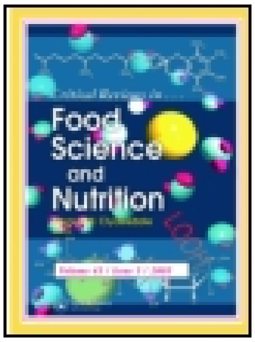

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Spice use in food: Properties and benefits

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Abstract

Spices are parts of plants that due to their properties are used as colorants, preservatives or medicine. The uses of spices have been known since long time, and the interest in the potential of spices is remarkable due to the chemical compounds contained in spices, such as phenylpropanoids, terpenes, flavonoids and anthocyanins. Spices, such as cumin (cuminaldehyde), clove (eugenol) and cinnamon (cinnamaldehyde) among others, are known and studied for their antimicrobial and antioxidant properties due to their main chemical compounds. These spices have the potential to be used as preservatives in many foods namely in processed meat to replace chemical preservatives. Main chemical compounds in spices also confer other properties providing a variety of applications to spices, such as insecticidal, medicines, colorants and natural flavoring. Spices provide beneficial effects, such as antioxidant activity levels that are comparable to regular chemical antioxidants used so they can be used as a natural alternative to synthetic preservatives. In this review, the main characteristics of spices will be described as well as their chemical properties, different applications of these spices and the advantages and disadvantages of their use.

Key words: Antioxidant, Antimicrobial, Spices, Colorants, Preservatives, Properties.

Introduction

Spices have been used since ancient civilization, their flavor and properties make them important for culinary and medicinal uses (Parthasarathy et al., 2008). Conquer travels to India and Africa and exploration to new countries, such as Spice Islands made possible the discovery of new species into Europe and the developing of trading networks of spices. Since past times, several countries had fought for the control of spice trade but the strongest nations have been the ones who manage the spice trade. Nowadays spice production is mainly controlled by China, Madagascar, India and Indonesia (World Trade Organization, 2012).

Due to their important properties, spices have become essential for culinary and medicinal proposes in several regions around the world, the trading of these spices has been an important commercial activity since ancient times and a mean of economic development (Tufail, 1990).

Asia is the super producer of spices, where all kinds of spices such as cinnamon, pepper, nutmeg, clove and ginger are found. There are also Latin American countries that have the leadership in production of some trade spices, such as Brazil as the major supplier of pepper or Guatemala is the leading producer of cardamom (Parthasarathy et al., 2008).

Due to spices properties and large applications, they have become an important economical activity. Between the year 2000 and 2004, the value of spice imports increased by 1.9% per year and the volume increased by 5.9%. In the year 2004, the trade of spices was around 1.547 millions of tons with a value of US 2.97 billions reflecting the importance of spices in the world and their demand (International Trade Centre, 2006).

Spices have many applications, namely as flavoring agent, medicinal, preservative and coloring agents. Spices and their extracts possess preservative and natural antioxidant properties, spice extracts are popular and certain of them have antibacterial, antifungal and antiviral activities (Hernández et al., 2011). Due to the different applications discovered in spices, research has been done over the most popular spices to determine the chemical components that confer their properties. Main chemical compound actives have been identified in several spices, such as cinammaldehyde in cinnamon, eugenol in clove and cuminaldehyde in cumin which have proven to prevent food from spoilage and inhibit the growth of pathogenic microorganisms (Carlos and Harrison, 1999).

Spice phenolic compounds are responsible for the majority of antimicrobial and antioxidant properties, these compounds confer properties that make spices useful for medicinal and preservative uses (Bozin et al., 2008). Food preservation is a main concern nowadays and most of the existing preservatives are based on synthetic chemicals. The application of some spices as preservatives in food has been evaluated in order to determine its efficiency since spices are natural sources and offer an opportunity to replace synthetic preservatives in food, such as nitrates, which have been claimed to possess negative effect on human health (Anand and Sati, 2013). Along this review, the main characteristics of spices are examined as well the chemical compounds in spices which confer several properties that lead to wide ranging applications of spices. Finally, a brief discussion is presented about the advantages and disadvantages of use of spices regarding their potential.

General description of spices

Spices are defined by Geneva International Organization for Standardization as ñvegetable products or mixtures thereof, free from extraneous matter, used for flavoring, seasoning and imparting aroma to foodsò (ISO, 1995). The spices have special properties that make them useful for several proposes, among them there are special characteristics that give them distinct features which have been given in details in **Figure 1.**

Spices include leaves as mint or rosemary flowers as clove, bulbs as garlic or onion, fruits, such as cumin or red chili, stems as cinnamon and rhizomes as ginger. Since all the spices are coming from plants they have been generally recognized as safe (GRAS). Plants synthesize, via a secondary metabolism, many compounds with complex molecular structures. Among these metabolites are found alkaloids, flavonoids, isoflavonoids, tannins, cumarins, glycosides, terpenes and phenolic compounds which confer most of the properties of spices, such as flavoring, antimicrobial activity (Ceylan and Fung, 2004), and antioxidant activity (Shobana and Akhilender, 2000; Souza et al., 2005). Spices are well known due to their medicinal (Shan et al., 2007), preservative and antioxidant (Burt, 2004) properties but they have been currently used for flavoring proposes rather than for extending shelf-life of food.

All spices are considered as different dried plant organs and they reside among different taxonomical categories that correspond to several vegetal species. The wider classification corresponds to spices that come from monocotyledoneae plants, such as garlic, ginger, turmeric and vanilla or from dicotyledoneae plants, such as paprika, pepper, nutmeg, cinnamon and clove (Spices Board, 2013). A more informal but common classification of spices refers to their sensorial properties and classify spices within their flavor intensity or aromatic properties, for example chili, pepper and ginger belonging to hot spices or cinnamon clove and cumin belonging to aromatic spices (Peter and Shylaja, 2012). Spices are defined as useful for different proposes, such as flavoring and preservation of food, these properties are due to several chemical compounds contained in spices, namely phenylpropanoids, terpenes, flavonoids and anthocyans (Sajilata and Singhal, 2012). All these compounds confer different properties to the spices such as antimicrobial and antioxidant activity that will be explained further in this review.

