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Chemistry and antioxidant activity of plants containing some phenolic compounds

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ABSTRACT

Natural antioxidants inhibit the adverse effects of the Reactive Oxygen Species produced in living things and enable to survive. Depending on this principle, humans started using some plant products to cure from various diseases. Natural products have proved of great health impact on human traditionally and scientifically. Moreover, the research has so far done in the field of natural antioxidants. Therefore, antioxidants have been traditionally used as well as experimentally proved beneficial. The antioxidant components of the natural products constitute the major source of human health promotion and maintenance. The nature is still the perfect source for health promotion and for the supplementation of safe drugs. Great attention is mandatory to explore many underestimated plants with highly effective antioxidant activity. Few classes of natural products have received as much attention as phenolics and polyphenols.

Capsule Summary: The chemistry and antioxidant activity of plants containing some phenolic compounds is overviewed and it was found that plants are perfect sources for providing safe drugs for health promotion.

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INTRODUCTION

Plant species still serve as a rich source of many novel biologically active compounds. The interest in phytomedicine and many medicinal plant species are being screened for biological activities (Gautam et al., 2007). Human has used herbs to treat various infectious diseases and some of these traditional medicines are still included as part of the habitual treatment of various problems (Rios and Recio, 2005). All cultures around the world have relies on medicinal herbs for primary health care. The worldwide increase in the use of herbal preparations and their active ingredients in health care (Jassim and Naji, 2003). Natural drugs have been used worldwide in traditional medicines for the treatment of various diseases. Natural medicines are becoming more popular and used increasingly (Gautam et al., 2007). In medicinal plants, some of which have proved useful to humans as pharmaceuticals. Therefore herbs seem to be the most promising material for discovering novel pharmacologically-active compounds (Hoareau and Dasilva, 1999) that used for treating and preventing various disorders. Natural herbs are often considered to be harmless compared with synthetic medicines (Hsieh, et al, 2008). At present, natural plant and herb resources are unlimited. Natural products have provided the pharmaceutical industry with most important sources of lead compounds and up to 40% of modern drugs are derived from natural sources (Jassim and Naji, 2003). The studies have shown an inverse relationship between vegetarian diet and the incidence of cancer, cardiovascular diseases and mortality (Rajaram and Sabaté, 2000). This suggests a potential therapeutic role of plants in human health (Barthwal et al., 2008). Epidemiological studies suggested that the habit of vegeteranian diet is related with reduced risk of cancer, cardiovascular and neurodegenerative disorders. The incidence of these disorders is least in populations where fruits, vegetables and spices are the major elements in the human diet. Diet can modify the pathophysiological processes of metabolic disorders and can be an effective for various disease processes most of which are known to involve oxidative damage (Ullah and Khan, 2008).

