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Bachelor Thesis

Plant-derived products with antimicrobial and antioxidant properties as potential alternatives to sulphites in food: a literature review

by

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Abstract

Sulfites are widely used preservative with antioxidant and antimicrobial properties Although, sulfites are recognized as safe (GRAS) substance for use in food products, its residues in food have been responsible of some health complications. In recent time demand for safe alternatives to sulfites increase. With aim to identify plant compounds as possible sources of safe and effective substitutes to sulfites literature data on their antimicrobial, Maillard reaction product and tyrosinase inhibitory actions have been analyzed in this thesis.

As a result 260 plant-derived products have been identified which have previously been found to possess antioxidant and/or antimicrobial properties. Inhibition concentration of all of these plant compounds are in same range or lower as sulfites. According to the result of this thesis, some of plant-derived compounds (e.g. resveratrol, luteolin) seem to be prospective for future researching this area.

Keywords: plant, enzymatic, non-enzymatic, browning, antimicrobial, sulfites

Abstrakta

Siřičitany se často používají jako konzervanty pro své antioxidační a antimikrobiální vlastnosti. Siřičitany mají statut bezpečných konzervačních látek, ale přesto mohou způsobovat řadu zdravotních komplikací. V současnosti dochází k hledání bezpečných srovnatelných siřičitanových náhrad.

Cíl této práce spočívá v identifikaci rostlinných látek, které mohou být potencionálními bezpečnými a efektivními ekvivalenty siřičitanů a které mají podobné antimikrobiální vlastnosti, inhibují produkty Maillardovy reakce a tyrosinasu.

Výsledkem této práce je zhodnocení účinnosti antioxidačních a/nebo antimikrobiálních vlastnostií 260-ti rostlinných látek.Inhibiční koncentrace těchto látek se pohybují v rozmezí stejném, jako je tomu u siřičitanů. Některé z těchto rostlinných látek mohou být použity v budoucím výzkumu.

Klíčová slova: rostliny, enzymatické, neenzymatické, hnědnutí, antimikrobiální, siřičitany

Certification

I, Veronika Čamková, declare that this thesis, submitted in partial fulfilment of the requirements for the degree of Bc, in the Faculty of Tropical AgriSciences of the Czech University of Life Sciences Prague, is wholly my own work unless otherwise referenced or acknowledged.

Veronika Čamková

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I would like to thank also to my family and friends for the emotional support and help they gave me.

Obsah

Introduction

Sulfites

History

Sulfur, as an element, is well known from the ancient times. The burning of sulfur had long time been regarded as a process of physical cleaning and spiritual purification (driving out evil spirits). From the Greek era until relatively modern times, sulfur was burned for the disinfection by its vapors. Burning of sulfur was used in places and vessels where food and drink was stored (Gould and Russell, 1991; Gould and Russell, 2003). The ancient Romans used sulfur fumes as improving agent for wine (Lück and Jager, 1997; Davidson et al., 2002). The fumes from burning sulfur contain gaseous sulfur dioxide (also spelled sulphur dioxide). Sulfur dioxide is probably the predominant form, by which sulfites take up microbial cells killing action (Gould and Russell, 1991; Gould and Russell, 2003).

The use of sulfur dioxide most likely became common practice only in the late Middle Ages (Lück and Jager, 1997).

In the centuries that followed, sulfur dioxide remained a widely used preservative for a large number of foodstuffs (Lueck, 1980; Lück and Jager, 1997). The sulfur dioxide as food preservative was first reported in the literature in the 17th century by John Evelyn (1664), English writer and diarist. He suggested that carts should be filled with cider that contained sulfur dioxide (Davidson et al., 2002). Although one of the oldest preservatives is still in use, sulfur dioxide remains essential for the production of many foods despite several side effects (Lueck, 1980; Lück and Jager, 1997).

Nowadays, the source of sulfur dioxide are dissolved salts, mainly sodium metabisulfite. Gaseous sulfur dioxide has specific field of use and his application is permitted by regulations apply to all forms of sulfites (Gould and Russell, 1991; Gould and Russell, 2003).

Source and production

Elemental sulfur in the free state can be find in some world regions as a pure element mainly in volcano regions and volcano hot springs. Sulfates and sulfites can be also found in the nature. Sulfur burns in the presence of air to obtain sulfur dioxide (Ought and Were, 2005). Sulfur dioxide (SO_2), which is under normal pressure and at room temperature a non-combustible, colorless gas with an extremely stinging odor and which is highly liquefied to yield a liquids at -10 °C (Lück and Jager, 1997, Prabharak and Reddy, 1999).

Commercially sulfur dioxide is prepared by heating sulfidic ores, or in purer form, by elemental sulfur burning. As a method of purification, either the crude sulfur dioxide is deep-frozen, whereupon pure sulfur dioxide separates out as a liquid, or else the crude sulfur dioxide is washed out with cold water then desorbed again from the solution by heating (Lueck, 1980; Lück and Jager, 1997). Direct burning of sulfur is the cheapest of all sources of sulfur dioxide and very effective method of disinfection. Grapes and cut fruits are exposed to fumes of burning sulfur before transporting or dehydration (Prabharak and Reddy, 1999). Liquid SO_2 is free from impurities and is commonly used in wineries. Accurately measured quantities can be incorporated. Storage and transportation of SO_2 requires special steel containers and it makes it a source of SO_2 costly (Prabharak and Reddy, 1999).

The anhydrous sulfites salts are prepared and produced by precipitation of the sulfur dioxide and then dehydrated with relevant hydroxide (Ought and Were, 2005). Depending on the stoichiometric condition, solutions of sulfites or bisulfite are formed. The solid sulfites are produced by evaporation (Lück and Jager, 1997; Lueck, 1980). Most of these salts are hydroscopic and easily hydrolyzed (Ough and Were, 2005).

Sulfite, metabisulfite and bisulfite are white powders, which are extensively used in food and beverages because of theirs easy applications in solutions or in dry forms (Lück and Jager, 1997). This salts are low-cost, stable and comparatively free from heavy metal impurities. Sulfites solutions are easily absorbed by fruits, which are dipped in the solution before freezing or dehydration (Prabharak and Reddy, 1999). The dry salts are easier to

store if they are kept in dry and cool environment. At the case of high relative humidity or in the moisture, caking may occur and, particularly in the case of the more acidic salts, a slow loss of sulfur dioxide may occur (Gould and Russell, 1991). Otherwise they are less of problem to handle contrary to the gaseous or liquid sulfur dioxide (Ought and Were, 2005).

Chemistry of sulfites

Contrary oxygen atom, the sulfur atom allows to be in ´hypervalent´ state due to the energies of the electrons in the outer sulfur atom orbitals – higher d-orbitals, these orbital are forming existence of six covalent bonds. This situation promotes electrons onto 3d levels and allows pd-orbital hybridization for bonding. As to bonding with oxygen, any empty d-orbitals of sulfur atom can accept electrons from p-orbitals of oxygen that are at lower energy level. Such hybridization formats wide range of oxoanions of sulfur. This complex city allows the creation great variety of different salts forms. The simple oxoaniont of sulfur in tetravalent states are salts of sulfurous acid (H_2SO_3), which is theoretically formed by the aqueous dissolution of gaseous sulfur dioxide (Gould and Russell, 1991). In comparison of infrared spectra of dissolved sulfur dioxide with gaseous or liquid sulfur dioxide have indicated that very little H_2SO_3 exist in solution. Sulfur dioxide in solution exists predominantly as hydrate $SO_2 \cdot H_2O$, or as a clathrate inside a shell of about seven water molecules (Gould, 2000).

The first dissociate, relevant in food, produces the bisulfate anion HSO_3^-:

$$SO_2 \cdot H_2O \leftrightarrow HSO_3^- + H^+$$

Bisulfites can go through the second dissociation to form sulfite anions:

$$HSO_3^- \leftrightarrow SO^{2}{}_3^- + H^+$$

Pk values of the first dissociation is 1.86 (depending on conditions), Pk value of second dissociation is 7.18. Consequently, in acid foods will be predominant mixture of hydrated sulfur dioxide ($SO_2 \cdot H_2O$) and bisulfite anionts (HSO_3^-). In neutral or in near-neutral foods will be generally sulfite ($SO^{2}{}_3^-$) and bisulfite (HSO_3^-) (Fig. 1) (Gould and Russell, 1991). The first two dissociation, which are described above occur in dilute solution is

relevant to those, which can be find in food (Gould, 2000). Only in higher concentration, bisulfites can condense and dehydrate to metabisulfite form (Gould and Russell 1991; Gould 2000). „Metabisulfite is the anhydride of the acid sulfite (Ough and Were, 2005).

$$2HSO_3^- \leftrightarrow S_2O_5^{2-} + H_2O$$

This form is significant in the context of food preservatives, because the principal generating salts is sodium and potassium metabisulfites. Sodium and potassium sulfites and bisulfites are less frequently used (Gould and Russell, 1991). On the air and at the room temperature, sulfiting salts show increasing stability in the order sulfite > bisulfite > metabisulfite (Ough and Were, 2005). Reason for the choice of these salts in because the sulfites of the other metals, which generate sulfite when dissolved in aqueous media (Gould and Russell, 1991).

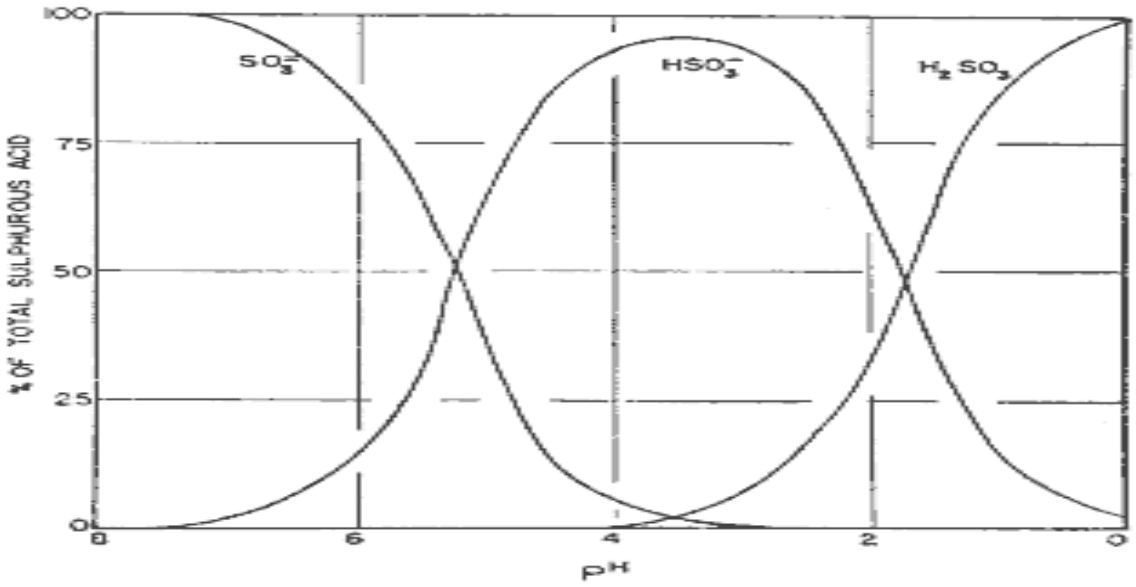

Figure 1 Distribution of the ionized forms of sulfurous acid at various pHs (source: Ough and Were, 2005)

Sulfites in foods

Sulfur dioxide is used in many foodstuff and beverages for its versatility and technological efficacy (Pizzoferrato et al., 1997). It gained popularity as a food additive owing to its apparent relatively lack of toxicity in mammals (Prabhakar and Reddy, 1999).

Sulfur dioxide with its neutral or acid salts, commonly refer as sulfiting agents (Tab. 1), sodium sulfite, potassium sulfite, sodium bisulfite, potassium bisulfite, sodium metabisulfite and potassium metabisulfite, are extensively used for control of enzymatic browning, which is caused by the activity of polyphenol oxidase (also known as tyrosinase) and non-enzymatic browning, where is inhibited the reactions between amino groups and reducing sugars. Sulfiting agents possess antimicrobial properties. Sulfites are capable to effectively inhibit growth of bacteria, yeasts and molds. Sulfites also act as antioxidants. They delay organoleptic changes like the onset of rancidity due to oxidation of compounds and other oxidative deterioration of food during storage. In addition, sulfites are used as bleaching agents, flour treatment agents, ascorbic acid and color stabilizers (Gould and Russell, 1991; Leclercq et al., 2000; Gould and Russell, 2003).

Table 1 Chemical formulas and SO_2 contents of the most important sulfites (source: Lueck, 1980; Gould and Russell, 1991; Lück and Jager, 1997)

Chemical	Formula	Content of active SO_2	Solubility in g/L at temperature specified
Sulfur dioxide	SO_2	100%	200, 20°C
Potassium sulfite	K_2SO_3	33%	250, 20°C
Sodium sulfite	Na_2SO_3	50.8%	280, 40°C
Potassium bisulfite	$KHSO_3$	53.3%	1000, 20°C
Sodium bisulfite	$NaHSO_3$	61.6%	3000, 20°C
Potassium metabisulfite	$K_2S_2O_5$	67.4%	250, 0°C
Sodium metabisulfite	$Na_2S_2O_5$	57.7%	540, 20°C

Sulfur dioxide in used preferably for preserving food intended for futher processing (Lück and Jager, 1997). In food industry the major utilization (Tab. 2) of sulfiting agents is on dried fruits and vegetables to prevent undesirable darken with inhibit oxidation, on lobsters and shrims to prevent melanosis, or "black spot", in alcoholic and non-alcoholic beverages, particularly in wines to inhibit spoilage bacterial growth, to bleach certain food and in dough as a conditioner (Pizzoferrato et al., 1997). A small number of application are in meat and fish products. Sulfur dioxide restores a bright color, but gives a false impression of freshness (Davidson, 2002).

Sulfites extend shelf life products by slow growth of microorganism (Gould and Russell, 1991; Gould and Russell, 2003). However, many of food dyes, like anthocyanins in natural plant foods, are not stable to sulfites and can be partially bleached (Gould and Russell, 1991). Sulfites are also use rarely in foods recognizable as source of thiamine-vitamin B1 (Jay et al., 2005). Sulfites destroy thiamine by breaking open the bond between the pyrimidine and the thiazole portion of the molecule (Lueck, 1980; Lück and Jager, 1997). In addition, sulfites are used in pharmaceutical industry to maintain the potency and stability of some medications (Pundir and Rawal, 2013).

The sulfite salts all share the ability to generate molecular SO_2. For this reason are sulfites treatments levels for the various salts in foods normally quoted as parts per million (ppm) or mg/kg SO_2 (Gould and Russell, 2003). However, it is not usual to make use of sulfur dioxide itself, except in application such as fumigation or during drying of some cut fruits, but the use SO_2-generating salts (Gould and Russell, 1991; Gould and Russell, 2003).

Table 2 Summary of major applications of sulfites in foods and levels of use (source: Gould, 2000)

Foods*	Typical Use Concentrations (as SO_2 $mg \cdot kg^{-1}$)	Major purpose**
Fresh vegetables (onion, garlic, horseradish pulp	50 - 1000	c, m
Frozen vegetables (white vegetables, mushrooms	50	c
Dried vegetables	250 - 2500	c, o

Canned vegetables	20 - 200	c
Pickles	20 - 100	c, o
Peeled potatoes	20 - 100	c
Potato powders and flakes	100 - 500	c
Frozen potatoes	100	c
Fresh fruits	100	c, m
Dried fruits	100 - 2000	c, o
Fruits pulps, purees and fillings	50 - 500	c, m
Fruit juices	10 - 100	c, m
Jams and jellies	50 - 100	c, m
Fruit-based sauces and related products	50 - 100	m
Sugar confectionary	50	c, m
Nonalcoholic beverages	20 - 200	m
Alcoholic beverages		
beers	10 - 30	m
wines	100 - 300	m
Vinegar	50 - 200	m
Sausage meat, burgers and other meat products	450	c, m
Dried or salted fish	350 - 1000	c, o
Raw and frozen crustaceans	30 - 350	c, o
* Food uses and allowed concentrations vary greatly in different countries. ** m: antimicrobial; c: color retention; o: antioxidant		

Mechanism of action

The main reason for the reactivity of sulfites in food is the nucleophilicity of the sulfite ion (Wedzicha, 1992). The chemical reactivity of sulfites results from its strong reducing activity and its ability to take part in nucleophilic attack (Gould, 2000). Sulfite anion posses a lone pair of electrons and so act as Lewis base. (Because this compound has ability to accommodate 3d-electrones in its outer electron shell, it can act as Lewis acid.) Thus sulfites have the ability to produce range of reactive intermediates. The chemical versatility makes the sulfites anionts not only reactive, but capable to forming bonds with a very wide range of other compounds and functional grouping (Gould and Russell, 1991). The sulfiting agents act mostly by the interfering with chemical or enzymatic changes

(Gould and Russell, 1991). It is generally due to the nucleophilicity of the sulfite ion that may react by addition to carbonyl group, carbon-carbon double bond, heterocyclic nitrogen compounds, quinones or by cleaving disulfite bonds (Tab. 3). Sulfites are chemically equivalent compounds in foods since they are converted to the same ionic or nonionic species at a given pH, ionic strength and no electrolyte concentration (Pizzoferrato et al., 1997). Intracellular pH of microorganism is close to the neutral or low–pH. Therefore, sulfites and bisulfites are formed intracellular (even if the species that enter in cellular is SO_2 (Gould and Russell, 1991).