Chemical properties of spices

There are many properties in spices that make them unique, such astheir aroma but amongst all, their chemical characteristics allow spices to be used as preservatives in food. Due to several chemical compounds, spices present antimicrobial activity and inhibit the growth of pathogens in meat and other foods. **Table 1** presents main chemical characteristics that have been identified in several common spices.

The main components of all spices are mostly phenolic compounds, flavonoids and terpenes which are the base of the properties and uses of spices, for example eugenol and cinnamaldehyde in clove are related to their antimicrobial and antibacterial activity. However,these compounds are not exclusive from clove, cinnamon also contain cinnamaldehyde and possess the antimicrobial activity but it also contains other chemical compounds, such as pinene which confers antioxidant activity, there are a variety of phenolic compounds which possess these properties and some of them are common among spices (Chaieb et al., 2007).

Different spices provide antimicrobial activity; this is due to certain chemical compounds with the capacity to inhibit the growth of microorganisms. **Figure 2** summarizes the range of inhibition achieved by different spices. Cinnamon clove, rosemary and oregano have achieved levels of bacterial inhibition between 75% and 100% due to their chemical compounds, such as pinenes, eugenol and cinnamaldehyde (Holley and Patel 2005; Naidu, 2000; Ceylan and Fung, 2004).

Depending on the chemicals contained on each spice, several studies have been done to identify which spices have a better inhibitory effect for specific bacteria that commonly invades food in order to describe their antimicrobial properties and achieve a preservative use for foods. *Listeria monocytogenes* is one of the most common food pathogen, specifically in meat because of the favorable conditions of microbial growth. However, this microorganism does not exist in the meat as it is harmful to health. Spices, such asoregano, thymine, clove, coriander and rosemary have shown the best inhibitory effect for this microorganism. In order to use these spices as preservatives for the meat and avoid contamination by *Listeria,* further studies are needed to determine an inhibitory dose and the qualitative aspects of the final product (Burt, 2004; Du and Li, 2008; Hayouni et al., 2008). Another important bacteria that infects food is *E. coli* and among all spices that had shown a pronounced inhibitory effect for *E.coli* are clove, oregano and thyme. Mixtures of different spices have been proven against *E. coli*, such as marjoram with thyme or oregano with Jamaica pepper showing inhibitory results (Moriera et al., 2007). **Table 2** summarizes main food bacteria and the spices that present the major inhibitory effect.

Antimicrobial activity of spices depends on several factors which include the type of spices, composition and concentration of spices, microbial species and its occurrence level, the substrate composition and the processing conditions and storage. Spices stabilize foods from the microbial deterioration by making the microbial growth progressively slower and eventually totally suppressed (Souza et al., 2005).

Main applications of spices

All given properties of spices lead to numerous uses of spices now days, from coloring to flavoring spices that have been also used since ancient times. The main uses of spices are their natural colorants (Ravindran et al., 2006), flavoring, antioxidants (Shobana and Akhilender, 2000) and antimicrobials (Ceylan and Fung, 2004). The application of spices correspond mainly with the food industry, but they are also used for medicine (Shan et al., 2007), cosmetics, perfumery and nutraceuticals industry (Peter and Shylaja, 2012).

Insecticides

Some spices have been used as insecticides, as they have the potential of killing insects in several life stages. Plants have been used as botanical insecticides as long time traditions, for example neem is commonly applied to grain and act as a repellent and insecticide, pyrethrum is used in flowers to control stored products insects. These plants which possess insecticidal uses contain essential oils which have specific chemical structures that confer this insecticidal property. Sometimes, these essential oils are secondary metabolites that the plants produce for defense against herbivores or disease (Suthisut et al., 2011).

The compounds that confer insecticidal properties are mostly complex mixtures of low molecular weight, such as terpenoid compounds that give characteristic odor and flavor to leaves, flowers, fruit, seeds bark and rhizomes (Bakkali et al., 2008). Many essential oils of plants as spices are toxic to insects and act as fumigants, contact insecticides, anti-feedants or repellents. It is important to mention that these essential oils are toxic to insects but due to their low toxicity to warm blooded mammals they can be used as sources to control store products insects (Suthisut et al., 2011). **Table 3** summarizes the main insecticidal uses of spices. The use of some spices as insecticides provide an opportunity to replace the synthetic compounds from insecticides by natural alternatives which creates a sustainable market for this kind of products. Several chemical insecticides in market are claimed to have toxic compounds adverse to human health. With the use of spices as insecticidal natural products, this problem can be solved by the substitution of the synthetic compounds that have been related to harmful health effects with the main active compound of spices which are safe (Eddleston et al., 2006).

Medicine

Spices are used for different medicinal applications, such as stimulants, diuretics, carminatives, anti-inflammatory, stomachic, antibiotics, digestives, astringents, antihelminitics, expectorants and tonics, among others (Chattopadhyay et al., 2004; Platel and Srinivasan, 2004). The spices for medicinal proposes are used in different presentations as infusions, decoctions, macerations, tinctures, fluid extracts, teas, juices, syrups, poultices, oils, ointments and powders. Spices have been used since ancient times for different proposes, their essential oils are used as aromatherapy and used for depression, stress and anxiety (Peter and Shylaja, 2012).

One of the main uses of spices is the analgesic use, spices, such as coriander and peppermint due to their main chemical compounds provide an analgesic effect. Spices, such as cumin, coriander and celery have been proving to have anti-inflammatory effect (McKay and Blumberg, 2006;

Peter and Shylaja, 2012). Lately, the anti-carcinogenic activity of some spices, namely cumin and basil has been studied (Peter and Shylaja, 2012). **Figure 3** shows the medicinal uses of spices.