A plant-based diet protects against chronic oxidative stress-related diseases. Dietary plants contain variable chemical families and amounts of antioxidants. It has been hypothesized that plant antioxidants may contribute to the beneficial health effects of dietary plants. Our objective was to develop a comprehensive food database consisting of the total antioxidant content of typical foods as well as other dietary items such as traditional medicine plants, herbs and spices and dietary supplements. This database is intended for use in a wide range of nutritional research, from in vitro and cell and animal studies, to clinical trials and nutritional epidemiological studies. The results demonstrate that there are several thousand-fold differences in antioxidant content of foods. Spices, herbs and supplements include the most antioxidant rich products in our study, some exceptionally high. Berries, fruits, nuts, chocolate, vegetables and products thereof constitute common foods and beverages with high antioxidant values. It shows that plant-based foods introduce significantly more antioxidants into human diet than non-plant foods. Because of the large variations observed between otherwise comparable food samples the study emphasizes the importance of using a comprehensive database combined with a detailed system for food registration in clinical and epidemiological studies. The present antioxidant database is therefore an essential research tool to further elucidate the potential health effects of phytochemical antioxidants in diet. Indeed, phenolic compounds are ubiquitously distributed in the plant kingdom and exhibit a wide range of medicinal properties, including anti-inflammatory, anti-carcinogenic viral, anti-allergic and immune-stimulating agents. These protective effects have been mostly ascribed to their free radical scavenging, metal chelating and chain breaking effects. Many literature reports show a relatively strong correlation between the total phenolic content and the antioxidant capacity of plant extracts (Tawaha et al., 2007). In recent years, intensive research on natural antioxidants derived from plants has grown due to their potential health-benefits in the search for replacements of synthetic antioxidants. The phenolic compounds and their antioxidant properties present in no fewer than 3,000 plant species, including some Thai plants, have been studied (Maisuthisakul et al., 2008).Various parts of many Thai wild plants are traditionally used as food or medicine and may contribute as potential sources for new natural antioxidants. Therefore, the aim of this study was designed for the evaluation of antioxidant activity of twenty selected Thai wild plants in order to identify new sources of natural antioxidants and to investigate the relationship between antioxidant properties and total phenolic content. These data will provide some useful information for healthier living, as well as the further screening of plants as potential sources of natural antioxidants. Free radical reactions occur both in the human body as well as in food systems. Reactive oxygen and nitrogen radical species (ROS/RNS) are an integral part of normal physiology. The over-production of these reactive species due to oxidative stress can cause damage to biomolecules and cause cellular injury and death, which may lead to various chronic diseases such as cancers, cardio- and cerebrovascular diseases. In food systems, antioxidants have been used to prolong the shelf life of foods rich in polyunsaturated fatty acids and their derivatives which are readily oxidised by molecular oxygen via lipid peroxidation. This reaction is a major cause of quality deterioration, nutritional losses, off-flavour development and discolouration in foods. Synthetic antioxidants, such as butylated hydroxytoluene (BHT) have been widely used industrially to control lipid oxidation in foods. However, the use of these synthetic antioxidants has been questioned due to their health risks and toxicity. Hence numerous efforts have been put in to search and identify compounds that can act as suitable antioxidants to replace synthetic ones (Löliger, 1991). In addition, naturally occurring antioxidants, when consumed, can also act as neutraceuticals which can help protect one from oxidative damage in the body.

The alternative medicine: Natural herbs which exhibit a wide range of physiological and pharmacological properties. Herbs have a traditional history of use, with a remarkable role in the cultural heritage of appreciating food and its links to health. Current biomedical efforts are focused to provide the evidence for the traditional uses to develop functional foods or nutraceuticals (Krishnaswamy, 2008). Plants contain phytochemicals such as flavonoids, phenolic acids, used to show a remarkable biological activity. Some common foods were assessed for their anti-oxidant, anti-mutagenic, anti-carcinogenic effects, vitamin D activity for their plausible biological effects. Some medicinal plants have been used for treating allergic diseases, such as allergic rhinitis and asthma (Wiart et al., 2005). Although these medicinal plants or herbs have been used as a cure or for health since the olden days, they are now widely used especially in the pharmaceutical, health and food industries. These herbs are also used in cooking, cosmetics, perfumes and as flavors (Gonzalez-Tejero et al., 2008). We can estimate the huge number of plant species which is astoundingly inspiring for researchers to explore their medicinal benefit. The use of Traditional Medicine (TM) to help meet some of their primary health care needs, adaptations of traditional medicine are termed "Complementary "or "Alternative" Medicine (CAM) (Weeks, and Strudsholm, 2008). The medicinal plants research on antioxidants, antiradiation, anti-lipid peroxidation and free radicals scavenging plants. The plants act as a source of antioxidants or free radical scavengers, the antilipid peroxidation and immune modulator. The biological potential and antioxidant activities of some of the most prominent plants and herbs were investigated (Table 1 and Fig. 1).

Plants' antioxidants: Plants are potential sources of natural antioxidants. They absorb the sun's radiation and generate high levels of oxygen as secondary metabolites of photosynthesis. Oxygen is easily activated by Ultra Violet (UV) radiation and heat from the sunlight to produce toxic Reactive Oxygen Species (ROS) (Sharma and Davis, 1997). These ROS are highly reactive because they can interact with a number of cellular molecules and metabolites thereby leading to a number of destructive processes causing cellular damage (Allen et al., 1997). Plants produce various antioxidative, enzymes and non-enzymes, compounds to counteract and detoxify these ROS in order to survive. Hence, naturally occurring phytochemicals possessing antioxidative properties appear to contribute to their chemopreventive or chemoprotective activity (Chiang et al., 2004), has been used to the benefit of human beings.