The reactions that are most important in sulfits antimicrobial activity include those with carbonyl groups, because they occurs aldehydes and ketones, which are present in many critical biological molecule including proteins and some enzyme cofactors (Gould, 2000). Glucose is far the most abundant of the reactive aldehydes and ketones. The rate of formation ant the amount of sulfonate formed depended on the concentration of the reactive substances, the pH and the temperature. These factors limit the effective use of the added sulfites (Ough and Were, 2005).

Table 3 Some examples of organic reactions of sulfite (source: Gould, 2000)

Reactive group	**Biological source**
Carbonyl	Aldehydes and ketones
Disulfite bonds	Proteins and glutatione
Schiff ´s bases	Enzymes / cofactors
Pyridines	NAD^+ , $NADP^+$
Pirimidines	DNA , RNA
Quinones	Electron carriers
Carbon - carbon double bonds	Fatty acids, enzyme cofactors

Sulfur dioxide is very reactive with other component in foodstuff (Gould, 2000**),** but in comparison with some other widely-used preservatives are sulfites relatively unstable in foods. Level of sulfur dioxide decrease considerably during storage (Prahbarak and Reddy, 1997). Sulfites may oxidize to the ineffective sulfates. It occurs in no hermetically

conditions (Gould, 2000). These forms do not posses either antimicrobial or antioxidant properties or any of the other sulfites properties (Gould and Russell., 1991). Sulfites also can react with the molecular component to form products, which again do not retain the functionality of the free sulfite (Gould and Russell, 1991). Reactions products are formed through reversible and irreversible reactions in foods, which are treated by sulfur dioxide. Sulfur dioxide (SO_2) and the potassium and sodium salts of sulfite (=SO_3), metabisulfite (=S_2O_5) and bisulfite (-HSO_3) all appear to act similarly (Jay et al., 2005). The amount interaction products vary in different foods depending on the processing and storage conditions (Prabharak and Reddy, 1999).

Antimicrobial activity

Sulfurous acid and its salts belong to the preservatives with a powerful antimicrobial action (Lueck, 1980; Lück and Jager, 1997). Sulfites are effective against bacteria, yeasts and molds. Bacteria are more sensitive than are yeasts and molds (Ough and Were, 2005; Davidson, 2002). Molecular mechanism of sulfites react with many critical components of cell (Tab. 4) for inhibit or inactive growth of microorganism (Gould, 2000). The antimicrobial action of sulfites is based essentially on various forms of interference in the enzyme structure of the cell. Sulfites inhibit enzymes with SH groups (Lueck, 1980; Lück and Jager, 1997). As written above, sulfur dioxide is highly soluble in water and forms sulfurous acid which dissociates into bisulfate or sulfite depending on pH (Prabharak and Reddy, 1999). The predominant ionic species of sulfurous acid depends on pH milieu. SO_2 is favored by pH3.0, HSO_3^- by pH between 3.0 and 5.0 and $SO^2{}_3^-$ by pH >= 6.0. (Jay et al., 2005). The inhibitory effect of sulfites is most pronounced when the acid (H_2SO_3) or $SO_2 \cdot H_2O$ is in the undissociated form (Davidson, 2002). In different food, pH can range below 3 or near to neutrality. However, within cytoplasm of bacteria homeostatic mechanism operate to maintain a near-constant internal pH that is commonly near 6.5. (Gould, 2000). At higher pH values like more than 7.0, sulfites do not appear to have significant inhibitory action. In general, the antimicrobial action of sulfur dioxide is more effective in foodstuff with acidic pH. Two to four times as much sulfur dioxide is required to control growth of bacteria at pH 3.5 compared with pH 2.5 (Prabharak and Reddy, 1999).

Table 4 Sulfite-sensitive metabolic systems in microorganisms (source: Gould, 2000)

Metabolic system	**Components Affected**
Intermediary metabolism	Enzymes, cofactors, prosthetic groups
Energy production	Enzymes, cofactors, electron carriers
Protein synthesis	Synthetized proteins, enzymes, nucleic acids
DND replication	Enzymes, nucleic acids
Membrane functions	Transport proteins, lipids

The major use of sulfites as antimicrobial agents is in beverages and fruits. There are three main groups of interest of interest

1) acetic acid-producing and lactic-acid producing bacteria,
2) spoilage and fermentation yeasts
3) fruits molds (Ough and Were, 2005).

Sulfur dioxide is essential in the production of wine, because otherwise the fermentation by product acetaldehyde would give the wine undesirable flavor and odor (Lück and Jager, 1997). Sulfites are more effective against growth of gram-negative bacteria, than against gram-positive rods of bacteria (Davidson, 2002). Gram positive rods of bacteria common in acid fruits and beverages are the lactic acid producing genera Lactobacillus, Pediococcus, Leuconostoc and Oenococcus. Levels about 120 ml/L of sulfur dioxide decrease incidence of these bacteria. Gram negative aerobic rod Acetobacter is effectively inhibit in concentration up to 100 mg/L of sulfur dioxide for red wines, grape juices and soft drinks (Ough and Were, 2005). Salmonellae and other Enterobacteriaceae were inhibiting on concentration of 600 mg/L. Yeasts are inhibited in lower concentrations of SO_2. The inhibitory concentration range is 0.2-20.2 mg/L for Saccharomyces, Candida and Pichia. Zygosaccharomyces is more tolerant to SO_2. For inhibition Zygosaccharomyces fruit drinks is required up to 230 mg/L at pH 3.1 (Jay et al., 2005).

Botrytis species is probably the most prevalent fungi, which infect fruits. Other originators of molds are Aspergillus, Alternaria, Cladospirium, Pennicillium, Rhizopus and others. 30-220 mg/L of sulfur dioxide can inhibit molds growth, depending on the strain (Lueck, 1980).

Owing to its good antimicrobial activity, sulfites are frequently combined with the sorbic acid and benzoic acid, which have more of the antifungal active. This improves antimicrobial spectrum of both groups of preservatives (Lueck, 1980; Lück and Jager, 1997).

Tyrosinase inhibition and enzymatic browning

Enzymatic browning results from the action of a group of enzymes namely tyrosinase enzyme (Loizzo et al., 2012). The nomenclature for the enzymes distinguishes between tyrosinase (EC 1.14.18.1.[1]; monophenol oxidase), which initiates browning reaction and later involves catechol oxidase (EC 1.10.3. [1]; otherwise known as polyphenol oxidase and diphenol oxidase) (Martinez and Whitaker, 1994; Mayer, 2006). The term tyrosinase refers to its typical substrate, tyrosine (Chang, 2009; Loizzo et al., 2012). In this thesis will be used term tyrosinase.

Tyrosinase was firstly detected in mushrooms (Sanchez-Ferrer et al., 1995). It is a copper-containing enzyme widely occurs in many higher plants, microorganism, fungi and animal tissue (Eskin et al., 1990; Martinez and Whitaker, 1995). The enzyme is primary responsible for enzymatic browning in food and beverages. In mammals tyrosinase catalyzes the first two steps of melanogenesis (Chang, 2009; Loizzo et al., 2012; Yu et al., 2013). Originate melanins determine the color of mammalian skin and hair (Parvez et al., 2007) and have important function in the protection against skin photo carcinogenesis (Seo et al., 2003). Melanins shield from various types of ionizing radiations, including UV light.

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[1] *According to the Nomenclature Committee of the International Union of Biochemistry and Molecular Biology (NC-IUBMB)*

Malanins occur in two basic types: phaeomelanins, which are yellow or red and eumelanins, which are black or brown (Parvez et al., 2007).

In insect, tyrosinase is one of the key enzymes in the molting process and wound healing (Likhitwitayawuid, 2008). It was suggested, that the use of tyrosinase inhibitors can act as alternative insecticide control agents (Loizzo et al., 2012).

Enzymatic browning takes place in the presence of oxygen when tyrosinase and its polyphenol substrates are mixed after rupture of cell structure i.e. by crushing operation, brushing, peeling or when the issue is exposed to any abnormal conditions (Eskin, 1990; Kim and Uyama, 2005; Loizzo et al., 2012). The rate of tyrosinase activity depends mainly on the concentration of phenolic substrates, oxygen availability, pH and temperature (Zheng et al., 2008; Loizzo et al., 2012).

Plants tyrosinase have broad substrates specificities and are able to oxidize a variety of mono, di or polyphenols. Phenolic compounds are natural substances that contribute to the sensorial properties (color, taste, aroma and texture) associated with fruit quality (Quieroz et al., 2008).

This enzyme catalyzes both the o-hydroxylation of monophenols and the two-electron oxidation of o-diphenols to o-quinones (Fig. 1). The latter is much more rapid than the former, thus, the hydroxylation of tyrosine to 3,4-dihydroxyphenylalanine (L-DOPA) is considered to be the rate-determining step (Kim and Uyama, 2005). This reaction is followed by non-enzymatic polymerization of the quinones giving rise to melanins, pigments of high molecular mass and dark color (Quieroz et al., 2008).

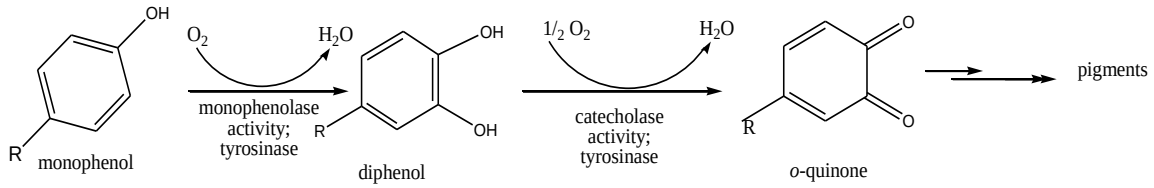

Fig. 1 The oxidation of phenols, catalyzed by tyrosinase (source: Sapers, 2002)

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It is estimated that over 50% of losses in fruits occur as a result of enzymatic browning and tropical and subtropical fruits and vegetables are the most susceptible to these reactions (Quieroz et al., 2008). For the food industry is enzymatic browning major problem, especially for vegetables, fruits and seafood's products (Loizzo et al., 2012). These undesirable reactions run in damaged and bruising fruits during post-harvest handling, processing and storage (Parvez et al., 2007). Enzymatic browning (Activity of tyrosinase) beget decrease quality of plant-derived products with loss of nutritional quality, undesirable appearance, color changes and off-flavor degeneration (Billaud et al., 2003; Zheng et al., 2008). In some cases the process of browning can get better sensory properties of some foods like fermented tea leaves, raisins and cacao (Martinez and Whitaker, 1995; Loizzo et al., 2012).

The production of abnormal melanin pigmentation is a serious esthetic problem in human beings (Parvez et al., 2007). Inhibition of tyrosinase plays an influential role in food medicinal and cosmetic industry (Yang et al., 2012). Tyrosinase inhibitors may be clinically useful for the treatment of skin cancer and some dermatological disorders associated with melanin hyperpigmentation and are important in cosmetics for whitening and depigmentation after sunburn (Shaheen et al., 2005).

Since enzymatic browning reduces nutritional and sensory qualities, several techniques and mechanism have been developed to control or inhibit tyrosinase activity. The mechanism, act on one or more of the essential components necessary for the reaction to occur: enzyme, oxygen, copper or substrate (Quieiroz et al., 2008).

A number of methods have been proposed for inhibiting tyrosinase activity, but only a few can we use in food materials. In generally, inhibitors of tyrosinase can be divided into four groups, based on their action – denaturation of enzyme proteins, exclusion of reactants (such oxygen), interaction with the copper prosthetic group and interaction with phenolic substrates or quinones (Eskin 1990).

Thermal processing is the most widely used method for stabilizing foods. In general, exposure of tyrosinase to temperatures of 70-90 °C destroy their catalytic activity. The time required to inactivation depends on the exact product. Another benefit of this processing is destroy effect on the microorganism. Water blanching can be disadvantageous because it results in losses in color, flavor, texture, vitamins and carbohydrates and other water-soluble components (Quieroz et al., 2008). The simplest method of controlling enzymatic

activity of tyrosinase is exclusion of oxygen. Is used immersing of the peeled products (such a potato) in water prior to cooking, to limit oxygen (Eskin, 1990).

Further very effective method for inactive enzyme is high hydrostatic pressure (HHP). This treatment is expected to be less determining that thermal process. For fruit and vegetables products offers the chance of producing food of high quality, greater safety and increase shelf life. The best results for decrease tyrosinase activity were found at pressure higher than 400 MPa. Other method frequently use in foods are Gamma Irradiation. γ rays are similar to light but with much higher energy. Irradiations extend shelf life and guarantees complete disinfection, delay senescence and ripening process. Last method of foods treatment hold promise to reduce tyrosinase is use of Pulses electric field. Foods in the chamber containing two electrodes apply high voltage pulses in order of 20-80 kV for microseconds. These electro pulses also lead to electroporation – inactivation of microbial cells (Queiroz et al., 2008).

The application of acids to inhibition enzymatic browning in used extensively. This principle in based on the fact, that lowering pH of tissues will inhibit enzymatic browning (Eskin, 1990). The most widespread agents used for browning control are sulfites. Due to adverse health effects is its application strictly regulated (Quieroz et al., 2008). Sodium sulfite by itself or in combination with citric acid is commercially used to inhibit enzymatic browning (Eskin, 1990). Ascorbic acid has been used as an antibrowning agent for more than five decades and is still extensively used as alternative to sulfites (Sapers, 2002). This vitamins act as an antioxidant because it reduced the quinone produced before it undergoes secondary reactions, that lead to browning and also contributes to decreasing pH (Quieroz et al., 2008). Other alternative to sulfites and sulfur-containing compound is cystein. It reacts with o-quinones intermediates to produce stable and colorless products (Quieroz et al., 2008). Cystein also directly inhibits the enzyme (Saper, 2002). Also kojic acid has been considered as alternatives to sulfites. Mechanism of inhibition action is the same like with ascorbic acid. Kojic acid reduces quinones to polyphenols (Sapers, 2002). Other frequently use inhibitors are 4-hydroxyresorcinol, β-cyclodextrin, sodium chloride, cinnamic acid (Eskin, 1990; Quieroz et al., 2008).

Plants are a rich source of biological chemicals, which are mostly free from harmful side effects, so there is a effort to search for tyrosinase inhibitors of them (Seo 2003; Parvez et al., 2007). A number of tyrosinase inhibitors from natural sources, like polyphenols, gallic

acid derivates from green tea, aldehydes and others, have been discovered and identified especially in the last decade (Chang, 2009).

Inhibition of Maillard reaction products and non-enzymatic browning

The Maillard reaction is named in honor of Luis-Camille Maillard, a French chemist whose first describe and published the non-enzymatic browning reaction in 1912 (Coghe, 2004). He described proteins sugar mixture browning in hot solution (glucose and lysin). Maillard reaction (also known as glycation) is a general term used for the complex of non-enzymatic reactions subsequent to the reaction between reducing sugar (simple monosaccharides glucose, fructose and the disaccharide maltose) and amino compounds (predominantly the ε-amino group of lysine and the guanidine group of arginine) without catalytic actions of enzymes (Obšil and Pavliček, 1997; Coghe, 2004). The first one, who integrate complex sequence of nonenzymatic reactions (Fig. 2) was American chemist John Hodge (1953) (Coghe, 2004) and subsequently reviewed by Ellis (1959), Heyns and Paulsen (1960). In spite of a huge volume of research on this reaction, the original reaction scheme proposed by Hodge is still valid. The products of the Maillard reaction are wide of range. In food chemistry these products lead to a darkening of color, reduced solubility of proteins, development of bitter flavors and reduced nutritional availability of certain amino acids such as lysine (Eskin., 1990). The rate of this reaction is influenced by the water activity, temperature and pH of the food product (Coghe, 2004).

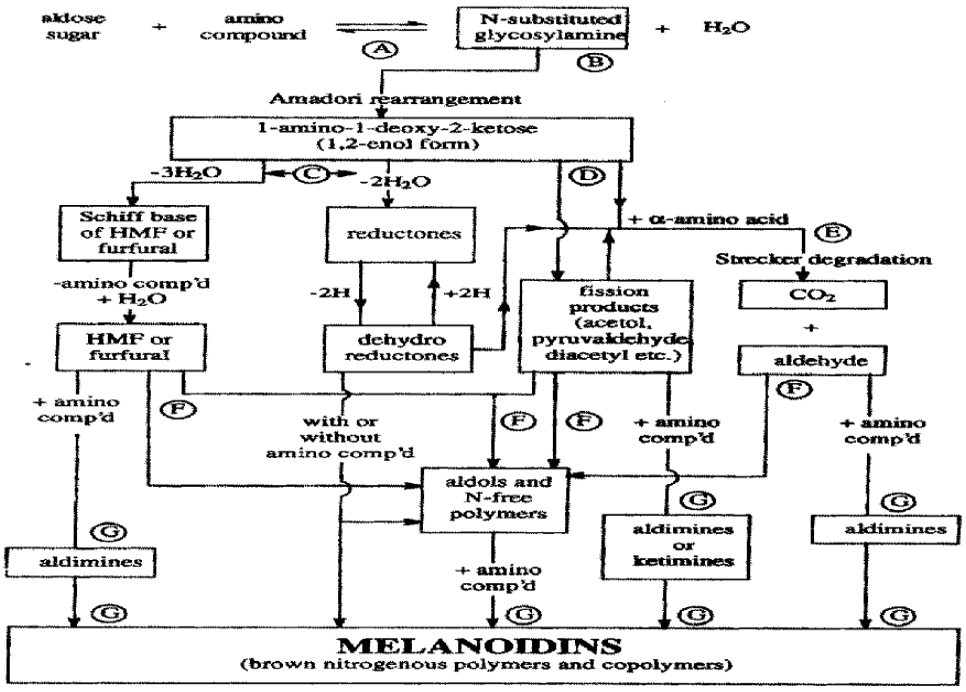
Maillard reaction is subdivided into three main stages: early, intermediate, and late. In the early stage, glucose (or other reducing sugars such as fructose, pentoses, galactose, mannose, xylulose) react with a free amino group of biological amines, to form an unstable aldimine compound, the Shiff base. Then through acid-base catalysis, this labile compound undergoes a rearrangement to a more stable early glycation product known as Amadori product (Neglia et al., 1983).