Spices may also be used as bioenhancers, for example, piperine in black pepper has been reported to possess bioavailability enhancing activity with various structurally and therapeutically diverse drugs (Singh et al., 2011). The use of spices is related to an increased absorption of a drug in the organism due to alteration in membrane lipid dynamics and enzymatic changes in the intestine, both of them being directly related to several chemical structures of spices (Parthasarathy et al., 2008). Medicinal applications of spices are important and the active compounds that provide these properties should be furthermore investigated to create natural based medicinal products with a variety of uses, such as analgesic or anti-inflammatory.

Colorants

The spices are used as colorants as they are natural sources of colorants bringing the advantage as against chemical or synthetic colorants. The spices tint in different colors from yellow and orange to different variations of red (except chlorophyll from herbs). The most common spices used for coloring are paprika, red pepper, mustard, parsley, ginger and turmeric (Ravindran et al., 2006).

The coloring properties of spices is due to several already mentioned chemical compounds in spices, the principal compound responsible for the color are the carotenoids, such as beta carotene, lutin and neoxanthin (Bartley and Scolnik, 1995). Other compounds that provide these coloring properties to spices are flavonoids with yellow colors, curcumin with orange and chlorophyllwith green (Ravindran et al., 2006; Peter and Shylaja, 2012). Spices provide strong color pigments commonly between orange, yellow and red, this can be advantageous since spices can be used as natural colorants especially for food. Using spices as colorants in food is natural alternative that avoid the use of conventional synthetic colorants.

Natural flavors

Flavoring food is one of the most common uses for spices, almost each spice is related to a specific flavor and they are basic for culinary proposes around the world. Depending on the region, different spices are used for flavoring foods bringing a distinguish flavor to each food style that even gives culinary identity. For example, Mexico is known for the use of flavors from cinnamon, vanilla, dried chilies and cocoa. England uses ginger, mustard seeds, cloves, coriander and allspice. France is known for different flavors in their foods, such as tarragon, savory marjoram, rosemary and thyme flavor. The Arabian Peninsula is known to use a variety of spices for flavoring proposes which include blackpeppercorn, caraway seed, whole cumin, cardamom seed, fresh hot pepper garlic and coriander (Exploratorium, 2013).

Flavors given by spices are due to the certain families of chemicals, such as phenylpropanoids, monoterpenes and other phenol compounds. Some important chemical compounds for the flavoring potential of spices are eugenol, apiol, sufranol, vanillin, piperine, beta caryophyllene, alfa pinene, carvacol, thymol, sabinene, cinnamaldehyde and gingerol (Peter and Shylaja, 2012).

Natural Antioxidants

Spices are considered as natural antioxidants for food, the antioxidants are necessary in food in order to preserve lipid components from deterioration. There are several studies that consider antioxidants as defense mechanisms in the body against cardiovascular diseases, cancer, arthiritis, asthma and diabetes. Synthetic antioxidants used nowadays in food, such as propyl gallate and hydroxyl toluene have been related to carcinogenesis promoters so that there is a strong tendency for the use of natural sources of antioxidants (Peter and Shylaja, 2012).

The antioxidant properties of spices are due to their chemical compounds especially to phenolic compounds, in fact there is a linear relationship between the phenolic content and the antioxidant activity of a spice. Essential oils, oleorosin and other spices extracts contain important antioxidant activity which can be profited by food industry (Wojdyğo et al., 2007). Among the most important spices with antioxidant properties, plants, such as lamiaceae, rosemary, oregano, thyme, sage, marjoram, basil, coriander and pimento are predominant. The most common chemical compounds that provide antioxidant properties to spices are eugenol, curcumin, gingerol, carcavol, thymol, pimento and capsaicin (Peter and Shylaja, 2012)

Preservation of food

Foods most susceptible to microbial contamination are dairy products, such as processed meat and chicken, they are a common vehicle for diseases and pathogens, among them we find *Escherichia coli, Salmonella, Listeria monocytogenes, Yersinia enterocolitica, Campylobacter jejuni, Clostridium perfringen, Staphylococcus aureus and Toxoplasma Gondi* which have been isolated from meat (Reuben et al., 2003). The meat processing industry is trying to find antimicrobial treatments to inhibit the pathogens or decontaminate their products, these

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treatments can be synthetic chemicals or antibiotics but also natural sources of antimicrobials (Hernández et al., 2011).

Optimal microbial growth occurs at pH values between 6.5 and 7 although most microorganisms continue to grow within the pH range of 4 and 9.5, for fresh meat, pH varies around 5.0 and 6.5, hence microorganisms can easily grow into the meat (Tarté, 2009). Temperature is also an important factor for microorganisms and processed meats, mesophiles replicate at temperatures between 20ºC and 40ºC, psychrotrophs have the ability to survive and slowly replicate under refrigeration, with their optimal growth occurring between 20ºC and 30ºC and for thermophiles, the optimal conditions of growth are between 55-65ºC so almost at any temperature in which food can be processed, there is a risk of contamination by one of these microorganism types (Ercolini et al., 2009).

Obtaining antimicrobials from natural sources is a good alternative for preservatives in meat products, other kinds of preservatives, such as synthetic chemicals have been claimed to cause several adverse effects and preservatives as antibiotics produce consequences, such as antibiotic resistance. Some natural antimicrobials studied in meat products include bacteriocins, lactoferrin, lysozyme species, essential oils and a variety of plant extracts. Species, such as clove cinnamon, cumin and oregano are effective against inoculated microorganisms on meat, particularly against gram positive and gram negative bacteria (Souza et al., 2006; Sema et al., 2007; Celikel and Kavas, 2008).