Plants' most abundant antioxidant substances: Phenolic substances, which possess high antioxidative activity, are actually common phytochemicals in fruits and leafy vegetables. Plants containing phenolic compounds have been reported to possess strong antioxidant properties (Xu and Chang, 2008). Most of these phenolics are classified into two principal groups of phenol; carboxylic acids and flavonoids, the latter being the most significant (Bitsch, 1996). According to Pratt (Pratt, 1992), phenolic compounds are found in all parts of the plant, such as wood, bark, stems, leaves, fruit, root, flowers, pollen and seeds. Antioxidative activity of phenolic compounds is based on their ability to donate hydrogen atoms to free radicals (Cook, 1996). Many phenolic compounds, particularly flavonoids, exhibit a wide range of biological effects, including antioxidant activity, antibacterial, antiviral, anti-inflammatory, antiallergic, anti-thrombotic, vasdilatory actions and the ability to lower the risk of coronary heart diseases (Simonetti et al., 2001). The protective effects of diets high in fruits and vegetables have been attributed to the presence of these compounds (Adedapo et al., 2008). The extracts of *Bidens pilosa* L. var. radiata (Asteraceae) revealed as a good source of caffeoylquinic acid derivatives and flavonoid glycosides which are attributed to a significant antioxidant activity and inhibitory effect on Nitric Oxide (NO) production (an inflammatory mediator) in macrophages (Chiang et al., 2004). The antioxidant effect of flavoniods, is *Scutellaria baicalensis* Georgi (Lamiaceae); used in traditional medical systems of China and Japan. The major constituents of *S. baicalensis* are flavonoids: baicalein, baicalin, wogonin, used as antioxidant, anti-inflammatory, antithrombotic, antibacterial and antiviral (Broncel, 2007).

The antioxidants and free radicals scavenging bioactivity: The antioxidant is used to describe a dietary component that can decrease tissue damage by reactive oxygen (Vimala and Mohd Ilham, 1999). Good examples of plants antioxidants are anthocyanins, which are water-soluble pigments (Lu and Foo, 1995). The antioxidants are help to protect plants from UV damage, which proves to be one of the most relevant environmental risks because of its hazardous effects to human being, such as premature skin aging and especially skin photocarcinogenesis (Ashraf, 2008). Most living organisms possess enzymatic and nonenzymatic defense systems against excessive production of ROS; However, different external factors (smoke, diet, alcohol and some drugs) and aging decrease the efficiency of such protecting systems, resulting in disturbances of the redox equilibrium established under healthy conditions (Leutner et al., 2001). The homeostatic balance between ROS and endogenous antioxidants is important in maintaining healthy tissues. Excessive ROS states are important in diseases such as acute respiratory distress syndrome and Idiopathic Pulmonary Fibrosis (Halliwell, 1994). Redox imbalance increases the breakdown of the extracellular matrix component hyaluronan into lower molecular weight fragments that in turn activate innate immune responses and perpetuate tissue injury (Eberlein et al., 2008). Thus, antioxidants that scavenge ROS may be of great value in preventing the onset and propagation of oxidative diseases like autoimmune diseases, cardiovascular diseases, neurovascular diseases (Willet, 1994). The role of natural antioxidants, mainly phenolic compounds, which may have higher antioxidant activities than those of conventional vitamins C, E and b-carotene (Vinson et al., 1995). Therefore, antioxidants, which can neutralize free radicals, may be of central importance in the prevention of carcinogenicity, cardiovascular and neurodegenerative changes associated with aging (Yu, 1994). The consumption of vegetables and fruits could protect humans against oxidative damage by inhibiting or quenching free radicals and ROS (Ames et al., 1993). Fruits and vegetables are rich sources of many food factors including vitamins, minerals and phytochemicals which may act as antioxidants (Lampe, 1999). The antioxidant activity of fruits and vegetables is often assumed to be of greatest importance in combating a number of degenerative diseases as free radical-related damage has been implicated in causing many of these conditions. Thus a daily consumption of antioxidant-rich food provides the body with the essential antioxidants needed to prevent degenerative diseases, premature aging symptoms, chronic fatigue and general disability (Baghurst et al., 1992). The antioxidants are needed by the human body for optimal well being, especially for maintaining a healthy body system and defense mechanism against cell damage (Rohana et al., 2002). Therefore, antioxidants are the more benefit to human beings. The daily consumption of *Piper sarmentosum* and *Morinda elliptica* (Rubiaceae) leaves, edible medicinal plants, can help maintain energy, general ability and fitness even during aging (Vimala, et al, 2003). The Naringenin, a naturally occurring antioxidant superoxide scavenger, was found in the methanolic leave extracts of *P. sarmentosum* and *M. elliptica* and considered as potent antioxidant food (Tsoyi et al., 2008). Therefore if consumed daily, they could scavenge access free-radicals in the human biological system and could prevent oxidative related diseases (Vimala et al., 2003). Antioxidant food, supplies the body with the essential antioxidant nutrients needed to enhance the immune system, eliminate excess free radicals and keep the oxidative stress state in balance. The consumption of *Morinda citrifolia* (Rubiaceae); may have potential health effects. All the examined fractions, demonstrated high antioxidative activity (Zin et al., 2006). The Rosaceae, *Rosa rugosa* and *Rosa davurica* showed strong radical-scavenging activity. The most effective medicinal plant from families other than Rosaceae was Cedrela sinensis (Meliaceae), *Nelumbo nucifera* (Nelumbonaceae), *Eucommia ulmoides* (Eucommiaceae), *Zanthoxylum piperitum* (Rutaceae), *Cudrania tricuspidata* (Carrière) and *Houttuynia cordata* (Saururaceae) (Cho et al., 2003). It is worth that synthetic antioxidants were found to be harmful to health while most of the natural antioxidants proved to be safer for health and possess better antioxidant activity (Krishnaiah et al., 2007).

