onion, garlic) (Embuscado, 2015).

Table 1: Classification of natural products derived from plants.

Type of Natural Product	Definition	Examples of Products
Herbs	Extracted from leaves of plants.	Rosemary, oregano, basil, coriander, bay leaf, marjoram
Spices	Derivative from different parts of plants such as fruits, seeds, roots, barks and shoots	Cinnamon, pomegranate, thyme, clove, nutmeg
Essential Oils	Substances produced by the secondary metabolism of plants.	Coriander seed essential oil, thyme, Clove (bud), Sage, Rosemary, Oregano, Cinnamon, Coriander

(Source: Bassolé and Juliani, 2012; Silva *et al*., 2013; Embuscado, 2015).

The essential oils or essences of aromatic plants are bioactive, volatile and fragrant compounds formed by a mixture of substances with an oily consistency, typically produced by the secondary metabolism of plants. They may be liquid at room temperature although some of them are solid or resinous, and showing different colours ranging from light yellow to emerald green and from blue to dark reddish brown. They are synthesised from all parts of plants; buds, flowers, leaves, stems, branches, seeds, fruits, roots, wood or bark, and are stored in secretory cells, cavities, channels, epidermal cells or glandular trichomes (Bassolé and Juliani, 2012; Silva *et al*., 2013).

Many factors affect the chemical composition of essential oils. The various components present in the constitution of the essential oils can significantly alter their biological action, causing synergistic or antagonistic effects between their constituents (Settanni *et al*., 2014). Thus, the antimicrobial and antioxidant properties of these natural additives are studied considering the composition as a whole and not a mixture of isolated components (Militello *et al*., 2011).

In addition to being known for their multifunctional and beneficial health properties, essential oils are gaining recognition for their potential as food preservatives with antimicrobial and antioxidant action (Viuda-Martos *et al*., 2010; Elaissi *et al*., 2011; Prakash, 2012). However, the antimicrobial and antioxidant effects found in natural products, whether they are in the form of herbs, spices or essential oils can be variable; not being detected with the same efficiency in all the plants, and vary even within the same species. This occurs because the efficiency of the natural preservative depends on its chemical composition, which varies according to the genotype of the plant, as well as on the environmental and agronomic conditions in which they are produced (Carović-Stanko *et al*., 2010).

Main constituents

The secondary metabolites as well as the by-products obtained from the plants have several components that determine their functionality. However, their composition can be variable according to soil type, climatic conditions and the environment in which they are produced. In addition, the antimicrobial and antioxidant efficacy of natural product components also depends on the chemical structure of the active components, the concentration and extraction method (Vilela *et al*., 2016).

Several chemical compounds present in plants have the ability to replace synthetic preservatives thereby helping to conserve food. Among them are saponin, flavonoids, thiosulfinates, glucosinolates, phenolics and organic acids. However, the main components of plants with antimicrobial action are phenolic compounds such as terpenes, aliphatic alcohols, aldehydes, ketones, acids and isoflavonoids (Hayek *et al*., 2013)

Phenolic compounds when added to foods act as reducing agents, donating hydrogen and oxygen suppressants, causing an antioxidant effect on the products. Some phenolic compounds have also the ability to chelate metal ions that act as catalysts in oxidation reactions. Flavonoids are natural polyhydroxylated aromatic compounds that are widely distributed in plants (fruits, vegetables, spices and herbs). Flavonoids have the ability to eliminate free radicals, including hydroxyl, peroxyl and superoxide radicals, and can form complexes with catalytic metal ions making them inactive. It has also been found that flavonoids can inhibit lipoxygenase and cyclooxygenase enzymes, the enzymes responsible for the development of oxidative rancidity in foods (Embuscado, 2015).

Mode of action of natural preservatives

The mechanisms of action of the natural preservatives are not yet very well understood. However, some studies have attempted to explain how inhibition or retardation of microbial development occurs (Viuda-Martos *et al*., 2011; Xing *et al*., 2012). According to Carović-Stanko *et al*. (2010), the antimicrobial activity might be caused by the major compounds of the natural products or may be also due to the synergistic effect between the major compounds and those that are in smaller amounts.

It is believed that the antimicrobial mechanism of the natural preservatives is related to the attack of the cell membrane phospholipid bilayer, hence the rupture of the enzymatic systems, which leads to the compromising of the genetic material of the microorganisms. This consequently leads to the formation of hydroperoxidase of fatty acids by the oxygenation of unsaturated fatty acids, coagulation of the cytoplasm which cause damage to lipids and proteins, and distortion of the proton motive force (FMP), electron flow and/or active transport (Viuda-Martos *et al*., 2011). They can also inhibit the activity of protective enzymes and consequently block one or more biochemical pathways (Xing *et al*., 2012).