Cumin as preservative

Cumin (*Cuminum cyminum*) is a spice traditionally used as an antiseptic agent and it has powerful antimicrobial activity in different kinds of bacteria, pathogenic and non-pathogenic fungi for humans (Haloci et al.,2012). The cumin essential oil contains cuminaldehyde, β-pinene, *p*-cymene and γ-terpinene as major chemical compounds (Hajhashemi et al., 2004;Heinz and Varo, 1970). The main compound of the cumin essential oil is cuminaldehyde which provides the antimicrobial properties. (Hernández et al., 2011)

The alcoholic extract of cumin has been proven to present a significant inhibition of microorganisms, such as *Bacillus subtilis, Escherichia coli and Saccharomyces cerevisiae* with an outstanding antimicrobial activity for species such as *A.tumefaciens, B. subtilis, Bacillus licheniformis, Pseudomonas oleovorans, Trichophyton rubrum, S. cerevisiae and Saccharomyces pombe* (De et al., 2003).

The antifungal propierties of cumin oil have been proven in recent studies, whole cumin oil inhibit *Aspergillus flavus* and *Aspergillus niger* by over 90% when aldehyde fraction of the oil containing the antimicrobial chemical compound cuminaldehyde was tested (Balacs, 1993; Pawar and Thaker, 2006).

Clove as preservative

Clove (*Eugenia caryophyllata*) is a common spice used around the world for culinary proposes but it also poses different properties that make cloves a potential preservative. Clove essential oil main compounds are eugenol and beta caryophyllene, both compounds have antibacterial activity against *Escherichia coli, Listeria monocytogenes, Salmonella enterica, Campylobacter jejuni and Staphylococcus aureus* (Chaieb et al., 2007).

The clove essential oil has a high concentration of eugenol of around 88.58% and it has been proved to have diverse antimicrobial activity. The clove oil treatment in concentrations from 1% to 2% has shown a reduction in growth rates of *Listeria monocytogenes* strains (Mytle et al., 2006). Clove plant leaf oil has been found toinhibit *Bacillus cereus* with a MIC of 39 µg/mL (Ogunwande et al., 2005).

Sensitivity of different bacterial strains to clove essential oil have been tested andthe highest level of sensitivity was observed against five strains of *Staphylococcus epidermidis* with an inhibition zone greater than 16 mm (Chaeib et al., 2007). Clove also has fungicidal activity and their chemical compounds, such as carvacrol and eugenol are known to possess fungicidal characteristics against *Candida albicans* and *Trichophyton mentagrophytes* (Tampieri et al., 2005).

Antioxidant capacity of clove is due to eugenol as the main chemical compound. The main mechanisms of antioxidant activity are scavenging the radicals and chelating metal ions and eugenol participates in photochemical reactions displaying strong antioxidant activity (Ogata et al., 2000). Chelating potential of clove essential oil has been proven resulting in the prevention of the hydroxyl radicals due to the eugenol in clove oil (Jirovetz et al., 2006).

Cinammon as preservative

Cinnamon (*Cinnamomum verum*) is considered as a preservative because it is an effective antimicrobial and antibacterial which can inhibit bacterial growth, especially gram positive bacteria. Cinnamon oil is composed of different chemicals, amongst them the most important are cynammyldehyde, cynammyl alcohol and eugenol (Herwita and Idris, 2007).

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Antimicrobial capacity of cinnamon has been tested against *Staphylococus aureus* proving its capacity to inhibit *S.aureus* growth with an optimum inhibiting effort of 0.09% this result is mainly attributed to the chemical compound in cinnamon called cynammyldehyde (Winias et al., 2011).

Cynammyldehyde inhibition to bacterial growth can be caused by inhibition of the synthesis of cell walls, inhibition of the cell membrane function, inhibition of protein synthesis or inhibition of the synthesis of nucleic acids (Winias et al., 2011).

Black pepper as preservative

Black pepper (*Piper nigrum*) is a spice native from India and itôs volatile oil has been proven to have antimicrobial activity (Dorman and Deans, 2000).The phenolic compounds of black pepper have been claim to be responsible for the antimicrobial activity by damaging the membrane of bacteria avoiding its growth (Karsha and Lakshmi, 2010).

Analysis using GC-MS have showed that black pepper essential oil contains main chemical compounds, such aspiperine, pierolein B and piperamide. This essential oil was obtained based on acetone extraction and has proven to be effective in controlling the mycelial growth of some fungi, such as *Fusarium graminearum* and *Penicillum viridcatum* (Singh et al., 2004).

Black pepper has been proven to have antibacterial activity with reported minimum inhibitory concentrations of around 50-500 ppm demonstrating excellent inhibition on the growth of gram positive bacteria, such as *Staphylococcus aureus*, followed by *Bacillus cereus* and *Streptococcus faecalis* and also demonstrated inhibition against some gram negative bacteria, such as *Pseudomonas aeruginosa* (Karsha and Lakshmi, 2010).

Rosemary as preservative

Rosemary (*Rosmarinus officinalis*) has been shown to possess preservative properties for their use in foods since itőś antioxidant activity has been tested in pork products, such as patties (Chen et al., 1999). The antioxidant properties of rosemary have been attributed to the variety of phenolic compounds in this spice, such as carnosol, carnosic acid, rosmarinic acid, rosmanol and tosemaridiphenol (Shahidi et al., 2003).

Carnosic acid is the main compound found in rosemary followed by other phenolic compounds, such as carnosol, the rosemary chemical compounds are classified into three groups, the phenolic diterpenes related to abietic acid structure, the flavonoids and the phenolic acids (Almela et al., 2006). The main preservative properties are due to carnosic acid in rosemary, which have a high antioxidant. The antioxidant activity of this carnosic acid has been compared to the antioxidant activity of substances, such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and tertiary butyl hydroquinone (TBHQ) and the results showed that this acid has antioxidant activity higher than BHT and BHA (Steven et al., 1996).