In the intermediate stage, *via* dehydratation, oxidation and other chemical reactions, the Amadori product degrades to a variety of reactive dicarbonyl compounds such as glyoxal, methylglyoxal and deoxyglucosones which, being much more reactive than the initial sugars, act as propagators of the reaction, again reacting with free amino groups of

biomolecules. In the late stage of the glycation process through oxidation, dehydratation and cyclization reactions, irreversible compounds, called advanced glycation end products (AGEs) are formed. The AGEs are yellow-brown, often fluorescent and insoluble adducts that accumulate on long-lived proteins thus compromising their physiological functions (Lapolla et al., 2005).

Nowadays non enzymatic browning reaction, which was earlier investigated only for food browning (Obšil and Pavliček, 1997; Ames, 1998) associated with heated and stored products, now take a part also as a problem in glycation of Western diet (Delgado-Andrade el. al., 2007) and connection with ability to prevent AGEs formation in medicine (Lee et al., 2006). Glycation of proteins can interfere with their normal functions by disrupting molecular conformation, altering enzymatic activity, reducing degradation capacity, and interfering with receptor recognition. Some plants important compounds such as phenolics (Yang, 2009), oligosaccharides and polysaccharides (Meng et al., 2011), carotenoids and unsaturated fatty acids (Sun et al., 2010) posses anti-glycation activity. Green tea consumption, the coffee consumption which is rich in phenolic compounds have high anti-glycation activity (Huang et al., 2008).

Figure 2 Outline of different Maillard reaction pathways (source: Cohge, 2004-from Hodge, 1953)



Inhibition of nonenzymatic browning in foods is major problem of food technologies. Minimize nonenzymatic browning effect in food processing is very important to each food must be adapted the particular method. There are many ways to inhibit nonenzymatic browning. Refrigeration is effective, since browning has a high-temperature coefficient, the rate increasing 3-6 times with a 10 °C rise in temperature. Most foods will not brown below -10°C during normal storage for up to a year (Labuza and Shapiro, 1978). Dehydration can be effective in preventing browning (Loncin et al., 1968; Eichner and Karel,1972; Fox et al.,1983). However, the rate of browning often exhibits a maximum with a moisture content of 5-30%. Partial dehydration may take browning worse rather than better (Nurtsen, 2005). Lowering the pH is useful up to a point (Fox et al.,1983). If the system contains ascorbic acid, then any measures taken to conserve vitamin C will help to prevent initiation of nonenzymatic browning by its oxidation. Other method excludes oxygen by packing under inert gas, This reduces formation of lipid oxidation products which can interfere with amino acids (Saper, 2002).

The direct applications of enzymes such as glucose oxidase and catalase mediate the conversion glucose to gluconic acid. This enzyme is in use many years to remove glucose from egg prior to spray–drying (Lightbody and Fevold,1948). Sulfur dioxide is frequently used as a gas or in solution. Increased concentrations increase the time lag before browning starts. Chemically, the obvious explanation for the use of sulfur dioxide is its reversible combinations with carbonyl intermediates of the browning reaction, but the substances that have been identified show that the situation is considerably more complex (McWeeny, 1975). Alternative to sulfite are aspartic and glutamic acids. A study by Nafisi and Markakis (1983) indicated the potential of aspartic and glutamic acids for inhibiting the Maillard browning reaction. Dipping specially prepared potato chips into either aspartic or glutamic acid solutions prior to frying was accompanied by less darkening Ascorbic acid has been used as an antibrowning agent for more than five decades and is still the most widely used alternative to sulfiting agents. Tressler and DuBois (1944) and Esselen et al. (1945) investigated that added ascorbic acid or its isomer to syrups or dips to control browning of fresh sliced and frozen apples and peaches. More recently, Sapers et al. (1990) reported that the "water-logging" effects seen in vacuum-infiltrated fresh apples could be avoided by infiltrating ascorbate solutions under pressure (Sapers et al. 1990).

Nowadays a big attention is given to the antiglycation capacity of numerous medicinal herbs and dietary plant‘s compounds. Except polyphenols which constitute a major group of plant derived compounds with anti-glycation activity, some amino acids (Huang et al.2008), triterpens and saponins (Wang et al.,2010) polysacharids and oligosacharides (Wang et al., 2009) were shown to decrease the AGEs activity. Plant-derived agents with anti-glycation activity are believed to have positive influence to major pathogenic reactions in many human metabolic disorders. Especially in metabolic diseases such as diabetes mellitus and its complications. The anti-glycation activity correlates with the phenolic content of the plant extract. The plant derived anti-glycation compounds are attractive candidates not only for antibrowning food nonenzymatic action, but mainly they are considered by new mode of treatment of such diseases as: diabetes mellitus, other metabolic diseases (Odjakova et al., 2012).

Effect on human health

Sulfur dioxide and sulfites are permitted in virtually all countries as food preservatives, especially for the treatment of plant products and wine (Lück and Jager, 1997). Sulfites are generally recognized as safe (GRAS) substance for use in food products by international bodies such as the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the European Community´s Scientific Committee for Food (SCF). Sulfites are included in *Codex Alimentarius. Codex Alimentarius* is a collection of international adopted food standards, which have been evaluated by the JECFA (Míková, 2001). However sulfites are recognized as safe, its residues in food have been responsible of some medical complications (Sapers, 2002). Human reactions to sulfites vary widely. Sulfite can induce asthmatic attacks, urticaria, genuine allergies and pseudo allergic reactions in humans. The worst complication can be life threatening as fatal anaphylactic reaction (Taylor et al., 1986; Sapers 2002). Sulfites are frequently accompanied by an intolerance reaction to acetyl salicylic acid (Lück and Jager, 1997). Depending on the sensitivity of the subject, they may be induced by 2 to 250 mg of sulfur dioxide. Asthmatics who are steroid-dependent or who have higher degree of airway hyper reactivity may be at greater risk of experiencing a reaction to sulfites containing foods. Sulfites reactions vary widely, ranging

from no reaction to severe. The majorities of reactions are mild and may include respiratory, dermatologic or gastrointestinal symptoms (Lester, 1995). This has led to more restricted and careful use (Gould, 2000). Whereas a number of persons can tolerate up to 4g (some 50 mg/kg) daily without adverse effects (Lück and Jager, 1997). The maximum permissible quantities vary according to the type of food. In the case of food for direct consumption, quantity seldom exceed 100 mg/kg (Lück and Jager, 1997). Maximum levels range from 15 mg/kg to 2000 mg/kg of sulfur dioxide. If the SO_2 content is no more than 10 mg/kg (or 10 mg/l) it is not considered to be present (Mikova, 2001). Regarding the toxicity of ingested sulfites, the World Health Organization (WHO) determined the acceptable daily intake (ADI) of sulfur dioxide in foodstuff. It has been established on 0.7 mg/kg of body weight (Queiroz et al., 2008). But the allowed levels vary in different countries (Gould, 2000; Míková, 2001).

For these reason foods containing sulfites should be labeled accordingly (Lück and Jager, 1997). The International Numbering System for Food Additives (INS) has been prepared by the Codex Committee on Food Additives and Contaminants for the purpose of providing an agreed international numbering system for identifying food additives. ISN for sulfites are 220-228 (Mikova et al., 2001).

Alternatives of preservatives and antioxidants in foods

Sulfites has been long time approved as very effective food preservation by vary ways of action. But heterogeneous substances in human organism, sulfites possess some adverse effects. Sulfites residues in foods have been responsible sometimes for mild or severe allergic reactions in susceptible individuals, especially skin or digestion allergy (Taylor et al., 1986). As a result, there has been a considerable focus on identifying appropriate sulfites substitutes use in foods. The food industry is seeking for source of natural antioxidants and antimicrobials to replace synthetic preservatives due to their potential toxicological effects (Loizzo et al., 2012). Also uncontrolled use of chemical antimicrobial preservatives has been inducing factor for appearance of microbial strains more and more resistant to classic antimicrobials preservatives (Leite de Souza et al., 2005). Thus, most of

the recent investigations have been targeted towards identification of novel preservatives and antioxidants from natural sources, which are free of any harmful side effects (Míková, 2001; Loizzo et al., 2012). Naturally occurring antimicrobial and antioxidant compounds can be applied directly to food to protect food quality, extent food shelf life by inhibiting or inactivating spoilage microorganisms, and improved food safety by inhibiting or inactivating food-borne pathogens. A number of natural preservatives and antioxidants are derived from animals, plants and microbial sources (Davidson et al, 2013). Due to the high phenolic compound content, plant materials provide good alternatives to conventional preservatives. Although there are many compounds that have been proposed to posses antioxidant properties to inhibit oxidative deterioration, only a few can be used in food products (Karre et al., 2013).

One of the alternatives to chemical preservatives are bacteriocins. Naturally occurring compounds with antimicrobial properties. Bacteriocins are antimicrobial peptides produced by a large number of bacteria, including lactic acid bacteria. These peptides are used for biopreservation, antimicrobial action, shelf life extension and for control of microflora (Balciunas et al., 2013). Among these substances nisin belongs. Nisin is an antibacterial peptide produced from Lactococcus lactis bacteria. Natamycin, also known as pimaricin, is produced by *Streptomyces natalensis*. This substance is active against yeasts and molds (Giese, 1994). Lysosyme is an enzyme occurs in milk and eggs. He effectively inhibits *Listeria monocytogenes, Campylobacter jejuni, Salmonella typhimurium*, *Baccilus cereus* and *Clostridium botulinum* (Chung et al., 1991). Naturally occurring compound use for preventing contamination and growth of microorganism in foods are organic acids. Benzoinic, sorbic, propionic acetic, citric and lactic acids are normally used in food industry to inhibit undesirable bacteria (Chung, 1991; Giese, 1994). Other big groups of naturally occurring preservatives form edible medical and herbs plants and their derived essential oils. Many derived compounds form spices and herbs have intensively been studied for their inhibitory effect against pathogenic bacteria (Leuner, 2011). Plants essential oil component are used in food not only like antimicrobial agent but also as flavoring agent. Typical example is Allium species. Garlic, cumin oregano, thyme and others are used for the same purpose (Chung, 1991; Leuner 2011). In recent time, rosemary and rosemary extracts are one of the most natural antioxidants used in meat and poultry products. Grape seed extracts, extracts form plums, cranberries, pomegranates,

bearberries, green tea and pine barks extracts act like antioxidant and antimicrobial agents. All these compounds are extensively studied due to their high phenolic compound content provide to be a good alternative to conventional antioxidants (Karre et al., 2013).

Hypothesis

Since there is an evidence of plant-derived compounds with antimicrobial and antioxidant properties, it is possible to suppose,that a systematic search of literature focused on plant secondary metabolites, previously found to be effective against tyrosinase, Maillard reaction products and against bacteria, yeasts and molds in laboratory experiments, could lead to identification of compounds prospective for a further, more detailed, evaluation of antimicrobials and antioxidant properties to set up alternatives to sulfites.

Objectives

The aim of this thesis is plant compounds identification with antioxidant and antimicrobial properties in literature. The data obtained as result of this thesis could be used for further research focused on development of new plant-derived food preservation to sulfites in foods.

Materials and Methods

The information in this thesis has been gathered using data from scientific databases, mainly in the form of scientific periodicals and papers. The database used were: Web of Science (via Web of Knowledge) from their inception until April 2013. Systematic literature review was also performed using relevant textbooks and bibliographies. The following keywords were used for searching: plant, antioxidant, antimicrobial, tyrosinase, polyphenol oxidase, Maillard reaction, glycation, enzymatic, non-enzymatic, *Acetobacter*, *Lactobacillus*, *Saccharomyces*, *Zygosaccharomyces*, *Botrytis*, *Aspergillus* and inhibition.

Results and discussion

As a result of this thesis, 260 plant-derived products, that have previously been found to possess either antioxidant or antimicrobial properties, were identified. 58 plant compounds possess polyvalent inhibition efficiency. The data about these plant-derived products are summarized in Table 1. 137 plant compounds, mentioned in Table 2 are able effectively inhibit only enzymatic browning, which is caused by tyrosinase enzyme. In addition, 62 compounds that have capability to inhibit Maillard reaction products and thus non-enzymatic browning are shown in Table 3. Both antimicrobial and antioxidant (tyrosinase and Maillard reaction products) effects are expressed as half-maximal inhibitory concentration (IC_{50}) and minimum inhibitory concentration (MIC) values, all converted to micromolar concentrations.

For identification of the most promising plant compounds, their effectiveness was compared with inhibition activity of sulfating agents. Inhibition concentrations of sulfites are shown in Table 1. Their effectiveness is expressed as an interval that was set from the lowest and the highest concentration, in which sulfating agent (sulfur dioxide, sodium sulfite, potassium sulfite, sodium metabisulfite, potassium metabisulfite, sodium bisulfite and potassium bisulfite) impacts tyrosinase activity, Maillard reaction product, *Acetobacter* spp., *Lactobacillus* spp., *Saccharomyces* spp., *Zygosaccharomyces* spp., *Botrytis* spp. and *Aspergillus* spp. growth. Sulfiting agents were tested in various type of assays. That the reason why I composed different values in intervals.

All plant compounds mentioned in Tables 1-3 possess equal or strongest inhibition effect than sulfites, whereas resveratrol and luteolin exhibited the widest range of antimicrobial and antioxidant action. Resveratrol effectively inhibits tyrosinase in range from 7.20 to 54.60 μM and all targeted microorganisms in the range from 546.25 to 2243.25 μM. However, there are no data on its ability to inhibit Maillard reaction products in the literature. Since resveratrol exhibited previously promising sulfites-like effect, and because of its well-known antioxidant, anticancer and anti-inflammatory properties (Du et al., 2013), this compound seems to be very promising agent for substitution of sulfites in

foods. However, its ability to inhibit Maillard reaction products should be evaluated to confirm this substance as effective substituent of broad spectrum activity of sulfites.

Luteolin effectively inhibits tyrosinase in range from 190.00 to 480.00 μM. Maillard reactions product were inhibit in range from 99.00 to 258.00 μM. All targeted microorganisms in the range from 894.35 to 1788.71 μM. However, there are no data on its ability to inhibit *Lactobacillus spp., Botrytis spp. and Aspergillus spp*. in the literature. Since luteolin exhibited previously promising sulfites-like effects, this compound seems to be very promising agent for substitution of sulfites in foods. However, its ability to inhibit *Lactobacillus spp.* should be evaluated to confirm this substance as effective substituent of broad spectrum activity of sulfites. According to recent research luteolin act like a free radical scavenger, antioxidant and may inhibit a cancer mechanism (Jackson et al., 2009).

It was found number of plants compounds which possess inhibition activity against tyrosinase and equally against Maillard reactions products. These compounds could be use in products, where sulfites are used only for its antioxidant actions. These properties in different inhibition concentration have quercitrin, quercetin, kaempferol, isovitexin, chlorogenic acid, oxyresveratrol, phloridzin, baicilein and others (Table 1).

11 plant-derived products, namely artocarpesin, glabridin, glyasperin C, hinokitiol, isoartocarpesin, kurarinol, kuraridiol morancin N, mulberroside F, norartocapreninand, steppogenin exhibited the strongest inhibitory activity against tyrosinase. Their concentrations were lower than 1 μM.

Artocarpesin, isoartocarpesin, norartocarpesin and steppogenin was isolated from *Artocarpus heterophylus*, a tree (mainly grown in the tropical and subtropical regions, which have been used in traditional folk medicine in Indonesia against inflammation and malarial fever (Zheng et al., 2008). Gylasperin C is a phenolic constituens of *Glycyrrhiza uralensis* (family Fabaceae). Mulberroside F and moracin N was isolated from *Morus alba* (family Moraceae). Kurarinol and kuraridiol were isolated from *Sophora flavescenc.* Glabridin was isolated from *Glycyrrhiza glabra* (family Fabaceae).
According to my best knowledge, there is no report on toxicological or other negative health effects of these plants in the literature. According to its very strong inhibition concentration this compound can be used for further laboratory research.

Compound with inhibition concentration in range of 1-10 μM is phlorotannin Dieckol. It occurs in *Ecconia cava* and *E. stolonifera*, showed effective inhibition activity of tyrosinase and also showed significantly higher intracellular radical scavenging activity (Yotsu-Yamashita et al., 2013) and thus can we supposed health benefits for human being.
A number of plant compounds with strong inhibition activity under 10 μM were mentioned The most effective are 8-Epi-cleomiscosin A, Norartocarpanone, Kushenol F, Norkurarinol, Moracin C Artocarbene, Fukugetin, Lyoniresinol, Sophoraflavanone G, Mirkoin, Peonidin, Panduratin A, Furanocoumarin and Campesterol. These compounds can be used for further research.
However antityrosinase of these compound are known, its antimicrobial effect on Acetobacter spp., Lactobacillus spp, Saccharomyces spp., Zygosaccharomyces spp, Botrytis spp., Aspergillus spp. was not mentioned.