Regarding to essential oils, their constituents are hydrophobic, a characteristic that allows their action on the lipids present in the bacterial and mitochondrial cell membrane, distorting the structure and making the microorganisms more susceptible to the antimicrobial action leading to the release of cellular content. Thus, it is believed that the chemical structure of the components of the essential oils can significantly affect the action and antimicrobial activity (Viuda-Martos *et al*., 2011).

The use of substances with antioxidant action in food causes the reduction or inhibition of lipid peroxidation due to the ability of these products to sequester chains of free radicals, to decompose peroxides, to reduce the concentration of oxygen and also their ability to catalyse metal ions (Karre *et al*., 2013). In addition, their mechanism of action is related to the ability of the natural product to neutralise the free radicals present in the food (Krishnan *et al*., 2014).

The antioxidant activity might be related to the amount of phenolic compounds present in the constitution of natural products, since phenolic compounds have high redox potential allowing them to act as reducing agents, hydrogen and oxygen donors. Therefore, the content of phenolic compounds could be used as an indicator due to the presence of antioxidant capacity (Miguel, 2010).

Application of natural products in foods

Among foods that are most likely to deteriorate, those of animal origins are more susceptible to oxidative and microbial degradation, even under normal storage conditions. The deterioration of these foods causes the development of undesirable odours, alteration in the nutritional value and can consequently influence the acceptance of the product by the consumers (Krishnan *et al*., 2014).

The use of natural preservatives in food has been widely accepted by consumers who are increasingly looking for natural and healthy products, free of synthetic additives (Viuda-Martos *et al*., 2010). According to Militello *et al*. (2011), herbs and spices are widely used and accepted by consumers of meat and meat products with the aim of flavouring such foods. In addition, essential oils can also be considered a good choice of natural preservatives for meat products. For example, lemon essential oil, used as a micro emulsion in salty sardines, has shown a bio-preservative effect by reducing the microbial counts of *Staphylococcus* spp., Enterobacteria and lactic acid bacteria (LAB). When compared to the control, it was also noticed that treated sardine samples yielded low accumulation of histamine (Alfonzo *et al*., 2017).

The antioxidant and antimicrobial potential of chamomile (*Matricaria recutita* L.) has already been verified, proving to be efficient in the natural conservation of functional dairy products (Caleja *et al*., 2015a). Another plant that showed great potential in the conservation of cottage cheese was the Funcho (*Foeniculum vulgare* Mill.) due to the high proportions of phenolic compounds in its constitution, manifesting high antioxidant capacity (Caleja *et al*., 2015b). During the evaluation of the antioxidant and antimicrobial potential of polyphenolic extracts from cherry tree and blackcurrant leaves as natural preservatives in meat products, it was found that the shelf life of vacuum-packed sausages was extended and that the development of almost all microorganisms studied was inhibited, in addition to providing a significant decrease in the amount of malonaldehyde generated in the product, which indicated antioxidant effect (Nowak *et al*., 2016). The essential oil of onion (*Allium cepa* L.), according to Ye *et al*. (2013) showed antioxidant and antimicrobial action against several pathogenic and spoilage bacteria such as *Escherichia coli*, Bacillus subtilis and *Staphylococcus aureus*, demonstrating great potential for use as a preservative in food.

Globalisation has enabled the dissipation of native herbs and spices from certain regions to other countries. Nowadays, native herbs such as saffron in India, basil, garlic and oregano typical of the Italian and Greek cuisines, and pepper powder from the Hungarian cuisines could also be found in other regions (Szucs *et al*., 2018).

In China, there are more than 400 native spices that are used as valuable ingredients in the country's cuisine. Some common spices, such as cinnamon, star anise, pepper and ginger are widely used in the Chinese food industry (Lu *et al*., 2011). In the European Union (EU), herb and spice consumption grew by 1.7% per year between 2010 and 2013, reaching 385,000 tonnes of spices consumed in 2012. China is currently the leading supplier of these products (CBI Market Intelligence, 2015).

In Central Europe and North America, the spices used are often native to the countries. In addition to their use as a flavouring agent and to alter the appearance and taste of food, their role as antioxidants and natural antimicrobials are also of great importance in extending shelf life and in consumer safety (Pokorný and Pánek 2012).

Over the past 45 years, spice use has been steadily increasing in the United States, which has been driven by increased immigration in the country, popularity of ethnic foods, the need to improve the taste of food, and by the consumers' concern with the reduction of salt and fat contents in the diet (Presse *et al*., 2015).