Carnosic acid, one of the main active compounds of rosemary, has originated from isopentenyl diphosphate via methylerythritol phosphate and is located in chloroplasts and intracellular membranes as carnosol (Almela et al., 2006). The rosemary has been compared with other chemical preservatives and antioxidant compounds proving efficiency that is comparable to the curretnly used preservatives so that rosemary can be used as a natural green alternative to some chemical antioxidants with comparable results. Rosemary can be used as natural antioxidant in many foods as it does not have a strong flavor akin to the majority of spices, namely cloves, cumin and cinnamon among others. Hence, the use of rosemary as antioxidant will not damage the organoleptic properties of foods.

Ginger as preservative

Ginger (*Zingiber officinale*) is a commonly used spice that contains polyphenolic compounds, among them the 6-gingerol and its derivatives, these chemical compounds made ginger a potent antioxidant (Stoilova et al., 2007). Fresh ginger contain moisture, proteins, fats, fiber carbohydrates and some minerals like iron or calcium (Govindarajan, 1982).

Ginger CO_2 extracts have been proven to contain high polyphenol content and found to have a enhanced efficiency as an antioxidant preservative at an earlier stage of fat oxidation. The antioxidant effect of ginger is comparable to BHT, which is a chemical antioxidant, inhibiting peroxidation in the range of temperature from 37°C to 80°C (Stoilova et al., 2007).

Ginger has been shown to inhibit the multiplication of colon bacteria (Gupta and Ravishankar, 2005) and other microorganisms, such as *Escherichia coli*, *Proteus sp, Staphylococci*, *Streptococci* and *Salmonella* (Ernst and Pittler, 2000;White, 2007). Ginger also has antifungal activity against some species, such as *Aspergillus* (Nanir and Kadu, 1987).

The phenolic compounds in ginger are denaturing agents that avoid microbial growth by changing the cell permeability leading to rupture of bacterial cells. Most of the phenolic compounds are metal chelators and attach to active sites of metabolic enzymes reducing enzyme activities and bacterial metabolism and reproduction (Ho et al., 1992).

Studies have showed that ginger extracts at concentrations of 0.4 mg/ml have better antimicrobial activity than commercial antibiotics, such as Gentamicin against *Klebsiella pneumonieae*, *Proteus vulgaris*, *Streptococcus pyogenes* and *Staphylococcus aureus* (Ahmed et al., 2012). Ginger root extracts have been shown to be more effective than extracts from other parts of the plants, such as leaves and has been able to inhibit the growth of *Staphylococcu*s species with better results than common antibiotics, such aschloramphenicol, ampicillin and tetracycline (Sebiomo et al., 2011).

Curry as preservative

Curry is a traditional spice used in conventional food, the origin of curry is found in India but nowadays, it is one of the most popular spices in the world with a characteristic flavor and aroma (Sathaye et al., 2011). Curry has been shown to have an important antimicrobial activity. Antimicrobial assays of coumarin extracts performed with petroleum ether and chloroform exhibited prominent antibacterial and antifungal activity. Chloroform extract of curry showed a good inhibitory property being effective in species, such as *Aspergillus niger* and *P. aeruginosa (*Vats et al., 2011).

Curry contains a variety of carbazole alkaloids and coumarins that confer an antimicrobial activity. Minimum inhibitory concentrations of curry compounds have been found to be between the range 3.13-100µg/ml. (Rahman et al., 2005)

The antimicrobial activity of curry extracts is proportional to the concentration used and growth inhibition has been reported against species, such as *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Escherichia coli* with a less minimum inhibitory concentration (MIC) than compared to other species such as *Staphylococcus aureus* and *Micrococcus luteus*. From these studies, *E.coli* has been determined as the most resistant microorganism and higher concentrations of curry are required for its inhibition (Vats et al., 2011).

Curry has been studied as a natural antimicrobial food preservative and also as a detoxifying agent in food preservation. Curry has been proven to be an antifungal and antiaflatoxigenic (Murugan et al., 2013), these characteristics have set curry as an important natural preservative with a high potential for becoming a replacement for other types of preservatives which are not natural.

Whole spices by themselves can be used as preservatives but their essential oils can also be isolated and their properties can be determined. Essential oils from spices are homogeneous mixtures of organic chemical compounds from the same chemical family, they are composed of terpenoids, monoterpenes and sesquiterpenes. The antibacterial activity of essential oils is not attributed to a specific mechanism but to several attack mechanisms to the cell with different targets (Burt, 2004). It is known that the substances act on the cellôs cytoplamsic membrane, in several cases, the presence of a hydroxyl group is related to the deactivation of enzymes and it is probable that this group causes cell component losses, a change in fatty acids and phospholipids and prevents energy metabolism and genetic material synthesis (Di Pascua et al., 2005).

Antioxidant properties are important for conservation of processed meats. Nowadays, there are several synthetic antioxidants, such as BHA, BHT and alfa tocopherol. It has been proved that antioxidant properties from different essential oils from black pepper, clove, geranium, Melissa, nutmeg, oregano and others show superior antioxidant capacity to tocopherol analogue Trolox, between all the species proven in the trial the clove and oregano were exceptionally potent in the assay (Dorman, 2000).

In recent studies, essential oils from cumin and clove at concentrations from 500mg/L to 750 mg/L were used on meat samples at three different concentrations; 750, 1500 and 2250microliters. The cumin essential oil produced a reduction of 3.78 log UFC/g with the application of 750 microliters and the clove essential oil produced a reduction of 3.78 l of UFC/g with the application of 2,250 microliter, and the clove and cumin extracts got a reduction of 3.6 log UFC/g demonstrating the antibacterial potential of these essential oils (Hernández et al., 2011).

Advantages & Disadvantages of using spices as preservatives

Antioxidant and antimicrobial activity has been found in spices proving an important preservative activity for food but several aspects need to be studied before assuring the effectiveness of spices as preservatives. As it has been reviewed, spices have different levels of aroma and flavor but most of them are characterized as being strong. If spices are used in high quantities in order to achieve a good antioxidant or antimicrobial activity, they can interfere with the original flavor of the food and products can be not useful for market since can interfere with commercial desired characteristics for several foods.