The anti-lipid peroxidation and immunemodulatory effects: The antioxidant potential in herbal extract therapeutically important medicinal plants was investigated. Such as *Crataeva nurvala* (Capparidaceae), *Buchanania lanzan* (Anacardium), *A. marmelos* (L.) (Rutaceae), *Dalbergia sissoo* (Fabaceae) and *Cedrela toona* (Meliaceae) showed an excellent lipid peroxidation inhibitory potential and a comparative high NO quenching capacity which was found to be the highest in *C.nurvala*. Hence, the bark of *Crataeva nurvula* has the highest antioxidant capacity (Kumari and Kakkar, 2008). Herbs which are abundant have been proved to possess high antioxidant activity that can be applied for preservation of lipids and reduce lipid peroxidation in biological systems. The antioxidant activity of spice extracts are retained even after boiling for 30 min at 100 °C, indicating that the spice constituents are resistant to thermal denaturation (Shobana and Naidu, 2000). The antioxidant activity of these dietary spices suggests that in addition to imparting flavor to the food, they possess potential health benefits by inhibiting the lipid peroxidation (Jessie, and Krishnakantha, 2005). Some of the dietary constituents commonly used in foods such as cloves (Syzygium aromaticum (L.) Merrill and Perry, Myrtaceae), licorice (*Glycyrrhiza glabra* L, *Fabaceae*), mace (aril of *Myristica fragrans* (Myristicaceae) and greater cardamom (*Amomum subulatum* (Zingiberaceae), were find their effect on the inhibition of lipid peroxidation (Tapsell et al., 2006). The results showed that spices used as significant ability to inhibit lipid peroxidation due to their polyphenol content, strong reducing power and superoxide radical scavenging activity. Cloves showed the highest antioxidant activity probably due to the higher polyphenol content as compared to other spices (Tapsell et al., 2006). A second example of bioactive effects of spices (Shobana and Naidu, 2000). Commonly used spices (garlic, ginger, onion, mint, cloves, cinnamon and pepper) revealed a dose-dependent oxidation inhibition of fatty acid and linoleic acid in the presence of soybean lipoxygenase. Among the spices tested, cloves exhibited the highest effect while onion showed the least antioxidant activity. The relative antioxidant activities decreased in the order of cloves, cinnamon, pepper, ginger, garlic, mint and onion. Spice mix namely ginger, onion and garlic; onion and ginger; ginger and garlic showed cumulative inhibition of lipid peroxidation thus exhibiting their synergistic antioxidant activity (Shobana and Naidu, 2000). Currently, research interest has focused on various herbs that possess hypolipidemic, antiplatelet, antitumor, or immune-stimulating properties that may be useful adjuncts in helping reduce the risk of cardiovascular disease and cancer (Craig, 1999). In different herbs, a wide variety of active phytochemicals, including the flavonoids, terpenoids, lignans, sulfides, polyphenolics, carotenoids, coumarins, saponins, plant sterols, curcumins and phthalides have been identified (Nakatani, 2000). The antioxidant and other properties, herbs and spices can be used in recipes to partially or wholly replace less desirable ingredients such as salt, sugar and added saturated fat. Several metabolic diseases and age-related degenerative disorders are closely associated with oxidative processes in the body, therefore the use of herbs and spices as a source of antioxidants to combat oxidations (Tapsell, et al, 2006). In the immune system, such as phagocytosis, ROS and nitrogen species are generated (Lojek et al., 2008). The generation of ROS by phagocytes is one of the irreplaceable microbicidal tools of innate immunity. If they are left unchecked they can affect the components of the immune system by inducing oxidative damage. This is more so in the elderly or during inflammation where there is excess generation of these reactive species than can be taken care of by the defenses in the form of antioxidants (Li et al., 2007). Dietary supplementation with antioxidants may greatly help in such conditions. There are some indications of possible benefits of antioxidant supplementation. Polyphenols or anti-oxidant-based immunomodulatory activities which can be as therapeutic agents in the inflammation-driven damaging oxidant load (Delgado et al., 2008).