In research and in the food industry, herbs and spices have aroused interest because of the wide variety of bioactive compounds, such as polyphenols, menthol, retinol, carotenoids and curcumin, known for their antimicrobial, antioxidant and anti-inflammatory benefits for health. These products are mainly found in ready-to-eat products and processed foods (Viuda-Martos *et al*., 2011; Jungbauer and Medjakovic, 2012; Presse *et al*., 2015; van Asselt *et al*., 2018).

Despite all the advantages related to the use of herbs and spices in food, several disadvantages warrant further investigation. When used in food matrices, the amount needed to achieve the desired action is not always sensorially acceptable. In addition, essential oils, herbs and spices have a strong aroma even when presented in low concentrations, which can make the product poorly accepted by consumers (Martínez-Graciá *et al*., 2015). This paves a wider avenue for researches to be conducted to better utilise the benefits of essential oils as food preservatives.

Final considerations

The demand of the consumers for increasingly healthy and shelf-stable foods has prompted the search for food preservatives with low potential health risks. Plants and their derivatives are viable alternatives in the process of preserving food, ensuring the stability of the organoleptic and nutritional characteristics of these products, as well as their quality and safety.

References

Alfonzo, A., Martorana, A., Guarrasi, V., Barbera, M., Gaglio, R., Santulli, A., Settanni, L., ... and Francesca, N. 2017. Effect of the lemon essential oils on the safety and sensory quality of salted sardines (*Sardina pilchardus* Walbaum 1792). Food Control 73: 1265–1274.

Bassolé, I. H. and Juliani, H. R. 2012. Essential oils in combination and their antimicrobial properties. Molecules 17(4):3989–4006.

Caleja, C., Barros, L., Antonio, A. L., Ciric, A., Barreira, J. C. M., Sokovic´, M. and Oliveira, M. B. P. P. 2015b. Development of a functional dairy food: exploring bioactive and preservation effects of chamomile (*Matricaria recutita* L.). Journal of Functional Foods 16: 114–124.

Caleja, C., Barros, L., Antonio, A. L., Ciric, A., Sokovic´, M., Oliveira, M. B. P. P. and Santos- Buelga, C. 2015a. *Foeniculum vulgare* Mill. as natural conservation enhancer and health promoter by incorporation in cottage cheese. Journal of Functional Foods 12: 428–438.

CBI Market Intelligence. 2015. CBI Trade Statistics: Spices and Herbs. The Hague, Netherlands: CBI.

Decker, E. A., Elias, R. J. and Mcclements D. J. 2010. Oxidation in foods and beverages and antioxidant applications. Volume 2: Management in different industry sectors. India: Woodhead Publishing.

Elaissi, A., Salah, K. H., Mabrouk, S., Larbi, K. M., Chemli, R. and Harzallah-Skhiri, F. 2011. Antibacterial activity and chemical composition of 20 *Eucalyptus* species essential oils. Food Chemistry 129: 1427–1434.

Embuscado, M. E. 2015. Spices and herbs: Natural sources of antioxidants – a mini review. Journal of Functional Foods 18: 811–819.

Fernandes, R. P. P.,Trindade, M. A.,Tonin, F. G., Pugine, S. M. P., Lima, C. G., Lorenzo, J. M. and de Melo M. P. 2017. Evaluation of oxidative stability of lamb burger with *Origanum vulgare* extract. Food Chemistry 233: 101–109.

Gracia, C. M, Gonzalez-Bermudez, C. A., Cabellero-Valcarcel, A. M., Santaella-Pascual, M. and Frontela-Saseta, C. 2015. Use of herbs and spices for food preservation: advantages and limitations. Food Science 6: 38–43.

Gyawali, R. and Ibrahim, S. A. 2014. Natural products as antimicrobial agentes. Food Control 46: 412–429.

Hayek, S. A., Gyawali R. and Ibrahim, S. A. 2013. Antimicrobial Natural Products. In: Microbial pathogens and strategies for combating them: science, technology and education, Volume 2 (A. Méndez-Vilas Eds.). Spain: Formatex Research Center.

Jungbauer, A. and Medjakovic, S. 2012. Anti-inflammatory properties of culinary herbs and spices that ameliorate the effects of metabolic syndrome. Maturitas 71: 227–239.

Krishnan, K. R., Babuskin, S., Babu, P. A. S., Sasikala, M., Sabina, K., Archana, G., Sivarajan, M. and Sukumar, M. 2014. Antimicrobial and antioxidant effects of spice extracts on the shelf life extension of raw chicken meat. International Journal of Food Microbiology 171: 32–40.

Lu, M., Yuan, B., Zeng, M. and Chen, J. 2011. Antioxidant capacity and major phenolic compounds of spices commonly consumed in China. Food Research International 44: 530–536.