Essential oils from spices extracts are a good alternative for preservatives in meat products but the main concern is that, when essential oils are used in meat, their antimicrobial effect is lower because high fat and protein levels contained in meat protect the bacteria from the essential oils' action, the essential oil is dissolved into the food fatty phase being less available to act against the microorganisms (Rasooli, 2007). Encapsulated rosemary essential oil has an improved antimicrobial effect than standard rosemary essential oil against *L.monocytogenes* in pork liver sausage and this is associated with the interaction of essential oils with the fatty phase of meat (Carraminana et al., 2008). Thus, higher concentration of spices might be needed to assure an antioxidant and antimicrobial activity but the strong flavor of spices can affect the flavor of meat and affect its commercial value.

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Essential oils from spices also require a process of extraction which can make the whole process more expensive and not really means a higher antimicrobial activity since for example in meat this essential oils can dissolve in the fatty phase of meat. Therefore , the use of the whole spices might be a better solution for preservation in meat and other foods since as they present less complexity, less expenses and equivalent antimicrobial activity.

Another important aspect is that spice formulation effectiveness against microorganisms differs depending on the food or media, same formulation can be effective for a type of meat and not for another. A combination of clove and oregano in broth culture showed inhibitory effect for *L.monocytogenes* but did not show the desired effect in meat slurry (Lis-Balchin et al., 2003). Different spices formulations have to be tested in vitro and in vivo in order to prove their antimicrobial effect for each type of meat.

Spices are provided from natural herbs and plants and thus do not have a synthetic origin, essential oils of cinnamon and clove and their main active chemical compound cinnamaldehyde and eugenol have been recognized as safe consumption products (GRAS) by regulatory agencies of U.S. (Raybaudi et al., 2008; Turgis et al, 2009). In contrast, nitrate and nitrite preservatives used nowadays in meat products have been found to produce carcinogenic N-nitroso compounds, such as nitrosamines and this has caused concerns about possible adverse health effects. (Assembly of Life Sciences U.S., 1982; Anand and Sati, 2013). Therefore, spices are a safe alternative for preservatives in food approved by regulation and with no adverse health effects reported.

Conclusions and future outlook

Spice uses vary from flavoring, coloring, medicinal or preservative uses and their trade is a significant economic activity in the world. The unique properties of spices have created a huge demand for several common spices around the world making the spices a niche of research and economical benefits.

Several spices have been proved to have microbial growth inhibition potential to some of the most common bacteria in food, such as *L.monocytogenes*, *E.colli and Salmonella*. Thus, it is possible to use spices as preservatives but is necessary to prove its antimicrobial effect on different foods, such as meat, poultry, dairy products, vegetables and fruit to guarantee a preservative effect comparable to the conventional synthetic preservative effect for each food prior to settle the use of spices as preservatives for industrial or commercial proposes.

Albeit, whole spices and their essential oil have proven good antimicrobial activity, but the use of the whole spice or essential oil is in debate due to the high purification costs that can be involved without necessarily having an improving efficiency in the antimicrobial or antioxidant activity. As whole spices owe this properties they can be settled as natural preservatives and adapted to the industry for this propose.

Finally, the antimicrobial and antioxidant properties of several spices such as black pepper, clove, nutmeg, turmeric, cumin, cinnamon among others leads to a research field in order to use them as preservatives in food. Spices used in foods, such as meats have a high possibility of success and potential antimicrobial activity that is comparable with the effect of nowadays used preservatives based on nitrites, which have been claimed to own negative health effects, making possible to research a way to substitute chemical based preservatives with natural based ones for food preservation.

Abbreviations

BHT-Butylated hydroxytoluene

BHA- Butylated hydroxyanisole

TBHQ- tertiary butyl hydroquinone

GRAS- Generally Recognized As Safe

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Table 1: Main chemical characteristics of common spices

Spice	Chemical profile	References
Clove ***Eugenia caryophyllata***	carvacrol, thymol, eugenol, cinnamaldehyde	Chaieb et al., 2007
Coriander ***Coriandrum sativum***	linalool ,oxygenated monoterpenes ,monoterpene hydrocarbons Coriander seed: 60%-70% linalool 20 % hydrocarbons Essential oil of leaves and fruits: 2-decenoic acid (30.8 %), E-11-tetradecenoic acid (13.4 %), capric acid (12.7 %), undecyl alcohol (6.4 %), tridecanoic acid (5.5 %), undecanoic acid (7.1 %)	Coleman and Lawrence, 1992 Leung and Foster, 1996 Guenther, 1950 Bhuiyan et al., 2009
cinammon ***Cinnamomum zeylanicum***	Leaves oil: eugenol (76.10 %), *trans*-ϐ caryophyllene (6.7 %),linalool (3.7 %), eugenol acetate (2.8 %) benzyl benzoate (1.9 %). Branches oil: linalool (10.6 %), Ŭ-pinene (9.9 %), Ŭ-phellandrene (9.2 %)	Trajano et al., 2010 Lima et al., 2005
Indan babyleaf	Linalool (50 %) is the major compound; Ŭ-	Sajilata and Singhal,