A potent antioxidant spices is turmeric; *Curcuma longa* L. (Zingiberaceae). The Indian traditional medical systems have long used turmeric; a spice is often found in curry powder; for wound healing, rheumatic disorders, gastrointestinal symptoms, deworming, rhinitis and as a cosmetic and traditionally known for its an anti-inflammatory effects (Jagetia and Aggarwal, 2007). Studies have explored its anti-inflammatory, cholekinetic and antioxidant potentials (Suryanarayana et al., 2007). The recent investigations have focused on its preventive effects on precarcinogenic, anti-inflammatory and anti atherosclerotic effects. Both turmeric and curcumin have been found to increase detoxifying enzymes, prevent DNA damage, improve DNA repair, decrease mutations and tumor formation and exhibit antioxidative potential in animals. Recent physiological, pharmacological and biochemical studies appear to support the wisdom of the traditional dietary practices (Krishnaswamy, 2008). Curcumin (diferuloylmethane), an orange-yellow and major component of turmeric; is responsible for its biological actions. Other extracts of this plant has been showing potency too. *In vivo*, curcumin exhibits antiparasitic, antispasmodic, anti-inflammatory and gastrointestinal effects; and also inhibits carcinogenesis and cancer growth (Aggarwal and Harikumar, 2008). The anti-parasitic and anti inflammatory potency was showed by curcumin and extracts of *C. longa* (Pari et al., 2008). Curcumin has been shown in the last two decades to be a potent antioxidant and immunomodulatory agent that can modulate the activation of T cells, B cells, macrophages, neutrophils, natural killer cells and dendritic cells (Varalakshmi et al., 2008). Curcumin can also downregulate the expression of various proinflammatory cytokines and chemokines, most likely through inactivation of the transcription factor NF-kappaB. Interestingly, however, curcumin at low doses can also enhance antibody responses. This suggests that curcumin's reported beneficial effects in arthritis, allergy, asthma, atherosclerosis, heart disease, Alzheimer's disease, diabetes and cancer might be due in part to its ability to modulate the immune system (Jagetia and Aggarwal, 2007).

The *Panax ginseng* C.A. Meyer (Araliaceae) is a well-known medicinal herb and has been used as a herbal remedy and is now a popular and worldwide used natural medicine. The active ingredients of ginseng are ginsenosides which are also called ginseng saponins (Xiang et al., 2008). However, there is different evidence of ginseng efficacy between Traditional Chinese Medicine (TCM), modern pharmacological experiments and clinical trials. In TCM, ginseng is a highly valued herb and has been applied to a variety of pathological conditions and illnesses such as hypodynamia, anorexia, shortness of breath, palpitation, insomnia, impotence, hemorrhage and diabetes (Hwang, et al, 2008). Ginseng possesses multiple constituents (ginsenosides, polysaccharides, peptides, polyacetylenic alcohols), with actions (potent antioxidant activity, CNS effects, neuroprotective effect, immunomodulation, anticancer). And ginsenosides proved to be the part that posses the most of active ingredients, especially Ginsenosides Rg3, which proved to have antioxidant, antiinflammatory, antiapoptotic and immunostimulant properties (Xu et al., 2008). A recent study demonstrated the potential anti-rheumatoid activity of *Panax ginseng* head part and it has potential analgesic and anti-inflammatory activities (Lee et al., 2008). Ginseng has also showed effect mainly on physical, psychomotor performance and cognitive function (Gupta et al., 2001; Reay et al., 2006), immunomodulation, diabetes mellitus (Reay et al., 2005), CVDs (Xiang et al., 2008).