In case of Maillard reaction product (Table 2) was found only 2 plants compounds with inhibition concentration of Maillard reaction products under 1 μM. Puerariafuran and coumestrol occurs in *Pueraria lobata* (family Fabaceae). Coumestrol is widespread in legume plants. Plantagoside occurs in family Plantaginaceae, is very effective inhibitor of Maillard reactions products. Compounds with inhibition activity in range from 1 to 10 μM are polyphenol Cyanidin-3-O- galactoside and hyperin. Hyperoside is occurs in *Artemisia capillaris* (family Asteraceae). Also can be extracted from *Rumex acetosella, Camptotheca acuminata, Drosera rotundifolia* and from other plants.

The most numbers of plants compound with Maillard reaction inhibition properties is in concentration higher than 10 μM. Inhibition of the rest of plant coumpounds is about 100 μM. In generall, higher concentration of plant compounds are needed to inhibition Maillard reaction products than tyrosinase concentration inhibition.

Some of the above-mentioned compounds effectively inhibiting Maillard reaction product formation or tyrosinase activity could be used as substituent of antioxidant action of sulfites, for example in shrimps and prawns are sulfites used only for inhibition of browning (Gould, 2000).

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	Antioxidant activity IC_{50}* [µM]		Antimicrobial activity MIC** [µM]					
			Bacteria		Yeast		Mold	
	Tyrosinase inhibition	Maillard reaction inhibition	Acetobacter spp.	Lactobacillus spp.	Saccharomyces spp.	Zygosaccharomyces spp.	Botrytis spp.	Aspergillus spp.
Sulfites	**100.00 - 10000.00 (Eskin, 1990; Davidson et al., 2002; Edhin et al., 2008; Gao et al., 2011)**	**100.00 - 31218.00 (Lehman and Ortwerth, 2001; Davidson et al., 2002; Kwak and Lim, 2005; Oliviera et al., 2011)**	**780.00 - 4606.00 (Ough and Were, 2005; Jay et al., 2005; Pastorkova et al., 2013)**	**15.60 - 2411.00 (Lueck, 1980; Surekha and Reddy, 1999; Davidson et al., 2002; Ough and Were, 2005; Ruiz et al., 2011)**	**1.60 - 2500.00 (Lueck 1980; Surekha and Reddy, 1999; Gould, 2000; Davidson et al, 2002; Jay et al., 2005; Ough and Were, 2005)**	**112.40 - 4606.00 (Lueck, 1980; Davidson et al, 2002; Jay et al., 2005; Ough and Were, 2005; Martorell et al., 2007; Pastorkova et al., 2013)**	**1561.00 - 31218.00 (Davidson et al., 2002)**	**1561.00 - 3434.00 (Lueck, 1980; Surekha and Reddy, 1999; Davidson et al., 2002)**
Amentoflavone	not found	50.00 (Ferchichi et al., 2012)	nm	not found	9.29 (Jung et al., 2006)	not found	not found	not found
Baicalein	273.00 (Gao et al., 2007)	93.00 (Matsuda et al., 2003)	not found	not found	not found	not found	not found	not found
Butein	29.30 (Nerya et al., 2004)	210.30 (Lee et al., 2008)	not found	not found	not found	not found	not found	not found
Caffeic acid	not found	7.56 - 47.13 (Jang et al., 2008; Jung et al., 2012)	not found	1665.19 - 2220.25 (Garcıa-Ruiz et al., 2009)	not found	not found	not found	1110.12 (Aziz et al., 1998)

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Catechin	IC_{50} > 100.00 (Cheng et al., 2007)	5.00- 13.60 (Saito et al., 2004; Jang et al., 2009)	not found	IC_{50} < 861.30 (Parkar et al., 2008)	no significancy (Muthuswamy et al., 2007)	not found	616.32 (Mendoza et al., 2013)	not found
Cinnamic acid	2100.00 (Shi et al., 2005)	1748.00 (Shimoda et al., 2011)	not found	no significance (Landete et al., 2008)	not found	910.00 - 3050.00 (Martorell et al., 2007)	not found	not found
Daidzein	200.00-240.00 (Chang et al., 2005; Loizzo et al., 2012)	47.20 (Yang et al., 2006)	not found	3933.45 (Parkar et al., 2008)	not found	not found	not found	not found
Dihydro-5,6-dehydrokawain (DDK)	1085.73 (Chompoo et al., 2012)	842.53 (Chompoo et al., 2011)	not found	not found	not found	not found	not found	not found
EC (epicatechin)	not found	24.00- 125.20 (Saito et al., 2004; Jang et al., 2009)	not found	no significance (Hervert-Hernández et al., 2009; Ruiz et al., 2011)	not found	not found	716.50 (Mendoza et al., 2013)	not found
EGCG	34.00- 34.10 (No et al., 1999; Kim et al., 2005)	200 (Matsuda et al., 2003)	not found	no significance (Chae et al., 1999)	not found	not found	not found	not found

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Ellagic acid	not found	26.0 (Kim et al., 2008)	not found	no significance (Garcia-Ruiz et al., 2011)	205.16 (Silva et al., 2010)	not found	1290.55 (Mendoza et al., 2013)	IC_{50} > 3309.10 (Silva et al., 2010)
Esculetin	43.00 (Masamoto et al., 2002)	5.02 (Jung et al., 2012)	not found	not found	not found	not found	not found	not found
Esculin	43.00 (Sollai et al., 2008)	0.85 (Jung et al., 2012)	not found	not found	not found	not found	not found	not found
Ferulic acid	150.00 (Gong et al., 2005)	323.43 (Jung et al., 2012)	2636.73 (Pastorkova et al., 2013)	no significance (Ruiz et al., 2011)	2636.73 (Pastorkova et al., 2013)	1287.47 - 2636.73 (Lee et al., 2005; Pastorkova et al., 2013)	not found	not found
GA (gallic acid)	3.59 (Kim 2007)	82.06 - 401.70 (Sultana et al., 2009)	not found	1763.46 (Garcıa-Ruiz et al., 2009)	not found	not found	1862.80 (Mendoza et al., 2013)	IC_{50} > 4000.00 (Jermnak et al., 2012)

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
(+)-GCG	17.00 - 17.34 (No et al., 1999; Nerya, 2003)	13.60 - 28.75 (Jang et al., 2009; Beaulieu et al., 2010) - 64.5 (Yagi et al., 2013)	2181.64 (Peres et al., 1997)	no significance (Ruiz et al., 2011)	not found	not found	not found	not found
Genistein	300.00 - 820.00 (Chang et al., 2005; Zheng et al., 2013)	260.00 (Yang et al., 2006)	not found	3700.41 (Parkar et al., 2008)	not found	not found	not found	no significancy (Yoon et al., 2006)
Hesperetin	11250.00 (Si et al., 2012)	not found	not found	827.08 (Dudak-Chodak, 2012)	IC_{50} > 3308.30 (Mandalari et al., 2007)	not found	not found	no significancy (Salas et al., 2011)
Hesperidin	16080.00 (Zhang et al., 2007; Lou et al., 2012)	not found	not found	no significance (Dudak-Chodak, 2012)	not found	not found	not found	no significancy (Salas et al., 2011)

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Chlorogenic acid	IC_{50} < 28.22 (Akihisa et al., 2013)	2.00 - 21.08 (Ferchichi et al., 2012; Jung et al., 2012)	not found	no significance (Muthuswamy et al., 2007); ≤ 705.60 (Parkar et al., 2008)	not found	not found	not found	not found
Isovitexin	12951.57 (Yao et al., 2012)	85.20 (Kim et al., 2008)	not found	not found	not found	not found	not found	not found
Kaempferol	7.15 - 42.00 (Lim et al., 2006; Yang et al., 2012)	73.37 - 74.41 (Jung et al., 2011; Shimoda et al., 2011)	not found	17.47 (Garcia-Ruiz et al., 2008) (Garcıa-Ruiz et al., 2009)	not found	not found	352.51 (Mendoza et al., 2013)	not found
Kurarinone	1.40 - 5.00 (Ryu et al., 2007; Seo et al., 2003)	not found	not found	not found	IC_{50} > 136.82 (Sohn et al., 2004)	not found	not found	not found
Kuwanon C	49.20 (Lee et al., 2004)	not found	not found	not found	no significancy (Sohn et al., 2004)	not found	not found	not found
Labdadiene	1722.00 (Chompoo et al., 2012)	309.96 (Chompoo et al., 2011)	not found	not found	not found	not found	not found	not found

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Luteolin	190.00 - 480.80 (Kim et al., 2005; Zheng et al., 2008)	99.00 (Matsuda et al., 2003)	894. 35 (Pastorkova et al., 2013)	not found	1788.71 (Pastorkova et al., 2013)	894.35 - 1788.71 (Pastorkova et al., 2013)	not found	not found
Morin	720.00 (Xie at al., 2003)	not found	not found	3.31-674.97 (Garcıa-Ruiz et al., 2009; Garcia-Ruiz et al., 2011)	not found	not found	not found	not found
Myricetin	not found	199.00 (Matsuda et al., 2003)	804.44 - 1608.87 (Pastorkova et al., 2013)	no significancy (Figueiredo et al., 2008)	no significancy (Pastorkova et al., 2013)	1608.87 (Pastorkova et al., 2013)	not found	not found
Naringenin	IC_{50} >500.00 (Zheng et al., 2013)	not found	not found	215.32 - 430.63 (Parkar et al., 2008; Dudak-Chodak, 2012)	IC_{50} > 1722.53 (Mandalari et al., 2007)	not found	not found	not found
Naringin	1900.00 (Lou et al., 2012 , Itoh et al., 2009)	not found	not found	no significancy (Dudak-Chodak, 2012)	IC_{50} > 1722.53 (Mandalari et al., 2007)	not found	not found	IC_{50} > 250.00 (Salas et al., 2011)

Compounds	**Antioxidant activity IC_{50}* [µM]**	37 **Antimicrobial activity MIC** [µM]**

	Tyrosinase inhibition	Maillard reaction inhibition	Bacteria		Yeast		Mold	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Neohesperidin	not found	not found	not found	not found	IC_{50} > 1632.44 (Mandalari et al., 2007)	not found	not found	250.00 (Salas et al., 2011)
Nobiletin	46.20 (Sasaki and Yoshizaki, 2002)	not found	not found	not found	not found	not found	not found	0.80 (Liu et al., 2012)
Oxyresveratrol	1.20 - 7.80 (Shi et al., 1998; Kim et al., 2002; Liang et al., 2012)	8.31 (Povichit et al., 2010)	not found	not found	not found	not found	not found	not found
P-coumaric acid	2.30- 3.65 (Mai ? Nguyen ? et al., 2012; Parvey et al., 2007: Lim et al., 1999)	no significance (Beaulieu et al., 2010)	3188. 90 (Pastorkova et al., 2013)	7675.44 (Garcia-Ruiz et al., 2011)	no significancy (Pastorkova et al., 2013)	no significancy (Pastorkova et al., 2013)	583.58 (Mendoza et al., 2013)	1827.49 (Aziz et al., 1998)
Phloridzin	110 (Wang et al., 2007)	2500.00 (Dugé de Bernonville et al., 2010)	not found	no significance (Muthuswany et al., 2007)	not found	not found	not found	not found

Table 1: Antioxidant and Antimicrobial inhibition

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Piceatannol	1.50 (Yokozawa et al., 2007)	not found	not found	not found	not found	not found	not found	89.19 (Bavaresco et al., 2003)
Protocatechuic acid	IC_{50} > 500.00 (Zheng et al., 2013)	61.90-125.40 (Jang et al., 2008; Yagi et al., 2013)	not found	no significance (Landete et al., 2008)	not found	not found	2487.67 (Mendoza et al., 2013)	1946.54 (Aziz et al., 1998)
Quercetin	0.52- 70.00 (Yang et al., 2012; Ho Jeong and Shui 2004; Kubo et al., 2000)	4.78 (Ferchichi et al., 2012; Beaulieu et al., 2010)	not found	66.17 - 165.43 (Dudak-Chodak, 2012)	not found	not found	399.69 (Mendoza et al., 2013)	992.60 (Aziz et al., 1998)
Quercitrin	83.18 (Loizzo et al., 2012; Ko et al., 2011)	25.2 (Jang et al., 2008)	not found	not found	not found	not found	not found	not found
Resorcinol	145.10 (Sakuma et al., 1999)	not found	not found	not found	not found	not found	not found	not found

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Resveratrol	7.20-54.60 (Kim et al., 2002; Khatib et al., 2005; Yanagihara et al., 2012)	not found	1121.63 (Pastorkova et al., 2013)	547.67 (Garcia-Ruiz et al., 2008)	1121.63 (Pastorkova et al., 2013)	1121.63 - 2243.25 (Pastorkova et al., 2013)	IC_{50} < 701.00 (Adrian et al., 1997)	IC_{50} < 96.39 (Filip et al., 2003)
Rutin	not found	70.00 - 162.00 (Matsuda et al., 2003; Yagi et al., 2013)	not found	not found	not found	not found	not found	57.33 (Pereira et al., 2008)
Sanggenon D	7.30 (Lee et al., 2004)	not found	not found	not found	35.28 (Sohn et al., 2004)	not found	not found	not found
Scopoletin	not found	3.90 (Jung et al., 2012)	not found	not found	not found	not found	not found	2602.00 (Kwon et al., 2002)
Sophoflavescenol	100.00 (Lee et al., 2004)	48.56 (Jung et al., 2011)	not found	not found	not found	not found	not found	not found

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Syringic acid	no significancy (Wang et al., 2011)	not found	not found	no significance (Landete et al., 2008)	no significance (Zaldivar and Ingram, 1999)	not found	823.03 (Mendoza et al., 2013)	1513.85 (Aziz et al., 1998)
Tannic acid	22.00 (Kubo et al., 2003)	not found	not found	181.6 (Chung et al., 1998)	not found	not found	not found	not found
Trans-resveratrol	not found	not found	not found	547.67 (Garcıa-Ruiz et al., 2009)	not found	not found	not found	1314.41 (Bavaresco et al., 2003)
Umbelliferone	420.00 (Fais et al., 2009; Matos et al., 2011)	2.95 (Jung et al., 2012)	not found	not found	not found	not found	6167.51-6659.66 (Bai et al., 2012; Zhao et al., 2012)	not found
Vanillic acid	174.40 (Wang et al., 2011)	93.93 (Yoo et al., 2010)	not found	no significance (Landete et al., 2008)	not found	not found	1233.50 (Mendoza et al., 2013)	1189.48 (Aziz et al., 1998)

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
Vanillin	not found	IC_{50} > 1000.00 (Yagi et al., 2013)	not found	no significance(Fitzgerald et al., 2004)	no significanceFitzgerald et al., 2003)	no significance (Fitzgerald et al., 2003)	not found	8544.20 (Lopez-Malo et al., 2002)
Vitexin	14570.52 (Yao et al., 2012)	IC_{50} < 100000.00 (Peng et al., 2008)	not found	not found	not found	not found	not found	not found
3,5-Dicaffeoylquinic acid	90.00 (Iwai et al., 2004)	not found	not found	not found	not found	not found	not found	> 1099.83 (Pereira et al., 2008)
4,5-Dicaffeoylquinic acid	90.00 (Iwai et al., 2004)	6.48 (Jung et al., 2012)	not found	not found	not found	not found	not found	not found
4-Hydroxycinnamic acid	500.00 (Shi et al., 2005)	not found	not found	670.08	no significance (Cho et al., 1998)	not found	not found	not found

Table 1: Antioxidant and Antimicrobial inhibition

Compounds	**Antioxidant activity IC_{50}* [µM]**		**Antimicrobial activity MIC** [µM]**					
	Tyrosinase inhibition	**Maillard reaction inhibition**	**Bacteria**		**Yeast**		**Mold**	
			Acetobacter spp.	**Lactobacillus spp.**	**Saccharomyces spp.**	**Zygosaccharomyces spp.**	**Botrytis spp.**	**Aspergillus spp.**
4-Chlorosalicylic	1100.00-1890.00 (Han et al., 2008)	not found	not found	not found	not found	not found	not found	2897.37 (Han et al., 2008)
5,6-dehydrokawain (DK)	350.66 (Chompoo et al., 2012)	69.69 (Chompoo et al., 2011)	not found	not found	not found	not found	not found	not found

*IC_{50} -constant to determine extent of inhibition, which indicate ś the inhibitor concentration required for 50% inhibition

**MIC- minimum inhibitory concentration, which marks the concentration above which no growth is observed by comparison with the positive control