Cinnamomum tejpata	pinene, *p*-cymene, ϐ-pinene, limonene 5ï 10 %	2012
Nutmeg ***Myristica fragrans***	Nutmeg oil a-pinene, ϐb-pinene, and sabinene(77.83%) in general 76.8 % monoterpenes, 12.1 % oxygenated monoterpenes, 9.8 % phenyl propanoid ether	Mullavarapu and Ramesh, 1998 Gopalakrishnan, 1992
Origan ***origanum vulgare***	**Leaf essential oil** carvacrol (18.06 %) thymol (7.36 %), g-terpinene (5.25 %), *p*-cymene (5.02 %), limonene (4.68 %), caryophylene (4.12 %), cymene (3.56 %), ledene (3.41 %), linalool (2.47 %), Ŭ-pinene (2.15 %), g-terpineol (2.10 %), and germacrene (2.08 %).	Derwich et al., 2010
Rosemary ***Rosmarinus officinalis***	a-pinene (18.25 %), followed by camphor (6.02 %), 1.8-cineole (5.25 %), camphene (5.02 %), b-pinene (4.58 %), bornyl acetate (4.35 %), limonene (3.56 %), borneol (3.10 %), a-terpineol (2.89 %), and cymene (2.02 %)	Derwich et al., 2011

Table 2. List of bacterial strains inhibited by spices

Bacteria	Spice with inhibitory effect	Reference
Listeria monocytogenes	Nisin, Origan, thymine, origan with marjoram, thyme with sage Clove oil, coriander, eugenol, origan, rosemary	Burt, 2004 Du and Li, 2008 Hayouni al., 2008
Escherichia coli O157:H7	Clove,tea tree Origan, thymine, origan with marjoram, thyme with sage, pepper, origan with pepper	Moriera et al., 2007 Du and Li, 2008 Mosqueda-Melgar et al., 2008 Oussalah et al., 2004
B.aereus and P. aeruginosa	Origan, thymine, origan with marjoram, thyme with sage	Du and Li, 2008
Pseudomonas ssp.	Origan, pepper and origan with pepper	Mosqueda-Melgar et al., 2008 Oussalah et al., 2004
Aeromonas hydrophila	eugenol	Burt, 2004
Salmonella typhimurium	Carvacrol, citral, geraniol	Burt, 2004
Photobacterium phosphoreum	Oregano oil	Burt, 2004
Salmonella enteritidis	Mint oil	Burt, 2004

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Table 3. Use of spices as insecticides

Spice	Insects species	Reference
Cardamom	*Tetropium castaneum, Sitophilus zeamais,*	Huang et al., 2000
Cinammon	*Acanthoscelides oblectus Ceratitis capitata*	Parthasarathy et al., 2008
Nutmeg/Mace	*Toxocara canis*	Nakamura et al., 1988
Curry	*Rhizopus stolonifer Gloeosporium psidii*	Dwivedi et al., 2002

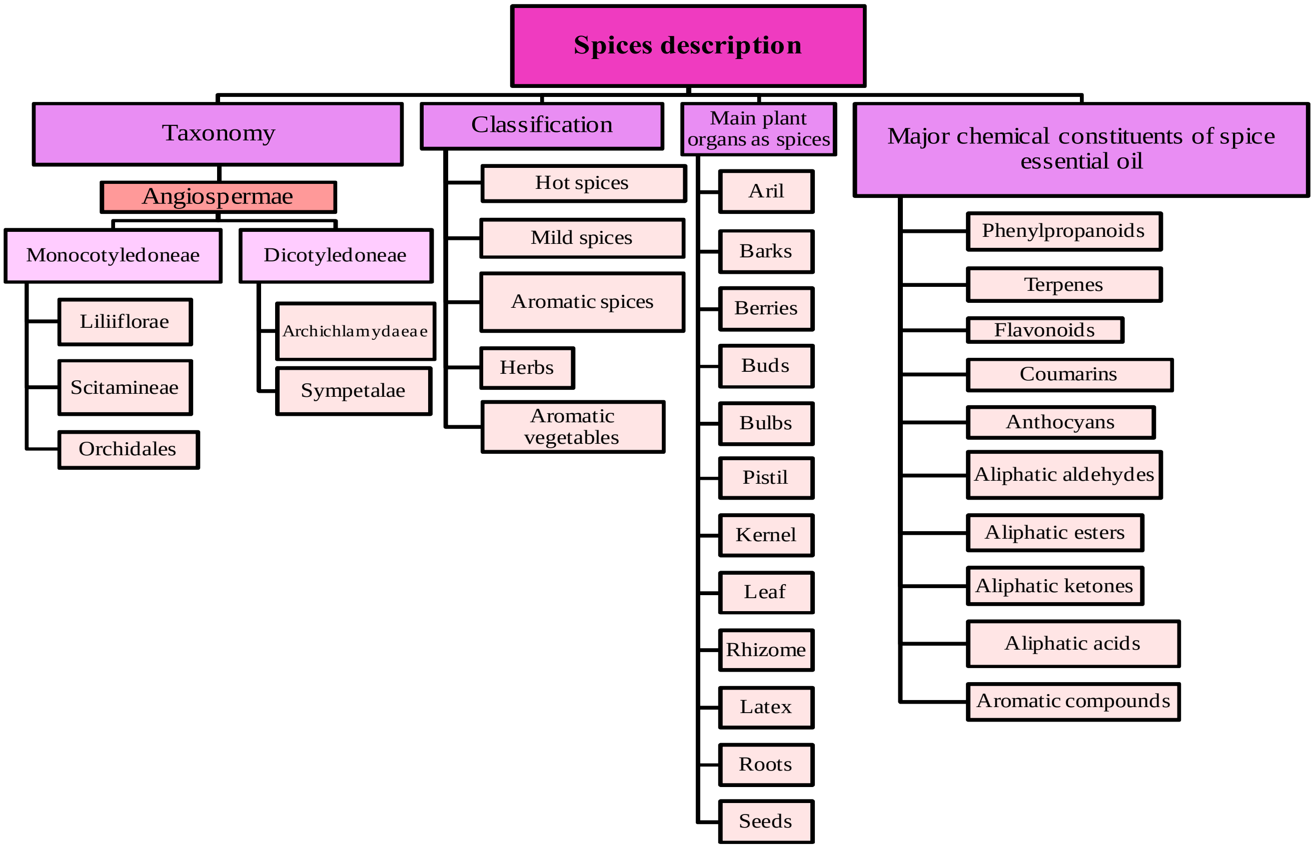

Figure 1: Spices classification (adapted from Peter and Shylaja, 2012, Sajilata and Singhal 2012)