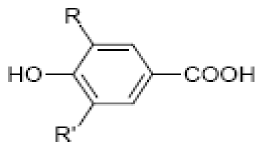
Natural products as radioprotectors: Due to the increased use of ionizing radiation in various aspects of human life especially in areas pertaining to radiotherapy of cancer, food preservation, agriculture, industry and power generation, there is a need to develop an effective and non-toxic radioprotector (Maurya et al., 2006). So, the search for alternative sources, including natural compounds. In traditional of medicine, several plants have been used to treat free radicalmediated ailments and, such plants may also render some protection against radiation damage (Arora et al., 2005). A systematic approach can provide leads to identifying potential new drugs from natural sources, for mitigation of radiation injury (Arora et al., 2005). The available radioprotectors have many drawbacks including high cost, side effects and toxicity (Vasin et al., 2004). Some antioxidant nutrients and phytochemicals have the advantage of low toxicity at pharmacological doses (Weiss and Landauer, 2003). A number of natural compounds, including caffeine, genistein and melatonin, have various physiological effects, as well as antioxidant activity, which in radioprotection (Weiss and Landauer, 2003). A potent radioprotector from plants, include mimics of antioxidant enzymes (Naik et al., 2004), nitroxides, melatonin (Shirazi et al., 2007), growth factors (Dittmann, et al, 2007), gene therapy (Kim and Oh, 2000) and natural products (Naik et al., 2004). Several advantages like they are non-toxic with proven therapeutic benefits. Antioxidant nutrients, such as vitamin E and selenium compounds, are protective against lethality and other radiation effects but to a lesser degree than most synthetic protectors (Maurya et al., 2006). For instance, *Rosemarinus officinalis* (Lamiacea) leave extract and *Zingiber officinale* (Zingiberaceae) have been demonstrated to be good radioprotectors. The latter possesses antioxidant properties that can be effectively utilized for behavioral radioprotection (Haksar, et al., 2006; Jindal et al., 2006).

Phenolics and their antioxidant mechanisms: The “Phenolics and Polyphenolics”, from their rich chemistry to their extensive list of biological properties. Polyphenols are among the most widespread class of metabolites in nature, and their distribution is almost ubiquitous. The majority of the natural-occurring phenolics like cinnamic acids, benzoic acids, flavonoids, proanthocyanidins, coumarins, lignans and lignins and stilbenes (Ralston et al., 2005). Monophenols, such as *p*-coumaric acid, are not polyphenols, they share many of their properties and characteristics, being thus known as “functional polyphenols” (Dixon, 2004). Although a large variety of plant phenols exists (Seabra et al., 2006). Phenolics are act as antioxidants. Phenolic hydroxyl groups are good hydrogen donors: hydrogen-donating antioxidants can react with RO and RN species (Valentão et al., 2003), which breaks the cycle of generation of new radicals. Interaction with the initial reactive species, a radical form of the antioxidant is produced, having a much greater chemical stability than the initial radical. The formation of these relatively long-lived radicals is able to modify radical-mediated oxidation processes (Parr and Bolwell. 2002). The antioxidant capacity of phenolic compounds is also attributed to their ability to chelate metal ions involved in the production of free radicals (Yang et al., 2001). However, phenolics can act as pro-oxidants by chelating metals in a manner that maintains or increases their catalytic activity or by reducing metals, thus increasing their ability to form free radicals (Croft, 1998). Phenolic structures often have the potential to strongly interact with proteins, due to their hydrophobic benzenoid rings and hydrogen-bonding potential of the phenolic hydroxyl groups. This gives phenolics the ability to act as antioxidants also by virtue of their capacity to inhibit some Although strictly speaking monophenols, such as *p*-coumaric acid, are not polyphenols, they share however with these many of their properties and characteristics, being thus known as “functional polyphenols” (Dixon, 2004). Phenolic structures often have the potential to strongly interact with proteins, due to their hydrophobic benzenoid rings and hydrogen-bonding potential of the phenolic hydroxyl groups. This gives phenolics the ability to act as antioxidants also by virtue of their capacity to inhibit some enzymes involved in radical generation, such as various cytochrome P450 isoforms, lipoxygenases, cyclooxygenase and xanthine oxidase (Parr and Bolwell, 2002). Additionally, synergistic effects of phenolics with other antioxidants, namely ascorbic acid, β-carotene and α-tocopherol (Croft, 1998), and regulation of intracellular glutathione levels have also been described (Seabra et al., 2006).