Table 2: Tyrosinase inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Tyrosinase inhibition**	**Compound**	**Tyrosinase inhibition**
Acetacin	774.00 (Roh et al., 2004)	Broussoflavonol F	388.60 (Zheng et al., 2008)
xAloesin	100.00 (Jin et al., 1999) 253.55 - 275.41 (Seo et al., 2003; Wu et al., 2012)	Broussochalcone A	421.50 (Zheng et al., 2008)
Anacardic acid	100.00 (Parvez et al.,2007)	Bryoamaride	85.00 (Khan et al., 2006)
Andalasin A	39.00 (Likhitwitayawuid and Sritulak, 2001)	Campesterol	8.90 (Sabudak et al., 2006)
Anemonin	43.40 (Huang et al., 2008)	Carpachromene	94.38 (Zheng et al., 2008)
Aquillochin	15.69 (Ahmad et al., 2004)	Cyanidin	27.10 - 45.00 (Tsuda and Osaka, 1997; Hanamura et al., 2008)
Arbutin	40.00 (Parvez et al.,2007; Maeda et al., 2007)	cis-p-Coumaric acid	197.90 (Wang et al., 2011)
Artocarbene	2.45 (Khatib et al., 2005)	Cleomiscosin A	18.69 (Ahmad et al., 2004)
Artocarpanone	81.00 (Arung et al., 2006)	Cudraflavone B	166.65 (Zheng et al., 2008)
Artocarpanone	1.54 - 81.00 (Shimizu et al., 1996; Arung et al., 2006; Zheng et al., 2008)	Cuminaldehyd	50.00 (Parvez et al., 2007)
Artocarpesin	0.53 (Zheng et al., 2008)	Cyanidin 3-O-β-D-glukosid (C3G)	40.30 (Tsuda and Osaka, 1997)
Artocarpfuranol	47.92 (Zheng et al., 2008)	cyanidin-3-α-O-rhamnoside	40.00 (Hanamura et al., 2008)
Artogomezianol	68.00 (Likhitwitayawuid and Sritulak, 2001)	Cycloorbicoside G	54.60 (Khan et al., 2006)
Askendoside B	13.95 (Khan et al., 2006)	Cyclosieversioside F	95.00 (Khan et al., 2006)
Askendoside D	49.00 (Khan et al., 2006)	Daidzin	270.00 (Loizzo et al., 2012)
Brosimone I	60.80 (Zhenh et al., 2008)	Delfinidin 3-O-β-D-glukosid (D3G)	46.20 (Tsuda and Osaka, 1997)

Table 2: Tyrosinase inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Tyrosinase inhibition**	**Compound**	**Tyrosinase inhibition**
Delphinidin	25.40 - 57.40 (Tsuda and Osaka, 1997; Hanamura et al., 2008)	Furanocoumarin, 8-hydroxy-5-methoxypsoralen,	8.60 (Piao, 2009)
Dieckol	2.90 - 20.00 (Kang et al., 2004; Casanola-Martin et al., 2007; Kang et al., 2012; Loizzo et al., 2012)	Galangin	101.00 (Xie at al., 2003)
Dihydromorin	10.35 (Zheng et al., 2008; Loizzo et al., 2012)	GB-2a	26.00 (Masuda et al., 2004)
DPPacid	3.20 (Parvez et al., 2007)	Genistin	33-340.00 (Kim et al., 2010; Loizzo et al., 2012)
ECG	17.00- 34.58 (No et al., 1999; Kim et al., 2005)	Glabrene	3.50 (Nerya et al., 2003; Nerya et al., 2006)
EGC	350.00 (Kim et al., 2005)	Glabridin	0.77 (Kim et al., 2005) 0.09 - 18.58 (Nerya et al., 2006; Jirawattanapong et al., 2009)
Eckol	34.02 (Kang et al., 2004; Casanola-Martin et al., 2007)	Glyasperin C	0.36 (Kim et al., 2005)
Eckostolonol	8.91 (Kang et al., 2004; Casanola-Martin et al., 2007)	Glycitein	260.00 (Chang et al., 2005)
Fisetin	130.00 (Xie et al., 2003)	Glycyrrhisoflavone	IC_{50} > 200.00 (Zheng et al., 2013)

Fukugetin	2.50 (Masuda et al., 2004)	Gnetin C	7.00 (Yanagihara et al., 2012)

Table 2: Tyrosinase inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Tyrosinase inhibition**	**Compound**	**Tyrosinase inhibition**
Gnetol	4.50 (Ohguchi et al., 2002)	Kushenol F	2.00 (Ha et al., 2000; Casanola-Martin et al., 2007)
Hinokitiol	0.21 - 9.67 (Zhu et al., 2010)	Lappaconitine	93.30 (Shahee et al., 2005)
Chalcomoracin	26.80 (Yang et al., 2012)	Licuraside	72.00 (Fu et al., 2005)
Chamaecin	2.30 (Nihei et al., 2003)	Lyoniresinol	3.20 (Azhat-ul-Haq, 2006)
Chlorophorin	2.60 (Khabib et al., 2005; Likhitwitayawuid, 2008	Methyl 2β(2S)-hydroxyl-7(E)tritiacontenoate	1.36 (Khan et al., 2004)
Isoartocarpesin	0.66 (Zheng et al., 2008)	Methyl gallate	219.93 (Loizzo et al., 2012)
Isoliquiritigenin	8.10 - 480.8 (Nerya et al., 2003; Nerya et al., 2006; Zheng et al., 2008)	Mirkoin	5.00 (Kim et al., 2010)
Isoliquiritin	38.00 (Fu et al. 2005)	Moracin C	2.27 (Yang et al., 2012)

Kurarinol	0.10 - 8.60 (Ryu et al., 2007; Hyun et al., 2008; Loizzo et al., 2012)	Moracin D	12.00 (Yang et al., 2012)
Kuraridiol	0.88 (Hyun et al., 2008)	Moracin N	0.92 (Yang et al., 2012)

Table 2: Tyrosinase inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Tyrosinase inhibition**	**Compound**	**Tyrosinase inhibition**
Mudanpioside B	370.00 (Ding et al., 2009)	Pelargonidin 3-O-β-D-glukosid (P3G)	61.20 (Tsuda and Osaka, 1997)
Mudanpioside H	320.00 (Ding et al., 2009)	pelargonidin-3-α-O-rhamnosid	19.10 (Hanamura et al., 2008)
Mulberroside F	0.51 (Lee et al., 2002)	Peonidin	8.10 (Hanamura et al., 2008)
N-(p-Courmaroyl)serotonin	27.00 - 74.00 (Roh et al., 2004; Sultana and Lee, 2009)	Phlorofucofuroeckol	29.47 (Kang et al., 2004; Casanola-Martin et al.,2007)
Negundin A	10.00 (Azhar-ul-Haq, 2006)	Phloroglucinol	73.58 (Kang et al., 2004; Casanola-Martin et al.,2007)
Negundin B	6.00 (Azhar-ul-Haq, 2006)	Piceid	100.00 - 500.00 (Shin et al., 1998; Kim et al., 2002; Kim et al., 2004)
N-Feruloylserotonin	23.00 - 26.00 (Roh, 2004; Sultana and Lee, 2009)	Pinoresinol	15.30 (Azhar-ul-Haq, 2006)
Norartocarpanone	1.76 (Khatib et al., 2005)	Rhaponticin	100.00 (Kim et al., 2002 ; Casanola-Martin et al., 2007)
Norartocarpetin	0.08-0.46 (Yang et al., 2012; Zheng et al., 2008)	Rhapontigenin	76.20 (Kim et al., 2002; Likhitwitayawuid, 2008)
Norkurarinol	2.10 (Son et al., 2003)	Rosmarinic acid	16.8 (Loizzo et al., 2012)
Panduratin A	8.20 (Lee et al., 2010)	Skimmidiol	51.25 (Sultana at al., 2005)
Papyriflavonol A	82.30 (Zheng et al., 2008)	Sophoraflavanone G	4.70 (Ryu et al., 2007)

Pelargonidin	66.00 - 74.60 (Tsuda and Osaka, 1997; Hanamura et al., 2008)	Steppogenin	0.57 (Zheng et al., 2008; Loizzo et al., 2012)

Table 2: Tyrosinase inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Tyrosinase inhibition**	**Compound**	**Tyrosinase inhibition**
Stigmast-5-ene-3β,26-diol	2.39 (Sabudak et al., 2006)	(±)2,3-cis-dihydromorin	31.10 (Zheng et al., 2011)
Stigmast-5-ene-3β-ol	5.25 (Sabudak et al., 2006)	(2S,3S)-2,3-trans-dihydromorin-7-O-β-D-glucoside	93.17 (Zheng et al., 2013)
Tectorigenin	20.00 (Kim et al., 2010)	2,3-Dihydro4_,4_-di-O-methylmentoflavone	9.80 (Cheng et al., 2007)
trans-p-Coumaric acid	168.70 (Wang et al., 2011)	2,3-trans-dihydromorin	21.10 (Zheng et al., 2011)
Trimethylresveratrol	100.00 - 500.00 (Shin et al., 1998; Kim et al., 2004)	2,4,2',4'-hydroxychalcone	0.02 (Khatib et al., 2005)
Uranol	50.00 (Zheng et al., 2008)	2,4,3',4'-hydroxychalcone	0.20 (Khatib et al., 2005)
Veratric acid	no significance (Wang et al., 2011)	2-Hydroxy-4-methoxybenzaldehyde	30.00 (Seo et al., 2003)
Vitrofolal E	10.00 (Azhar-ul-Haq, 2006)	3-(3',4',5'-trihydroxyphenyl)-6,8-dihydroxycoumarin	270.00 (Fais et al., 2009)
2,3-trans-dihydromorin	21.10 (Zheng et al., 2011)	3,4´-Dimethoxy-5-hydroxystilbene	490.00 (Shin et al., 1998)
(+)(-)Diasyringaresinol	5.60 (Azhar-ul-Haq, 2006)	3,4-Dicaffeoylquinic acid	90.00 (Iwai et al., 2004)

(+)-2,3-trans-dihydrokaempferol	126.00 (Fujiwara et al., 2011)	3,5,7,4´-tetrahydroxy-3´-(2-hydroxy-3-methylbut-3-enyl)flavone	96.60 (Zheng et al., 2008)
(+)-2,3-trans-dihydroquercetin	210.00 (Fujiwara et al., 2011)	3,5-dihydroxy-4´-methoxystilbene	78.40 - 86.20 (Kim and Uyama, 2002; Kim et al., 2004)
(+/-) 2,3-cis-dihydromorin	31.10 (Zheng et al., 2011)	3,7,4' trihydroxyflavone	270.00 (Xie at al., 2003)

Table 2: Tyrosinase inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Tyrosinase inhibition**	**Compound**	**Tyrosinase inhibition**
3-Hydroxyphloretin	63.40 (Lin et al., 2007)	4-Substituted benzaldehydes	50.00 (Nerya et al., 2003)
3-O-p-coumaroyl-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-O-beta-gulco-pyranosylpropanol	5.30 (Sultana and Lee, 2009)	5,6,7-Trimethoxycoumarin	8.50 (Ahmed et al., 2004)
3-O-p-coumaroyl-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone	5.50 (Sultana and Lee, 2009)	5-Methylsalicylic acid	2150.00 (Zhang et al., 2006)
4-Hydroxybenzyl benzoate	100.00 (Nerya et al., 2003)	6,7,4´-Trihydroxyisoflavone	9.00 (Chang et al., 2005)
4-Hydroxychalcone	21.80 (Nerya et al., 2004)	6-Hydroxy-4-(4-hydroxy-3-methoxy)-3-hydroxymethyl-7-methoxy-3,4-dihydro-2-naphtaledehyde	8.00 (Azhar-ul-Haq, 2006)

4-Isopropylsalicylaldehyde	13.80 (Song et al., 2005)	8-Epi-cleomiscosin A	1.33 (Ahmad et al., 2004)
4-Methoxycinnamic acid	420.00 (Shi et al., 2005)	9-hydroxy-4-methoxypsoralen	8.61 (Piao et al., 2004)

*IC_{50} -constant to determine extent of inhibition, which indicate ś the inhibitor concentration required for 50% inhibition

**MIC- minimum inhibitory concentration, which marks the concentration above which no growth is observed by comparison with the positive control

Table 3: Maillard reaction products inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Maillard reaction products inhibition**	**Compound**	**Maillard reaction products inhibition**
Apigenin	172.00 (Matsuda et al., 2003)	Emodin	57.80 (Jang et al., 2008)
Arcapillin	77.84 (Jung et al., 2012)	Gallicin	18.04 (Lee et al., 2008)
(–)-Balanophonin	27.81 (Lee et al., 2008)	Hyperin	6.16 (Beaulieu et al., 2010)
Cirsilineol	289.28 (Jung et al., 2012)	Hyperoside	48.20 (Jung et al., 2012)
Cirsimaritin	138.38 (Jung et al., 2012)	Icaritin	89.21 (Jung et al., 2011)
Coumaric acid	1005.12 (Shimoda et al., 2011)	Isoquercitrin	14.60 - 167.00 (Matsuda et al., 2003; Jang et al., 2008)
Coumestrol	0.19 (Yang et al., 2006)	Isorhamnetin	272.50 (Jung et al., 2012)
Cyanidin 3-O-β-D-glucopyranosyl	132.00 (Matsuda et al., 2003)	Isorhamnetin 3-galactoside	155.05 (Jung et al., 2012)

Cyanidin 3-O-α-L-rhamnopyranosyl(→)-β-D-glucopyranosyl	154.00 (Matsuda et al., 2003)	Isorhamnetin 3-robinobioside	82.90 (Jung et al., 2012)
Cyanidin-3-O- galactoside	6.40 (Beaulieu et al., 2010)	Isoscopoletin	18.78 (Jung et al., 2012)
Daphnetin	43.21 (Jung et al., 2012)	Isoscopolin	41.04 (Jung et al., 2012)
Delphinidin 3-O-β-D-glucopyranosyl	99.00 (Matsuda et al., 2003)	Kaempferol 3-O-β-D-glucopyranoside	227.49 (Shimoda et al., 2011)
Delphinidin 3-O-α-L-rhamnopyranosyl(→)-β-D-glucopyranosyl	163.00 Matsuda et al., 2003)	Kaempferol 3-O-β-D-glucuronide methyl ester	108.80 (Kim et al., 2008)
Desmethylanhydroicaritin	104.30 - 294.34 (Jung et al., 2008; Jung et al., 2011)	Kaempferol-3-O-β-D-glucoside	90.40 (Jang et al., 2008)
Dihydrocaffeic acid	206.55 (Jung et al., 2012)	Kushenol C	192.94 (Jung et al., 2008)

Table 3: Maillard reaction products inhibition

Antioxidant activity IC_{50}* [µM]			
Compound	**Maillard reaction products inhibition**	**Compound**	**Maillard reaction products inhibition**
Lucidin	79.28 (Yoo et al., 2010)	Rhamnetin	156.00 (Matsuda et al., 2003
Luteolin 7-O-β-D-glucopyranosiduronic acid	200.00 (Matsuda et al., 2003)	Rhamnetin 3-O-α-L-rhamnopyranosy(1→6)-β-D-galactopyranoside	200.00 (Matsuda et al., 2003)
Luteolin 7-O-β-D-glucopyranosyl	169.00 (Matsuda et al., 2003)	Rubiadin	179.31 (Yoo et al., 2010)
Mangiferin	IC_{50} < 5.92 (Tang et al., 2004)	Scoparone	204.97 (Jung et al., 2012)
Myricitrin	200.00 (Matsuda et al., 2003)	Scopolin	60.10 (Jung et al., 2012)
PG-3 (3'-MethoxyPuerarin)	55.78 (Kim et al., 2006)	Sieboldin	200.00 (Dugé de Bernonville et al., 2010)
Plantagoside	1.20 (Matsuura et al., 2002)	Sulfuretin	124.70 (Lee et al., 2018)
Proanthocyanidin B-4	10.10 (Jang et al., 2009)	1,3,6-trihydroxy-2-hydroxymethyl-9,10-anthraquinone 3-O-β-primeveroside	IC_{50} > 86.20 (Yoo et al., 2010)
Puerariafuran	0.53 (Yang et al., 2006)	1,3,6-trihydroxy-2-methoxymethylanthraquinone	52.72 (Yoo et al., 2010)
Puerarin	20.89 (Kim et al., 2006)	3,3'-di-O-methylellagic acid	26.00 (Kim et al., 2008)
(+)-Puerol B	60.28 (Kim et al., 2006)	3,5-di-O-caffeoylquinic acid methyl ester	12.80 (Jang et al., 2008)
Quercetin 3-O-α-L-arabinopyranosyl-(1→6)-β-D-galactopyranoside	58.60 (Kim et al., 2008)	3,6-dihydroxy-2-hydroxymethyl-9,10-anthraquinone	IC_{50} > 185.20 (Yoo et al., 2010)
Quercetin 3-O-β-D-glucopyranoside	64.60 (Shimoda et al., 2011)	3,6-di-O-feruloylsucrose	31.90 (Jang et al., 2008)

Table 3: Maillard reaction products inhibition

Antioxidant activity IC_{50}* [µM]	
Compound	**Maillard reaction products inhibition**
6-(2-pyrrolidinone-5-yl)-(-)-epicatechin	36.00 (Jang et al., 2009)
7,4'-trihydroxy-5-methoxy-8-(gamma, gamma-dimethylally)-flavanone	704.65 (Jung et al., 2008)
7-Methoxycoumarin	490.20 (Jung et al., 2012)
8-(2-pyrrolidinone-5-yl)-(-)-epicatechin	47.80 (Jang et al., 2009)
8-C-Lavandulylkaempferol	132.70 (Jung et al., 2011)
8-Lavandulylkaempferol	312.68 (Jung et al., 2008)

*IC_{50} -constant to determine extent of inhibition, which indicate ś the inhibitor concentration required for 50% inhibition

**MIC- minimum inhibitory concentration, which marks the concentration above which no growth is observed by comparison with the positive control

Conclusions

Sulfur dioxide is one of the oldest food preservatives used for control of enzymatic and non-enzymatic browning and for microbial growth control. Although, sulfites are recognized as safe (GRAS) substance for use in food products, its residues in food have been responsible of some medical complications such as allergies, urticaria and asthmatic attacks. In recent years demand for safe alternatives to sulfites increase. The search for safe alternatives to sulfites has been complicated by the fact that sulfites are multifunctional a relatively inexpensive. The fact, that natural occurring compounds and plant extracts are used as preservatives and antioxidant or flavoring agents, lead us to seek alternatives to synthetic antioxidants and antimicrobials between plant compounds.