Michalczyk, M., Macura, R., Tesarpwocz, I. and Banas, J. 2012. Effect of adding essential oils of coriander (*Coriandrum sativum* L.) and hyssop (*Hyssopus officinalis* L.) on the shelf life of ground beef. Meat Science 90: 842–850.

Miguel, M. G. 2010. Antioxidant activity of medicinal and aromatic plants. A review. Flavour and Fragrance Journal 25: 291–312.

Militello, M., Settanni, L., Aleo, A., Mammina, C., Moschetti, G., Giammanco, G. M., Blàzquez, M. A. and Carrubba, A. 2011. Chemical composition and antibacterial potential of *Artemisia arborescens* L. essential oil. Current Microbiology 62: 1274–1281.

Negi, P. S. 2012 Plants extracts for the control of bacterial growth: efficacy, stability and safety issues for food application. International Journal Food Microbiology 156: 7–17.

Nowak, A., Czyzowska, A., Efenberger, M. and Krala, L. 2016. Polyphenolic extracts of cherry (*Prunus cerasus* L.) and blackcurrant (*Ribes nigrum* L.) leaves as natural preservatives in meat products. Food Microbiology 59: 142–149.

Pokorný, J. and Pánek, J. 2012. The effect of natural antioxidants in herbs and spices on food shelf-life. In: Handbook of herbs and spices. 51–70.

Presse, N., Potvin, S., Bertrand, B., Calvo, M. S. and Ferland, G. 2015. Phylloquinone content of herbs, spices and seasonings. Journal of Food Composition and Analysis 41:15–20.

Settanni, L., Randazzo, W., Palazzolo, E., Moschetti, M., Aleo, A., Guarrasi, V., Mammina, C., San Biagio, P. L., Marra, F. P., Moschetti, G. and Germanà, M. A. 2014. Seasonal variations of antimicrobial activity and chemical composition of essential oils extracted from three *Citrus limon* L. Burm. cultivars. Natural Product Research 28: 383–391.

Silva, J. M. A, Santos, S. M. D., Pintado, M. E., Pérez-Álvarez, J. A., Fernández-López, J. and Viuda-Martos, M. 2013. Chemical composition and *in vitro* antimicrobial, antifungal and antioxidant properties of essential oils obtained from some herbs widely used in Portugal. Food Control 32: 371–378.

Sultana, T., Rana, J., Chakraborty, S. R., Kanta Das, K., Rahman, T. and Noor, R. 2014. Microbiological analysis of common preservatives used in food items and demonstration of their *in vitro* anti-bacterial activity. Asian Pacific Journal of Tropical Disease 4 (6): 452–456.

Szucs, V., Szabo, E., Lakner, Z. and Szekacs, A. 2018. National seasoning practices and factors affecting the herb and spice consumption habits in Europe. Food Control 83: 147–156.

Tajkarimi, M. M., Ibrahim, S. A. and Cliver, D. O. 2010. Antimicrobial herb and spice compounds in food. Food Control 21: 1199–1218.

Thielmann, J., Kohnen, S. and Hauser, C. 2017. Antimicrobial activity of *Olea europaea* Linné extracts and their applicability as natural food preservative agents. International Journal of Food Microbiology 251: 48–66.

van Asselt, E. D., Banach, J. L., van der Fels-Klerx, H. J. 2018. Prioritization of chemical hazards in spices and herbs for European monitoring programs. Food Control 83: 7–17.

Vilela, J., Martins, D., Monteiro-Silva, F., González-Aguilar, G., Almeida, J. M. M. M. and Saraiva, C. 2016. Antimicrobial effect of essential oils of *Laurus nobilis* L. and *Rosmarinus officinallis* L. on shelf-life of minced “Maronesa” beef stored under different packaging conditions. Food Packaging and Shelf Life 8: 71–80.

Viuda-Martos, M., El Gendy, N. G. S., Sendra, E., Fernandez-Lopez, J., El- Razik, K. A. A., El-Sayed, A. and Perez-Alvarez, J. A. 2010. Chemical composition and antioxidant and anti-listeria activities of essential oils obtained from some Egyptian plants. Journal of Agricultural and Food Chemistry 58: 9063–9070.

Viuda-Martos, M., Mohamady, M. A., Fernández-López, J., Abd Elrazik, K. A., Omer, E. A., Pérez-Álvarez, J. A. and Sendra, E. 2011. *In vitro* antioxidant and antibacterial activities of essential oils obtained from Egyptian aromatic plants. Food Control 22(11): 1715–1722.

Ye, C-L., Dai, D-H. and Hu, W-L. 2013. Antimicrobial and antioxidant activities of the essential oil from onion (*Allium cepa* L.). Food Control 30: 48–53.