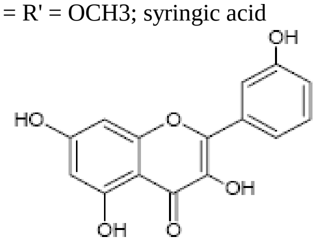
Flavonoids are characterized by a phenylbenzopyran chemical structure (Haslam, 1998). The center heterocycle most commonly exists in one of three forms: pyran, pyrilium, or γ-pyrone (Aron, and Kennedy. 2008). According to the position of the aromatic ring to the benzopyrane moiety, flavonoids can be grouped in four classes: major flavonoids (2-phenylbenzopyrans), isoflavonoids (3-benzopyrans), neoflavonoids (4-benzopyranes) and minor flavonoids. In plants, these compounds occur in nearly all species, usually as a result of their UV screening properties, thus constituting a protection for the plant (Bruneton, 1999). Also, their ability to attract pollinators is well established (Ferreres et al., 2008; Andrade et al., 2008). Increasingly, flavonoids are becoming the subject of medical research. They have been reported to possess many useful properties, including anti-inflammatory, oestrogenic, enzyme inhibition, antimicrobial, antiallergic, vascular and cytotoxic antitumour (Cushnie and Lamb, 2005), and antioxidant activity attributed to flavonoids. The antioxidant activity of flavonoids is also responsible for other biological activities in which the prevention of oxidative stress is beneficial. For example, the anticancer activity of some compounds is due to their ability to scavenge free radicals, thus avoiding the early stages of cancer promotion. Besides this mechanism, flavonoids have also been reported to act as anticancer agents *via* regulation of signal transduction pathways of cell growth and proliferation, suppression of oncogenes and tumor formation, induction of

PHENOLIC ACIDS

Benzoic acid derivatives

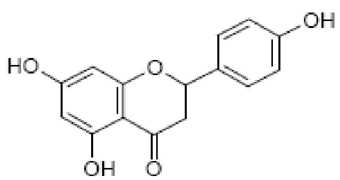


R = R' = H; *p*-hydroxybenzoic acid
R = OH, R' = H; protocatechuic acid
R = OCH3, R' = H; vanillic acid
R = R' = OH; gallic acid
R = R' = OCH3; syringic acid



Kaempferol

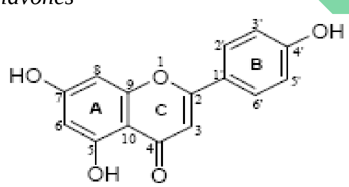
Flavanones



Naringenin

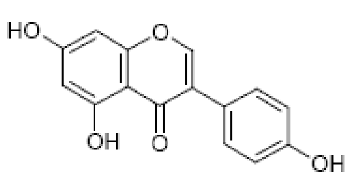
FLAVONOIDS

Flavones



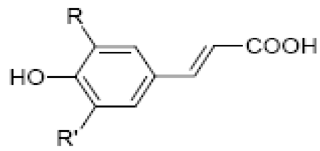
Apigenin

Isoflavones

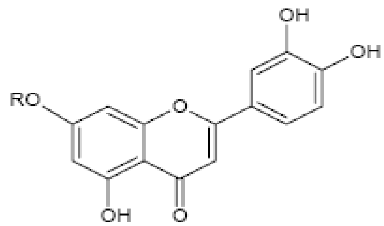


Genistein

Cinnamic acid derivatives

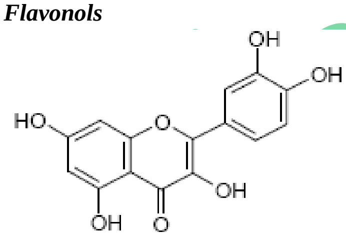


R = R' = H; *p*-coumaric acid
R = OH, R' = H; caffeic acid
R = OCH3, R' = H; ferulic acid
R = R' = OCH3; sinapic acid