In the course of this review 260 plant-derived products have been identified. Some of these products have either antioxidant or antimicrobial properties. Some products possess both properties. It was found that these plant-derived compounds promising antioxidant and antimicrobial inhibitory activity *in vitro*. All values of these plant compounds are equal to sulfites activity. Resveratrol and luteolin are promising for future research and investigation. These two compounds possess combination of antimicrobial and antioxidation properties. Artocarpesin, glabridin, glyasperin C, hinokitiol, isoartocarpesin, kurarinol, kuraridiol morancin N, mulberroside F, norartocapreninand, steppogenin exhibited the strongest inhibitory activity against tyrosinase. Their concentrations were lower than 1 μM. Puerariafuran and coumestrol have strongest inhibition activity of Maillard reaction products. Quercitrin, quercetin, kaempferol, isovitexin, chlorogenic acid, oxyresveratrol, phloridzin, baicilein effectively inhibit both, tyrosinase and Maillard reaction products. All these plant-derived products

References

Ahmad, V. U., Ullah, F., Hussain, J., Farooq, U., Zubair, M., Khan, M. T. H., Choudhary, M. I. 2004. Tyrosinase Inhibitors from Rhododendron collettianum and Their Structure-Activity Relationship (SAR) Studies. Chemical and Pharmaceutical Bulletin, 52 (12): 1458-1461.

Akihisa, T., Kawashima, K., Orido, M., Akazawa, H., Matsumoto, M., Yamamoto, A., Ogihara, E., Fukatsu, M., Tokuda, H., Fuji, J. 2013. Antioxidative and Melanogenesis-Inhibitory Activities of Caffeoylquinic Acids and Other Compounds from Moxa. CHEMISTRY & BIODIVERSITY, 10: 313-327.

Arung, E. T., Shimizu, K., Kondo, R. 2006. Inhibitory effect of artocarpanone from *Artocarpus heterophyllus* on melanin biosynthesis. BIOLOGICAL & PHARMACEUTICAL BULLETIN, 29 (9): 1966-1969.

Azhar-ul-Haq, Malik, A., Khan, M. T. H., Anwar-ul-Haq, Khan, S. B., Ahmad, A., Choudhary, M. I. 2006. Tyrosinase inhibitory lignans from the methanol extract of the roots of *Vitex negundo* Linn. and their structure-activity relationship. PHYTOMEDICINE, 13 (4): 255-260.

Aziz, N. H., Farag, S. E., Mousa, L. A. A., Abo-Zaid, M. A. 1998. Comparative antibacterial and antifungal effects of some phenolic compounds. Microbios, 93 (374): 43-53.

Bai, X. N., Liang, W., Cheng, J., Mao, L. Q., Liu, Y. B., Shi, G. L., Wang, Y. N., Gu, J. C. 2012. Inhibitory Effect and Antifunal Mechanism of Umbelliferone on Plant Pathogenic Fungi. Information Technology and Agricultural Engineering, 134: 693-702.

Bavaresco, L., Vezzulli, S., Battilani, P., Giorni, P., Pietri, A., Bertuzzi, T. 2003. Effect of ochratoxin A-producing Aspergilli on stilbenic phytoalexin synthesis in grapes. JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY , 51 (21): 6151-6157.

Beaulieu, L. P., Harris, C. S., Saleem, A., Cuerrier, A., Haddad, P. S., Martineau, L. C., Bennett, S A. L., Arnason, J. T. 2010. Inhibitory Effect of the Cree Traditional Medicine Wiishichimanaanh (*Vaccinium vitis-idaea*) on Advanced Glycation Endproduct Formation: Identifi cation of Active Principles. 24: 741-747.

Chang, T. S., Ding, H. Y., Lin, H. Ch. 2005. Identifying 6,7,4′-Trihydroxyisoflavone as a Potent Tyrosinase Inhibitor. Biosci. Biotechnol. Biochem., 69 (10): 1999-2001.

Cheng, K. T., Hsu, F. L., Chen, S. H., Hsieh, P. K., Huang, H. S., Lee, Ch. K., Lee, M. H. 2007. New Constituent from *Podocarpus macrophyllus* var. *macrophyllus* Shows Anti-tyrosinase Effect and Regulates Tyrosinase-Related Proteins and mRNA in Human Epidermal Melanocytes. Chemical and Pharmaceutical Bulletin, 55 (5): 757-761.

Cho, J. Y., Moon, J. H., Seong, K. Y., Park, K.H. 1998. Antimicrobial activity of 4-hydroxybenzoic acid and trans 4-Hydroxycinnamic acid isolated and identified from rice hull. Biosience Biotechnology and Biochemistry, 62 (11): 2273-2276.

Chompoo, J., Upadhyay, A., Kishimoto, W., Makise, T., Tawata, S. 2011. Advanced glycation end products inhibitors from *Alpinia zerumbet* rhizomes. Food Chemistry, 129: 709-715.

Chompoo, J., Upadhyay, A., Fukuta, M., Tawata, S. 2012. Effect of Alpinia zerumbet components on antioxidant and skin diseases-related enzymes. BMC Complementary and Alternative Medicine, 12: 106.

Coghe, S. 2004. Influence of non-enzymatic browning on malt colour , flavour and antioxidative activity. Dissertationes de Agricultura. Katholieke Universiteit Leuven, 150 p.

Chung, K. T., Murdock, C. A. 1991. Natural systems for preventing contamination and growth of microorganisms in foods. FOOD STRUCTURE, 10: 361-374.

Chung, K. T., Lu, Z., Chou, M. W. 1998. Mechanism of inhibition of tannic acid and related compounds on the growth of intestinal bacteria. FOOD AND CHEMICAL TOXICOLOGY, 36 (12): 1053-1060.

Davidson, P. M., Junela, V. K., Branen, J. K. Antimicrobial Agents. In: Food Additives, 2nd edition. New York, Marcel Dekker, Inc. 938 p.

Ding, H. Y., Lin, H. C., Chang, T. S. 2009. Tyrosinase inhibitors isolated from the roots of *Paeonia suffruticosa*. Journal of Cosmetic Science, 60 (3): 347-352.

Duda-Chodak, A. 2012. THE INHIBITORY EFFECT OF POLYPHENOLS ON HUMAN GUT MICROBIOTA. JOURNAL OF PHYSIOLOGY AND PHARMACOLOGY, 63 (5): 497-503.

Dugé de Bernonville, T., Guyot, S., Paulin, J. P., Gauche, M., Loufrani, L., Henrion, D., Debré, S., Guilet, D., Richomme, P., Dat, J. F. 2010. Dihydrochalcones: Implication in resistance to oxidative stress and bioactivities against advanced glycation end-products and vasoconstriction. Phytochemistry, 71: 443-452.

Eidhin, D. N., Degn, P., O´Beirne, D. 2008. CHARACTERIZATION OF POLYPHENOL OXIDASE FROM ROOSTER POTATO (*SOLANUM TUBEROSUM CV ROOSTER*). DOI: 10.1111/j.1745-4514.2009.00256.x

Eskin, N. A. M. 1990. Biochemistry of foods, 2nd edition. Academic Press, INC, 557 p

Fais, A., Corda, M., Era, B., Fadda, M. B., Matos, M. J., Quezada, E., Santana, L., Picciau, C., Podda, G., Delogu, G. 2009. Tyrosinase Inhibitor Activity of Coumarin-Resveratrol Hybrids. Molecules, 14: 2514-2520.

Ferchichi, L., Derbré, S., Mahmood, K., Touré, K., Guilet, D., Litaudon, M., Awang, K., Hamid, A., Hadi, A., Ray, A. M. L., Richomme, P. 2012. Bioguided fractionation and isolation of natural inhibitors of advanced glycation end-products (AGEs) from *Calophyllum flavoramulum*. Phytochemistry, 78: 98-106.

Figueiredo, A. R., Campos, F., De Freitas, V., Hogg, T., Couto, J. A. 2008. Effect of phenolic aldehydes and flavonoids on growth and inactivation of *Oenococcus oeni* and *Lactobacillus hilgardii*. FOOD MICROBIOLOGY, 25 (1): 105-112.

Filip, V., Plocková, M., Šmidrkal, J., Špičková, Z., Melzoch, K., Schmidt, Š. 2003. Resveratrol and its antioxidant and antimicrobial effectiveness. Food Chemistry, 83: 585-593.

Fitzgerald, D. J., Stratford, M., Gasson, M. J., Ueckert, J., Bos, A., Narbad, A. 2004. Mode of antimicrobial action of vanillin against *Escherichia coli*, *Lactobacillus plantarum* and *Listeria innocua*. Journal of Applied Microbiology, 97 (1): 104-113.

Fitzgerald, D. J., Stratford, M., Narbad, A. 2003. Analysis of the inhibition of food spoilage yeasts by vanillin. International of Food Microbiology, 86 (1-2): 113-122.

Fu, B. Q., Li, H., Wang, X. R., Lee, F. S. C., Cui, S. F. 2005. Isolation and identification of flavonoids in licorice and a study of their inhibitory effects on tyrosinase. JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, 53 (19): 7408-7414.

Frank, K. L., Patel, R. 2007. Activity of sodium metabisulfite against planktonic and biofilm *Staphylococcus* species. DIAGNOSTIC MICROBIOLOGY AND INFECTIOUS DISEASE, 57 (4): 355-359.

Fu, B. Q., Li, H., Wang, X. R., Lee, F. S. C., Cui, S. F. 2005. Isolation and identification of flavonoids in licorice and a study of their inhibitory effects on tyrosinase. JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, 53 (19): 7408-7414.

Fujiwara, M., Yagi, N., Miyazawa, M. 2011. Tyrosinase inhibitory constituents from the bark of *Peltophorum dasyrachis* (yellow batai). NATURAL PRODUCT RESEARCH, 25 (16): 1540-1548.

Gao, Z. J., Liu, J. B., Xiao, X. G. 2011. Purification and characterisation of polyphenol oxidase from leaves of *Cleome gynandra L*. Food Chemistry, 129: 1012-1018.

García-Ruiz, A., Bartolomé, B., Cueva, C., Martín-Álvarez, P. J., Moreno-Arribas, M. V. 2009. Inactivation of oenological lactic acid bacteria (*Lactobacillus hilgardii* and *Pediococcus pentosaceus*) by wine phenolic compounds. Journal of Applied Microbiology, 107: 1042-1053.

García-Ruiz, A., Moreno-Arribas, M. V., Martín-Álvarez, P. J., Bartolomé, B. 2011. Comparative study of the inhibitory effects of wine polyphenols on the growth of enological lactic acid bacteria. International Journal of Food Microbiology, 145: 426-431.

Giese, J. 1994. Antimicrobials: Assuring Food Safety. Food Technology: 102-109.

Gong, S. Z., Cheng, J. A., Yang, Z. R. 2005. Inhibitory effect of ferulic acid on oxidation of L-DOPA catalyzed by mushroom tyrosinase. CHINESE JOURNAL OF CHEMICAL ENGINEERING, 13 (6): 771-775.

Gould, G. W., Russell, N.J. 1990. Food Preservatives, 1st Edition. New York. Blackie and SonLtd, *304* p.

Gould, G. W. 2000. Sulfites and Nitrites. In: microbial safety and quality in food. Springer, 2080 p.

Gould, G.W. Russell, N.J. 2003. Sulfites. In: Food Preservatieves, 2nd edition. Springer, 386 p.

Han, P., Chen, Ch. Q., Zhang, Ch. L., Song, K. K., Zhou, H. T., Chen, Q. X. 2008. Inhibitory effects of 4-chlorosalicylic acid on mushroom tyrosinase and its antimicrobial activities. Food Chemistry, 107: 797-803.

Hanamura, T., Uchida, E., Aoki, H. 2008. Skin-Lightening Effect of a Polyphenol Extract from Acerila (Malpighia emarginata DC.) Fruit on UV-Induced Pigmentation. Biosci. Biotechnol. Biochem., 72 (12): 3211-3218.

Hervert-Hernández, D., Pintado, C., Rotger, R., Goñi, I. 2009. Stimulatory role of grape pomace polyphenols on *Lactobacillus acidophilus* growth. International Journal of Food Microbiology, 136: 119-122.

Hong, H., Landauer, M. R., Foriska, M. A., Ledney, G. D. 2006. Antibacterial activity of the soy isoflavone genistein. J. Basic Microbiol, 46 (4): 329-335.

Huang, Y. H., Lee, T. H., Chan, K. J., Hsu, F. L., Wu, Y. C., Lee, M. H. 2008. Anemonin is a natural bioactive compound that can regulate tyrosinase-related proteins and mRNA in human melanocytes. JOURNAL OF DERMATOLOGICAL SCIENCE, 49 (2): 115-123.

Hyun, S. K., Lee, W. H., Jeong, D. M., Kim, Y., Choi, J. S. 2008. Inhibitory Effects of Kurarinol, Kuraridinol, and Trifolirhizin from *Sophora flavescens* on Tyrosinase and Melanin Synthesis. Biological and Pharmaceutical Bulletin, 31 (1): 154-158.

Itoh, K., Hirata, N., Masuda, M., Naruto, S., Murata, K., Wakabayashi, K., Matsuda, H. 2009. Inhibitory Effects of Citrus hassaku Extract and Its Flavanone Glycosides on Melanogenesis. BIOLOGICAL & PHARMACEUTICAL BULLETIN, 32 (3): 410-415.

Iwai, K., Kishimoto, N., Kakino, Y., Mochida, K., Fujita, T. 2004. In vitro antioxidative effects and tyrosinase inhibitory activities of seven hydroxycinnamoyl derivatives in green coffee beans. JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, 52 (15): 4893-4898.

Jang, D. S., Lee, G. A., Lee, Y.M., Kim, Y. S., Sun, H. 2009. Flavan-3-ols Having a γ-Lactam from the Roots of *Actinidia arguta* Inhibit the Formation of Advanced Glycation End Products *in Vitro.* Chemical & Pharmaceutical Bulletin, 57 (4): 397-400.

Jang, D.S., Yoo, N. H., Lee, Y. M., Yoo, J. L., Kim, Y. S., Kim, J. S. 2008. Constituents of the flowers of *Erigeron annuus* with inhibitory activity on the formation of advanced glycation end products (AGEs) and aldose reductase. Archives of Pharmacal reseach, 31 (7): 900-904.

Jang, D. S., Lee, G. Y., Lee, Y. M., Kim, Y. S., Sun, H., Kim, D. H., Kim, J. S. 2009. Flavan-3-ols Having a γ-Lactam from the Roots of *Actinidia arguta* Inhibit the Formation of Advanced Glycation End Products *in Vitro.* Chemical and Pharmaceutical Bulletin, 57 (4): 397-400.

Jay, J. M., Sulfur dioxide and sulfites. In: Modern Food Microbiology, 7th edition. New York. Marcel Dekker, 790 p.

Jeong, C. H., Shim, K. H. 2004. Tyrosinase inhibitor isolated from the leaves of *Zanthoxylum piperitum*. BIOSCIENCE BIOTECHNOLOGY AND BIOCHEMISTRY, 68 (9): 1984-1987.

Jermnak, U., Yoshinari, T., Sugiyama, Y., Tsuyuki, R., Nagasawa, H., Sakuda, S. 2012. Isolation of methyl syringate as a specific aflatoxin production inhibitor from the essential oil of Betula alba and aflatoxin production inhibitory activities of its related compounds. International Journal of Food Microbiology, 153, 339-344.

Jin, Y. H., Lee, S. J., Chung, M. H., Park, Y. I., Cho, T. H., Lee, S. K. 1999. Aloesin and Arbutin Inhibit Tyrosinase Activity in a Synergistic Manner via a Different Action Mechanism. Archives of Pharmacal Research, 22 (3): 232-236.

Jirawattanapong, W., Saifah, E., Patarapanich, Ch. 2009. Synthesis of Glabridin Derivatives as Tyrosinase Inhibitors. Archives of Pharmacal Research, 32 (5): 647-654.

Jung, H. A., Yoon, N.Y., Kang, S. S:, Kim, Y. S., Choi, J. S. 2008. Inhibitory activities of prenylated flavonoids from Sophora flavescens against aldose reductase and generation of

advanced glycation endproducts. JOURNAL OF PHARMACY AND PHARMACOLOGY, 60 (9): 1227-1236.

Jung, H. A., Jin, S. E., Park, J. S., Choi, J. S. 2011. Antidiabetic Complications and Anti-Alzheimer Activities of Sophoflavescenol, a Prenylated Flavonol from *Sophora flavescens*, and its Structure–Activity Relationship. PHYTOTHERAPY RESEARCH, 25: 709-715.

Jung, H. A., Park, J. J., Islam, N., Jin, S. E., Min, B. S., Lee J. H., Sohn, H. S., Choi, J. S. 2012. Inhibitory Activity of Coumarins from *Artemisia capillaris* against Advanced Glycation Endproduct Formation. Archives of Pharmacal Research, 35 (6): 1021-1035.

Jung, H. J., Sung, W. S., Yeo, S. H., Kim, H. S., Lee, I. S., Woo, E. R., Lee, D. G. 2006. Antifungal Effect of Amentoflavone derived from *Selaginella tamariscina.* Archives of Pharmacal Research, 29 (9): 746-751.