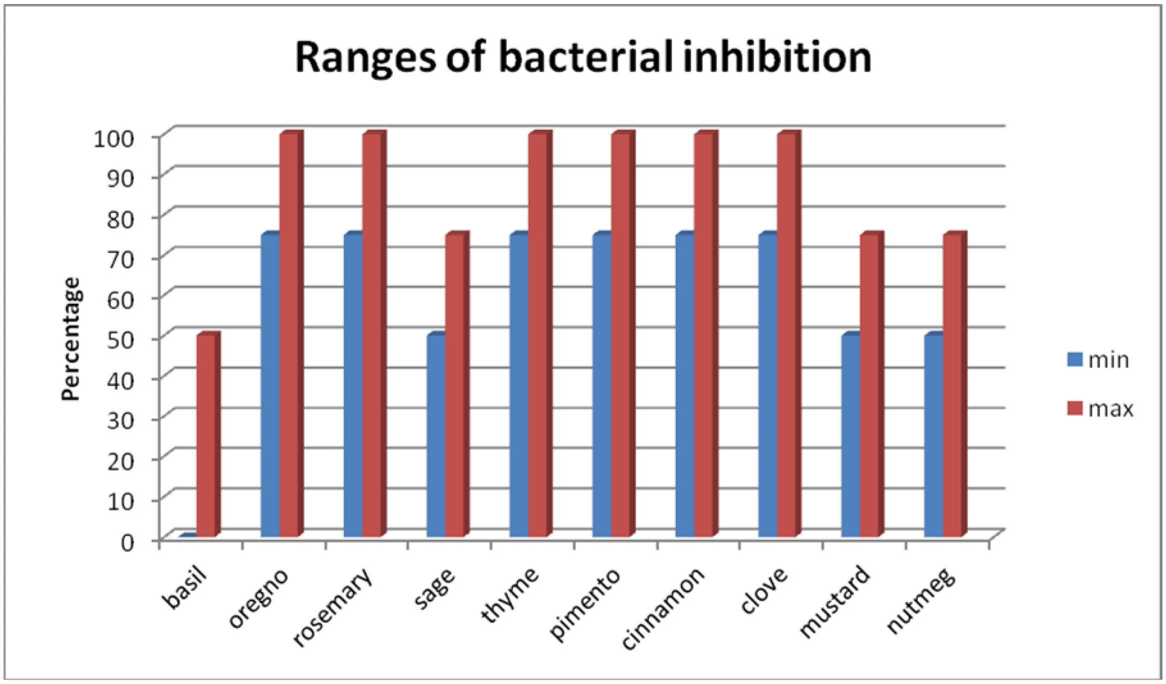

Figure 2. Ranges of bacterial inhibition data for different spices (adapted from Ceylan and Fung,2004; Holley and Patel, 2005; Naidu, 2000).

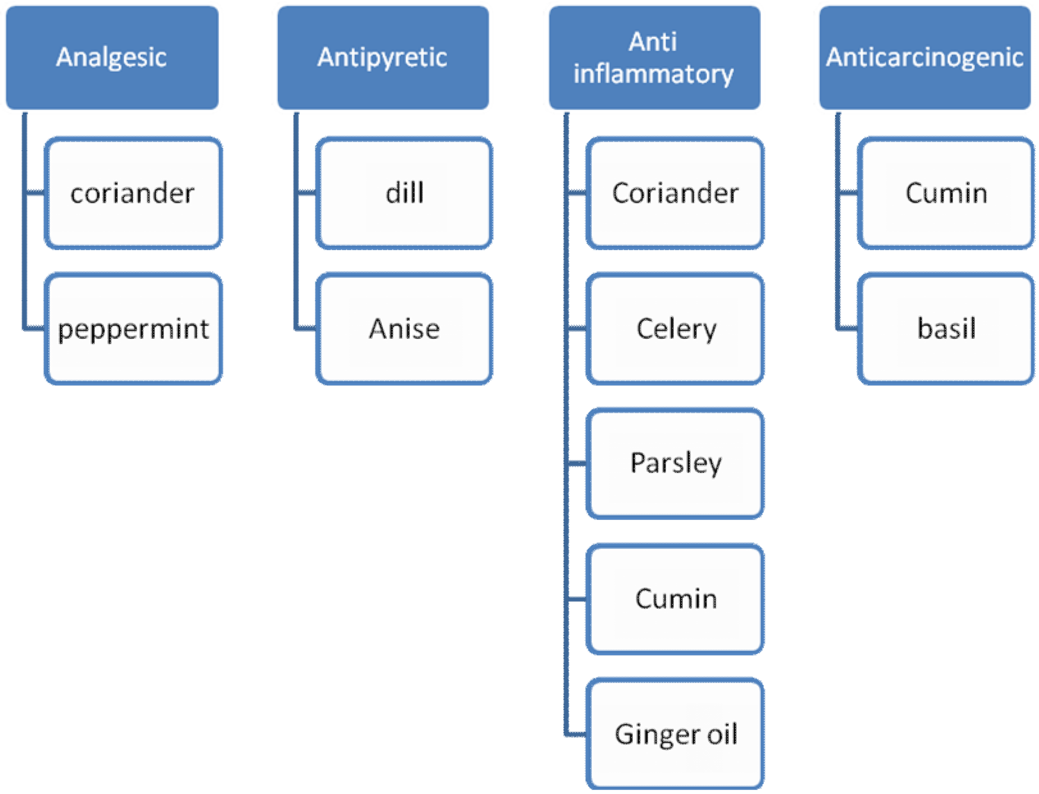

Figure 3. Main medicinal uses for several spices (modified from Peter and Shylaja, 2012)