Kang, H. S., Kim, H. R., Byun, D. S., Son, B. W., Nam, T. J., Choi, J. S. 2004. Tyrosinase Inhibitors Isolated from the Edible Brown Alga *Ecklonia stolonifera. Archives of Pharmacal Research, 27 (12): 1226-1232.*

Kang, S. M., Heo, S. J., Kim, K. N., Lee, S. H., Yang, H. M., Kim, A. D. 2012. Molecular docking studies of a phlorotannin, dieckol isolated from *Ecklonia cava* with tyrosinase inhibitory activity. Bioorganic & Medicinal Chemistry, 20: 311-316.

Karre, L., Lopez, K., Kelly, J.K.G. 2013. Natural antioxidant in meat and poultry products. Meat science, 94: 220-227.

Khatib, S., Nerya, O., Musa, R., Shmuel, M., Snait, T. 2004. Chalcones as potent tyrosinase inhibitors: the importance of a 2,4-substituted resorcinol moiet. Bioorganic & Medicinal Chemistry ,13: 433-441.

Khatib, S., Nerya, O., Musa, R., Shmuel, M., Tamir, S., Vaya. J. 2005. Chalcones as potent tyrosinase inhibitors: the importance of a 2,4-substituted resorcinol moiety. Bioorganic & Medicinal Chemistry, 13: 433-441.

Kim, D. H., Kim, J. H., Baek, S. H., Seo, J. H., Kho, Y. H., Oh, T. K., Lee, Ch. H. 2004. Enhancement of Tyrosinase Inhibition of the Extract of *Veratrum patulum* Using Cellulase. BIOTECHNOLOGY AND BIOENGINEERING, 87 (7): 849-854.

Kim, H. J., Seo, S. H., Lee, B. G., Lee, Y. S. 2005. Identification of tyrosinase inhibitors from *Glycyrrhiza uralensis*. Plant Madica, 71 (8): 785-787.

Kim, J. M., Ko, R. K., Jung, D. S., Kim, S. S., Lee, N. H. 2010. Tyrosinase Inhibitory Constituents from the Stems of *Maackia fauriei.* PHYTOTHERAPY RESEARCH, 24: 70-75.

Kim, J. M., Jang, D. S., Lee, Y. M., Yoo, J. L., Kim, Y. S., Kim, YH., Kim, J. S. 2008. Aldose-Reductase- and Protein-Glycation-Inhibitory Principles from the Whole Plant of *Duchesnea chrysantha*. Chemistry & Biodiversity, 5 (2): 352-356.

Kim, J. M., Lee, Y. M., Lee, G. Y., Jang, D. S., Bae, K. H., Kim, J. S. 2006. Constituents of the Roots of *Pueraria lobata* Inhibit Formation of Advanced Glycation End Products (AGEs). Archives of Pharmacal Research, 29 (10): 821-825

Kim, J., Jeong, I. H., Kim, C. S., Lee, Y. M., Kim, J. M., Kim, J. S. 2011. Chlorogenic Acid Inhibits the Formation of Advanced Glycation End Products and Associated Protein Cross-linking. ARCHIVES OF PHARMACAL RESEARCH, 34 (3): 495-500.

Kim, Y. J., Uyama, H. 2005. Tyrosinase inhibitors from natural sources and synthetic sources: structure, inhibition mechanism and perspective for the future. Review. CELLULAR AND MOLECULAR LIFE SCIENCES, 62 (15): 1707-1723.

Kim, Y. M., Yun, J., Lee, Ch. K., Lee, H., Min, K. R., Kim, Y. 2002. Oxyresveratrol and Hydroxystilbene Compounds. THE JOURNAL OF BIOLOGICAL CHEMISTRY, 277 (18): 16340-16344.

Kim, Y. M. 2007. Antimelanogenic and Antioxidant Properties of Gallic Acid. Biological and Pharmaceutical Bulletin, 30 (6): 1052-1055.

Kim, Y. M., Yun, J., Lee, C. K., Lee, H., Min, K. R., Kim, Y. 2002. Oxyresveratrol and hydroxystilbene compounds - Inhibitory effect on tyrosinase and mechanism of action. JOURNAL OF BIOLOGICAL CHEMISTRY, 277 (18): 16340-16344.

Ko, R. K., Kim, G. O., Hyun, Ch. G., Jung, D. S., Lee, N. H. 2011. Compounds with Tyrosinase Inhibition, Elastase Inhibition and DPPH Radical Scavenging Activities from the Branches of *Distylium racemosum Sieb. et Zucc.* Phytotherapy Research, 25 (10): 1451-1456.

Kubo, I., Kinst-Hori, I., Nihei, K., Soria, F., Takasaki, M., Calderon, J. S., Cespedes, C. L. 2003. Tyrosinase inhibitors from galls of *Rhus javanica* leaves and their effects on insects. ZEITSCHRIFT FUR NATURFORSCHUNG SECTION C-A JOURNAL OF BIOSCIENCES, 58 (9-10): 719-725.

Kubo, I., Kinst-Hori, I., Chaudhuri, S. K., Kubo, Y., Sanchez, Y., Ogura, T. 2000. Flavonols from *Heterotheca inuloides*: Tyrosinase inhibitory activity and structural criteria. BIOORGANIC & MEDICINAL CHEMISTRY, 8 (7): 1749-1755.

Kwak, E. J., Lim, S. I. 2005. Inhibition of browning by antibrowning agents and phenolic acids or cinnamic acid in the glucose–lysine model. *Journal of the Science of Food and Agriculture, 85: 1337-1342.*

Kwon, Y. S., Choi, W. G., Kim, W. K., Kim, W. K., Kim, M. J., Kang, W. H., Kim, Ch. M. 2002. Antimicrobial Constituents of *Foeniculum vulgare*. Archives of Pharmacal Research, 25 (2): 154-157.

Landete, J. M., Curiel, J. A., Rodriguez, H., Rivas, B., Munoz, R. 2008. Study of the inhibitory activity of phenolic compounds found in olive products and their degradation by *Lactobacillus plantarum* strains. Food Chemistry, 107 (1): 320-326.

Lee, N. K., Son, K. H., Chang, H. W., Kang, S. S., Park, H., Heo, M. Y., Kim, H. P. 2004. Prenylated Flavonoids as Tyrosinase Inhibitors. Archives of Pharmacal Research, 27 (11): 1132-1135.

Lee, S. K., Lee, H. J., Min, H. Y., Park, E. J., Lee, K. M., Ahn, Y. H., Cho, Y. J., Pyee, J. H. 2005. Antibacterial and antifungal activity of pinosylvin, a constituent of pine. Fitoterapia, 76: 258-260.

Lee, G. Y., Jang, D. S., Lee Y. M., Kim, Y. S., Kim, J. S. 2008. Constituents of the seeds of Cornus offinalis with Inhibitory Activity on the Formation of Advanced Glycation End Products (AGEs). Journal of the Korean Society for Applied Biological Chemistry, 51 (4): 316-320.

Lee, S. H., Choi, S. Y., Kim, H., Hwang, J. S., Lee, B. G., Gao, J. J., Kim, S. Y. 2002. Mulberroside F Isolated from the Leaves of *Morus alba* Inhibits Melanin Biosynthesis. Biological and Pharmacetical Bulletin, 25 (8): 1045-1048.

Lee, Y. S., Kim, S. H., Jung, S. H., Kim, J. K., Pan, Ch. H., Lim, S. S. 2010. Aldose Reductase Inhibitory Compounds from Glycyrrhiza uralensis. Biological and Pharmaceutical Bulletin, 33(5): 917-921.

Leclercq, C., Molinaro, M. G., Piccinelli, R., Baldini, M., Arcella, D., Stacchini, P. 2000. Dietary intake exposure to sulphites in Italy-analytical determination of sulphite-containing

foods and their combination into standard meals for adults and children. Food Additives and Contaminants, 17 (12): 979-989.

Lehman, T. D., Ortwerth, B. J. 2001. Inhibitors of advanced glycation end product-associated protein cross-linking. Biochimica et Biophysica Acta, 1535: 110-119.

Leite de Souza, E., Montenegro, T. L. M., Lima, E. O., Trajano, V. N., Filho, J. M. B. 2005. Antimicrobial Effectiveness of Spices: an Approach for Use in Food Conversation Systems.

Leuner, O. 2011. Konzervanty přírodníchho původu jako alternativy siřičitanům v potravinách. Navrh postdoktorskeho grantoveho projektu. Grantová Agentura České republiky.

Likhitwitayawuid, K. 2008. Stilbenes with tyrosinase inhibitory activity. CURRENT SCIENCE, 94 (1): 44-52.

Li, H., Cheng, K. W., Cho, Ch. H., He, Z., Wang, M. 2007. Oxyresveratrol as an Antibrowning Agent for Cloudy Apple Juices and Fresh-Cut Apples. Journal of Agricultural and Food Chemistry, 55: 2604-2610.

Liang, Ch., Lim, J. H., Kim, S. H., Kim, D. S. 2012. Dioscin: A synergistic tyrosinase inhibitor from the roots of *Smilax china*. Food Chemistry, 134: 1146-1148.

Lim, J. Y., Ishiguro, K., Kubo, I. 2007. Tyrosinase inhibitory p-coumaric acid from ginseng leaves. PHYTOTHERAPY RESEARCH, 13 (5): 371-375.

Liu, L., Xu, X., Cheng, D., Yao, X., Pan, S. 2012. Preparative separation of polymethoxylated flavones from Ponkan (*Citrus reticulata* Blanco cv. Ponkan) peel by high-speed countercurrent chromatography and their antifungal activities against *Aspergillus niger*. European Food Research and Technology, 235: 631-635.

Likhitwitayawuid, K., Sritularak, B. 2001. A new dimeric stilbene with tyrosinase inhibitiory activity from *Artocarpus gomezianus*. JOURNAL OF NATURAL PRODUCTS, 64 (11): 1457-1459.

Loizzo, M. R., Tundis, R., Menichini, F. 2012. Natural and Synthetic Tyrosinase Inhibitors as Antibrowning Agents: An Update. Comprehensive Reviews in Food Sciences and Food Safety, 11 (4): 378-398.

López-Malo, A., Alzamora, S. M., Palou, E. 2002. *Aspergillus flavus* dose–response curves to selected natural and synthetic antimicrobials. International Journal of Food Microbiology, 73: 213-218.

Lou, S. N., Yu, M. W., Ho, Ch. T. 2012. Tyrosinase inhibitory components of immature calamondin peel. Food Chemistry, 135: 1091-1096.

Lueck, E. 1980. Antimicrobial food additives : characteristics, uses, effects. Berlin. Springer, 280 p.

Lück, E. 1997. Antimicrobial food additives : characteristics, uses, effects. 2nd. Revised and Enlarged Edition. Berlin. Springer, 260 p.

Mandalari, G., Bennett, R. N., Bisignano, G., Trombetta, D., Saija, A., Faulds, C. B., Gasson, M. J., Narbad, A. 2007. Antimicrobial activity of flavonoids extracted from bergamot (Citrus bergamia Risso) peel, a byproduct of the essential oil industry. Journal of Applied Microbiology, 103: 2056-2064.

Martini, N. D., Katerere, D. R. P., Eloff, J. N. 2004. Biological activity of five antibacterial flavonoids from *Combretum erythrophyllum* (Combretaceae). Journal of Ethnopharmacology, 93: 207-212.

Martorell, P., Stratford, M., Steels, H., Fernández-Espinar, M.T., Querol, A. 2007. Physiological characterization of spoilage strains of *Zygosaccharomyces bailii* and

Zygosaccharomyces rouxii isolated from high sugar environments. International Journal of Food Microbiology, 114 (2): 234-242.

Masamoto, Y., Ando, H., Murata, Y., Shimoishi, Y., Tada, M., Takahata, K. 2003. Mushroom tyrosinase inhibitory activity of esculetin isolated from seeds of *Euphorbia lathyris* L. BIOSCIENCE BIOTECHNOLOGY AND BIOCHEMISTRY, 67 (3): 631-634.

Matos, M. J., Santana, L., Uriarte, E., Delogu, G., Corda, M., Fadda, M. B., Era, B., Fais, A. 2011. New halogenated phenylcoumarins as tyrosinase inhibitors. Bioorganic & Medicinal Chemistry Letters, 21: 3342-3345.

Matsuura, N., Sasaki, C., Aradate, T., Ubukata, M., Kojima, H., Ohara, M., Hasegawa, J. 2002. Plantagoside as Maillard reaction inhibitor - its inhibitory mechanism and application. MAILLARD REACTION IN FOOD CHEMISTRY AND MEDICAL SCIENCE: UPDATE FOR THE POSTGENOMIC ERA Book Series: INTERNATIONAL CONGRESS SERIES, 1245: 411-412.

McWeeny, D. J., Knowles, M. E., Hearne, J. F. 1975. The Chemistry of Non-enzymatic Browning in Foods and its Control by sulphites. Journal Sciences of Food Agriculture, 25: 735-746.

Muthuswamy, S., Rupasinghe, H. P. V. 2007. Fruit phenolics as natural antimicrobial agents: Selective antimicrobial activity of catechin, chlorogenic acid and phloridzin. JOURNAL OF FOOD AGRICULTURE & ENVIRONMENT, 5 (3-4): 81-85.

Matsuda, H., Wang, T., Managi, H., Yoshikawa, M. 2003. Structural Requirements of Flavonoids for Inhibition of Protein Glycation and Radical Scavenging Activities. Bioorganic & Medicinal Chemistry, 11: 5317–5323.

Mayer, A. M. 2006. Polyphenol oxidases in plants and fungi: Going places? A review. PHYTOCHEMISTRY, 67 (21): 2318-2331.

Mendoza, L., Yaňez, K., Vivanco, M., Melo, R., Cotoras, M. 2013. Characterization of extracts from winery by-products with antifungal activity against *Botrytis cinerea*. Industrial Crops and Products, 43: 360-364.

Míková, K. 2001. The regulation of antioxidants in food. In: Antioxidant in foods: Practical Application. Woodhead Published, 400 p.

Morimitsu, Y., Yoshida, K., Esaki, S., Hirota, A. 1995. Protein Glycation from Thyme (*Thymus vulgaris*). BIOSCIENCE BIOTECHNOLOGY AND BIOCHEMISTRY, 59 (11): 2018-2021.

Nerya, O., Musa, R., Khatib, S., Tamir, S., Vaya, J. 2004. Chalcones as potent tyrosinase inhibitors: the effect of hydroxyl positions and numbers. Phytochemistry, 65: 1389-1395.

Nerya, O., Ben-Arie, R., Luzzatto, T., Musa, R., Khativ, S., Vaya, J. 2006. Prevention of *Agaricus bisporus* postharvest browning with tyrosinase inhibitors. Postharvest Biology and Technology, 39: 272-277.

Nerya, O., Musa, R., Khatib, S., Tamir, S., Vaya, J. 2004. Chalcones as potent tyrosinase inhibitors: the effect of hydroxyl positions and numbers. PHYTOCHEMISTRY, 65 (10): 1389-1395.

Nerya, O., Vaya, J., Musa, R., Izrael, S., Ben-Arie, R., Tamir, S. 2003. Glabrene and isoliquiritigenin as tyrosinase inhibitors from licorice roots. JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, 51 (5): 1201-1207.

Nguyen, M. H. K., Nguyen, H. X., Mai, T. T. N., Nguyen, N. T. 2012. Phenolic Constituents from the Heartwood of *Artocapus altilis* and their Tyrosinase Inhibitory Activity. Natural Product Comminications, 7 (2): 185-186.

Nihei, K., Yamagiwa, Y., Kamikawa, T., Kubo, I. 2004. 2-Hydroxy-4-isopropylbenzaldehyde, a potent partial tyrosinase inhibitor. Bioorganic & Medicinal Chemistry Letters, 14: 681-683.

Nowakowska, Z. 2007. A review of anti-infective and anti-inflammatory chalcones. European Journal of Medicinal Chemistry, 42: 125-137.

Obšil, T., Pavlíček, Z. 1997. Glykace proteinů a fosfolipidů: Maillardova reakce *in vivo*. Chemické listy, 91: 558-569.

Ohguchi, K., Nakajima, C., Oyama, M., Iinuma, M., Itoh, T., Akayo, Y., Nozawa, Y., Ito, M. 2010. Inhibitory Effects of Flavonoid Glycosides Isolated from the Peel of Japanese Persimmon (*Diospyros kaki* 'Fuyu') on Melanin Biosynthesis. Biological & Pharmaceutical Bulletin, 33 (1): 122-124.

Ohguchi, K., Tanaka, T., Iliya, I., Ito, T., Iinuma, M., Matsumoto, K., Akao, Y., Nozawa, Y. 2003. Gnetol as a potent tyrosinase inhibitor from *Genus Gnetum*. BIOSCIENCE BIOTECHNOLOGY AND BIOCHEMISTRY, 67 (3): 663-665.

Oliva-Neto, P. de, Yokoya, F. 2001. SUSCEPTIBILITY OF *SACCHAROMYCES CEREVISIAE* AND LACTIC ACID BACTERIA FROM THE ALCOHOL INDUSTRY TO SEVERAL ANTIMICROBIAL COMPOUNDS. Brazilian Journal of Microbiology, 32: 10-14.

Ough, C. S., Were, L. 2005. Sulfur dioxide and sulfites. In Antimicrobials in food, 3rd edition. Taylor & Francis Group, 722 p.

Palumbo, J. D., O´Keeffe, T. L., Mahoney, N. E. 2007. Inhibition of ochratoxin A production and growth of Aspergillus species by phenolic antioxidant compounds. Mycopathologia, 164: 241-248.

Parkar, S. G., Stevenson, D. E., Skinner, M. A. 2008. The potential influence of fruit polyphenols on colonic microflora and human gut health. International Journal of Food Microbiology, 124: 295-298.

Parvez, S., Kang, M., Chung, H. S., Bae, H. 2007. Naturally occurring tyrosinase inhibitors: Mechanism and application in skin health, cosmetics and agriculture industries. PHYTOTHERAPY RESEARCH, 21 (9): 805-816.

Pastorkova, E., Zakova, T., Landa, P., Novakova, J., Vadlejch, J., Kokoska, L. 2013. Growth inhibitory effect of grape phenolics against wine spoilage yeasts and acetic acid bacteria. International Journal of Food Microbiology, 161 (3): 209-213.

Peng, X., Zheng, Z., Cheng, K. W., Shan, F., Ren, G. X., Chen, F., Wang, M. 2008. Inhibitory effect of mung bean extract and its constituents vitexin and isovitexin on the formation of advanced glycation endproducts. Food Chemistry, 106: 475-481.

Pereira, A. C., Oliveira, D. F., Silva, G. H., Figueiredo, H. C. P., Cavalheiro, A. J., Carvalho, D. A., Souza, L. P., Chalfoun, S. M. 2008. Identification of the antimicrobial substances produced by *Solanum palinacanthum* (Solanaceae). 2008**.** *An Acad Bras Cienc, 80 (3): 427-432.*

Peres, M. T. L.P., Monache, F. D., Cruz, A. B., Pizzolatti, M. G., Yunes, R. A. 1997. Chemical composition and antimicrobial activity of *Croton urucurana* Baillon (Euphorbiaceae). Journal of Ethnopharmacology, 56: 223-226.

Piao, X. L., Baek, S. H., Park, M. K., Park, J. H. 2004. Tyrosinase-Inhibitory Furanocoumarin from *Angelica dahurica. Biological and Pharmaceutical Bulletin, 27 (7): 1144-1146.*

Piao, X. L., Park, I. H., Baek, S. H., Kim, H. Y., Park, M. K., Park, J. H. 2004. Antioxidative activity of furanocoumarins isolated from *Angelicae dahuricae*. JOURNAL OF ETHNOPHARMACOLOGY, 93 (2-3): 243-246.

Pizzoferrato, L. Lulli di G., Quattrucci, E. 1997. Determination of free, bound and total sulphites in foods by indirect photometry-HPLC. Food Chemistry, 63 (2): 257-279.

Povichit, N., Phrutivorapongkul, A., Suttajit, M., Leelapornpisid, P. 2010. Antiglycation and antioxidant activities of oxyresveratrol extracted from the heartwood of *Artocarpus lakoocha* Roxb. MAEJO INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY, 4 (3): 454-461.

Prabhakar, K, Reddy, K.S. 1999. PRESERVATIVES/Permitted Preservatives – Sulphur Dioxide. In: Encyclopedia of Food Microbiology, Editor-in-Chief Richard K. Robinson. Elsevier, Oxford, Pages 1750-1754, ISBN 9780122270703, 1750-1754 p.

Queiroz, Ch., Mendes-Lopes, M. L., Fialho, E., Valente-Mesquita, V. L. 2008. Polyphenol Oxidase: Characteristics and Mechanisms of Browning Control. Food Reviews International, 24: 361-375.

Roh, J. S., Han, J. Y., Kim, J. H., Hwang, J. K. 2004. Inhibitory Effects of Active Compounds Isolated from Safflower (*Carthamus tinctorius* L.) Seeds for Melanogenesis. Biological and Pharmaceutical Bulletin, 27 (12): 1976-1978.

Ryu, Y. B., Westwood, I. M., Kang, N. S., Kim, H. Y., Kim, J. H., Moon, Y. H., Park, K. H. 2008. Kurarinol, tyrosinase inhibitor isolated from the root of *Sophora flavescens*. Phytomedicine, 15: 612-618.

Saewan, N., Koysomboon, S., Chantrapromma, K. 2011. Anti-tyrosinase and anti-cancer activities of flavonoids from Blumea balsamifera DC. JOURNAL OF MEDICINAL PLANTS RESEARCH, 5 (6): 1018-1025.

Sabudak, T., Khan, M. T. H., Choudhary, M. I., Oksuz, S. 2006. Potent tyrosinase inhibitors from Trifolium balansae. NATURAL PRODUCT RESEARCH, 20 (7): 665-670.

Saito, A., Doi, Y., Tanaka, A., Matsuura, N., Ubukata, M., Nakajima, N. 2004. Systematic synthesis of four epicatechin series procyanidin trimers and their inhibitory activity on the Maillard reaction and antioxidant activity. Bioorganic & Medicinal Chemistry, 12: 4783-4790.

Sakuma, K., Ogawa, M., Sugibayashi, K., Yamada, K., Yamamoto, K. 1999. Relationship Between Tyrosinase Inhibitory Action and Oxidation-Reduction Potential of Cosmetic Whitening Ingredients and Phenol Derivatives. Archives of Pharmacal Research, 22 (4): 335-339.

Salas, M. P., Céliz, G., Geronazzo, H., Daz, M., Resnik, S. L. 2011. Antifungal activity of natural and enzymatically-modified flavonoids isolated from citrus species. Food Chemistry, 124: 1411-1415.

Sapers, G. M., Hick, K. B. Miller, R. L. 2002. Antibrowning agents. In: Food Additives, 2nd edition. New York, Marcel Dekker, Inc. 938 p.

Sasaki, K., Yoshizaki, F. 2002. Nobiletin as a Tyrosinase Inhibitor from the Peel of *Citrus* Fruit. Biological and Pharmaceutical Bulletin, 25 (6): 806-808.

Schamberger, G. P., Labuza, T. P. 2006. Effect of green tea flavonoids on Maillard browning in UHT milk. LWT, 40: 1410-1417.

Serra, A. T., Matias, A. A., Nunes, A. V. M., Leitao, M. C., Brito, D., Bronze, R., Silva, S., Pires, A., Crespo, M. T., San Romao, M. V., Duarte, C. M. 2008. In vitro evaluation of olive- and grape-based natural extracts as potential preservatives for food. Innovative Food Science and Emerging Technologies, 9: 311-319.

Shaheen, F., Ahmad, M., Khan, M. T. M., Jalil, S., Ejaz, A., Sultankhodjaev, M. N., Afran, M., Choudhary, M. I., Rahman, A. 2005. Alkaloids of Aconitum laeve and their anti-inflammatory, antioxidant and tyrosinase inhibition activities. Phytochemistry, 66: 935-940.

Shi, Y., Chen, Q. X., Wang, Q., Song, K. K., Qui, L. 2005. Inhibitory effects of cinnamic acid and its derivatives on the diphenolase activity of mushroom (*Agaricus bisporus*) tyrosinase. Food Chemistry, 92 (4): 707-712.

Shin, N. H., Ryu, S. Y., Choi, E. J., Kang, S. H., Chang, I. M. Min, K. R., Kim, Y. 1998. Oxyresveratrol as the Potent Inhibitor on Dopa Oxidase Activity of Mushroom Tyrosinase. BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS, 243: 801-803.

Shimoda, H., Nakamura, S., Morioka, M., Tanaka, J., Matsuda, H., Yoshikawa, M. 2011. Effect of Cinnamoyl and Flavonol Glucosides Derived from Cherry Blossom Flowers on the Production of Advanced Glycation End Products (AGEs) and AGE induced Fibroblast Apoptosis. PHYTOTHERAPY RESEARCH, 25: 1328-1335.

Sholberg, P. L., Shimizu, B. N. 1991. USE OF THE NATURAL PLANT-PRODUCTS, HINOKITIOL, TO EXTEND SHELF-LIFE OF PEACHES. CANADIAN INSTITUTE OF FOOD SCIENCE AND TECHNOLOGY, 24 (5): 273-277.

Si, Y. X., Wang, Z. J., Park, D., Chung, H. Y., Wang, S. F., Yan, L., Yang, J. M., Qian, G. Y., Yin, S. J., Park, Y. D. 2012. Effect of hesperetin on tyrosinase: Inhibition kinetics integrated computational simulation study. International Journal of Biological Macromolecules, 50: 257-262.

Silva, I. F., Raimondi, M., Zacchino, S., Filho, V. C., Noldin, V. F., Rao, V. S., Lima, J. C. S., Martins, D. T. O. 2010. Evaluation of the antifungal activity and mode of action of *Lafoensia pacari* A. St.-Hil., Lythraceae, stem-bark extracts, fractions and ellagic acid. Brazilian Journal of Pharmacognosy, 20 (3): 422-428.

Sohn, H. Y., Son, K. H., Kwon, C. S., Kwon, G. S., Kang, S. S. 2004. Antimicrobial and cytotoxic activity of 18 prenylated flavonoids isolated from medicinal plants: *Morus alba* L., *Morus mongolica* Schneider, *Broussnetia papyrifera* (L.) Vent, *Sophora flavescens* Ait and *Echinosophora koreensis* Nakai. Phytomedicine, 11: 666-672.

Sollai, F., Zucca, P., Sanjust, E., Steri, D., Rescigno, A. 2008. Umbelliferone and Esculetin: Inhibitors or Substrates for Polyphenol Oxidases? Biological and Pharmaceutical Bulletin, 31 (12): 2187-2193.

Son, D. J., Lee, S. E., Park, B. S. 2003. Inhibitory effects of naturally occurring flavonoids on a human intestinal bacterium, *Clostridium perfringens*. FOOD SCIENCE AND BIOTECHNOLOGY, 12 (2): 180-182.

Son, J. K., Park, J. S., Kim, J. A., Kim, Y., Chung, S. R., Lee, S. H. 2003. Prenylated flavonoids from the roots of *Sophora flavescens* with tyrosinase inhibitory activity. PLANTA MEDICA, 69 (6): 559-561.

Sultana, N., Choudhary, M. I., Khan, A. 2009. Protein Glycation Inhibitory Activities of *Lawsonia inermis* and its Active Principles. JOURNAL OF ENZYME INHIBITION AND MEDICINAL CHEMISTRY, 24 (1): 257-261.

Sultana, N., Atta-ur-Rahman, Khan, T. H. 2005. Tyrosinase inhibitor fatty ester and a quinoline alkaloid from *Skimmia laureola*. ZEITSCHRIFT FUR NATURFORSCHUNG SECTION B-A JOURNAL OF CHEMICAL SCIENCES, 60 (11): 1186-1191.

Sultana, N., Lee, N. H. 2009. New Phenylpropanoids from *Sasa quelpaertensis* Nakai with Tyrosinase Inhibition Activities. BULLETIN OF THE KOREAN CHEMICAL SOCIETY, 30 (8): 1729-1732.

Tang, S. Y., Whiteman, M., Peng, Z. F., Jenner, A., Yong, E. L., Halliwell. 2004. CHARACTERIZATON OF ANTIOXIDANT AND ANTIGLYCATION PROPERTIES AND ISOLATION OF ACTIVE INGREDIENTS FROM TRADITIONAL CHINESE MEDICINES. Free Radical Biology & Medicine, 36 (12): 1575-1587.

Tsuda, T., Osawa, T. 1997. Inhibition of Tyrosinase Activity by the Anthocyanin Pigments Isolated from Phaseolus vulgaris L. Food Science and Technology International Tokyo, 3 (1): 82-83.

Wang, Q., Qui, L., Chen, X., Song, K. K., Shi, Y., Chen, Q. X. 2007. Inhibitory effects of phloridzin dihydrate on the activity of mushroom (Agaricus bisporus) tyrosinase. Bioorganic & Medicinal Chemistry, 15: 1568-1571.

Wang, B. S., Chang, L. W., Wu, H. Ch., Huang, S. L., Chu, H. L. 2011. Antioxidant and antityrosinase activity of aqueous extracts of green asparagus. Food Chemistry, 127: 141-146.

Wedzicha, B. L. 1992. Chemistry of sulfiting agents in food. FOOD ADDITIVES AND CONTAMINANTS, 9 (5): 449-459.

Wu, X., Yin, S., Zhong, J., Ding, W., Wan, J., Xie, Z. 2012. Mushroom tyrosinase inhibitors from *Aloe barbadensis* Miller. Fitoterapia, 83: 1706-1711.

Xie, L. P., Chen, Q. X., Huang, H., Wang, H. Z., Zhang, R. Q. 2003. Inhibitory Effects of Some Flavonoids on the Activity of Mushroom Tyrosinase. BIOCHEMISTRY-MOSCOW, 68 (4): 487-491.

Yanagawa, Y., Yamamoto, Y., Hara, Y., Shimamura, T. 2002. A Combination Effect of Epigallocatechin Gallate, a Major Compound of Green Tea Catechins, with Antibiotics on *Helicobacter pylori* Growth In Vitro. CURRENT MICROBIOLOGY, 47: 244-249.

Yanagihara, M., Yoshimatsu M., Inoue, A., Kanno, T., Tatefuji, T., Hashimoto, K. 2012. Inhibitory Effect of Gnetin C, a Resveratrol Dimer from Melinjo (*Gnetum gnemon*), on Tyrosinase Activity and Melanin Biosynthesis. Biological & Pharmaceutical Bulletin, 35 (6): 993-997.

Yagi, S., Drouart, N., Bourgaud, F., Henry M., Chapleur Y., Laurain-Mattar, D. 2013. Antioxidant and antiglycation properties of *Hydnora johannis* roots. South African Journal of Botany, 84: 124-127.

Yang, D. S., Kim, J. M., Lee, Y. M., Kim, Y. S., Kim, J. H., Kim J. S. 2006. Puerariafuran, a New Inhibitor of Advanced Glycation End Products (AGEs) Isolated from the Roots of *Pueraria lobata.* Chemical and Pharmaceutical Bulletin, 54 (9): 1315-1317.

Yang, Z., Wang, Y., Wang, Y., Zhang, Y. 2012. Bioassay-guided screening and isolation of a-glucosidase and tyrosinase inhibitors from leaves of *Morus alba.* Food Chemistry, 131: 617-625.

Yao, Y., Cheng, X., Wang, L., Wang, S., Ren, G. 2012. Mushroom tyrosinase inhibitors from mung beand (*Vigna Radiatae L.)* extracts. International Journal of Food Sciences and Nutrition, 63 (3): 358-361.

Yokozawa, T., Kim, Y. J. 2007. Piceatannol inhibits melanogenesis by its antioxidative actions. BIOLOGICAL AND PHARMACEUTICAL BULLETIN, 30 (11): 2007-2011.

Yoo, N. H., Jang, D. S., Lee, Y. M., Jeong, I. H., Cho, J. H., Kim, J. H., Kim, J. S. 2010. Anthraquinones from the Roots of *Knoxia valerianoides* Inhibit the Formation of Advanced Glycation End Products and Rat Lens Aldose Reductase *In Vitro.* Archive Pharmacal Research, 33 (2): 209-214.

Yoon, T. M., Kim, J. W., Kim, J. G., Kim, W. G., Suh, J. W. 2006. Talosins A and B: New isoflavonol glycosides with potent antifungal activity from *Kitasatospora kifunensis* MJM341 I. Taxonomy, fermentation, isolation, and biological activities. JOURNAL OF ANTIBIOTICS, 59 (10): 633-639.

Zaldivar, J., Ingram, L. O. 1999. Effect of Organic Acids on the Growth and Fermentation of Ethanologenic *Escherichia coli* LY01. BIOTECHNOLOGY AND BIOENGINEERING, 66 (4): 203-210.

Zhang, J. P., Chen, Q. X., Song, K. K., Xie, J. J. 2006. Inhibitory effects of salicylic acid family compounds on the diphenolase activity of mushroom tyrosinase. Food Chemistry, 95: 579-584.

Zhang, C. W., Lu, Y. H., Tao, L., Tao, X. Y., Su, X. C., Wei, D. Z. 2007. Tyrosinase inhibitory effects and inhibition mechanisms of nobiletin and hesperidin from citrus peel crude extracts. JOURNAL OF ENZYME INHIBITION AND MEDICINAL CHEMISTRY, 22 (1): 83-90.

Zhao, L., Wang, Y. N., Du, J., Bu, C. Y., Ma, L. Q., Liu, Y. B., Shi, G. L. 2012. Antifungal Activity of Extracts of Stellera chamaejasme against Botrytis cinerea. Information Technology and Agricultural Engineering, 134: 683-692.

Zheng, Z.P., Tan, H. Y., Chen, J., Wang, M. 2013. Characterization of tyrosinase inhibitors in the twigs of *Cudrania tricuspidata* and their structure–activity relationship study. Fitoterapia, 84: 242-247.

Zheng, Z. P., Zhu, Q., Fan, C. L., Tan, H. Y., Wang, M. F. 2011. Phenolic tyrosinase inhibitors from the stems of *Cudrania cochinchinensis.* Food and Function, 2 (5): 259-264.

Zheng, Z.P., Cheng, K. W., Chao, J. F., Wu, J. J., Wang, M.F. 2008. Tyrosinase inhibitors from paper mulberry (*Broussonetia papyrifera*). Food Chemistry, 106 (2): 529-535.

Zheng, Z. P., Cheng, K. W., To, J. T., Li, H., Wang, M. 2008. Isolation of tyrosinase inhibitors from *Artocarpus heterophyllus* and use of its extract as antibrowning agent. Molecular Nutrition & Food research, 52 (12): 1530-1538.

Zhu, Y. J., Qiu, L., Guo, H. Y., Hu, Y. H., Li, Z. C., Wang, Q., Chen, Q. X., Liu, B. 2010. Inhibitory effects of hinokitiol on tyrosinase activity and melanin biosynthesis and its antimicrobial activities. Journal of Enzyme Inhibition and Medical Chemistry, 25 (6): 798-803.