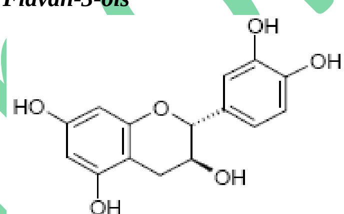
R=H, Luteolin
R=Glc, Luteolin-7-O-glucoside

Flavonols

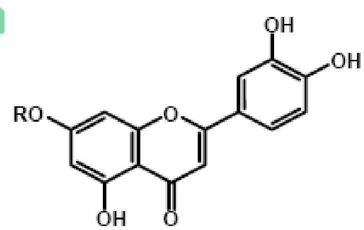


Quercetin

Flavan-3-ols



(+)-catechin

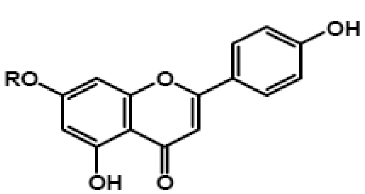


R=H Luteolin
*R=GlcU Luteolin 7-*O*-glucuronide*
*R=GlcU-GlcU Luteolin 7-*O*-diglucuronide*

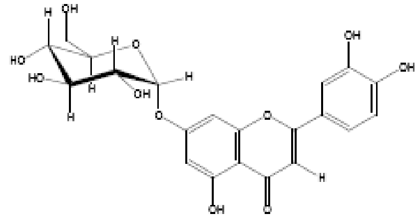
Fig. 1: Chemical classes of polyphenolic compounds; Structures of Some major polyphenolic compounds

apoptosis, modulation of enzyme activity related to detoxification, oxidation and reduction, stimulation of the immune system and DNA repair, and regulation of hormone metabolism (Aron and Kennedy, 2008). Other flavonoid classes also act as potent molecules for the treatment of other pathologies. Some isoflavones, whose estrogen-like capacity is now well established, the activity of these compounds is related with their similarity to estradiol estrogen for the treatment of conditions in which the agonist effect in estrogen receptors is beneficial, such as menopause conditions. Several preparations containing these compounds, mainly soya-derived, are now used in therapeutics (Dixon and Ferreira, 2002).

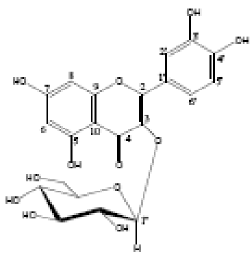
Cinnamic acids: L-Phenylalanine and L-tyrosine, as C6C3 building blocks, are precursors for a wide range of natural products. In plants, a frequent first step is the elimination of ammonia from the side-chain to generate the appropriate *trans*-(*E*)-cinnamic acid. In the case of phenylalanine, this would give cinnamic acid, whilst tyrosine could yield 4-coumaric acid (*p*-coumaric acid). All plants appear to have the ability to deaminate phenylalanine *via* phenylalanine ammonia lyase (PAL) enzyme, but the corresponding transformation of tyrosine is more restricted, being mainly limited to members of the grass family (the Graminae/Poaceae). The most common cinnamic acid is caffeic acid, occurs in fruits and vegetables mainly as an ester with quinic acid (chlorogenic acid or 5-caffeoylquinic acid) (Seabra et al., 2006). The antioxidant activity is related to the number and position of hydroxyl groups. The antioxidant efficiency of mono-phenols is strongly enhanced by the introduction of a second hydroxyl group at the *ortho*- or *para*- positions, and is increased by one or two methoxy substitutions in *ortho*-position with respect to the hydroxyl group (Fukumoto and Mazza, 2000; Dewick, 2002). While flavonoids present several physical properties, which have made photodiode array detection a very useful approach, phenolic acids. Contrarily to flavonoids, a great number of phenolic acids are commercially available, thus allowing a definitive identification. But this methodology is not applied to phenolic acids derivatives with quinic or tartaric acids, or glycosylated ones. Most polyphenols, cinnamic acids also exhibit strong antioxidant properties. This activity can be expressed in several ways. For instance, 1,5-dicaffeoylquinic acid has been revealed to be an hepatoprotector when challenged by carbon tetrachloride, a mechanism



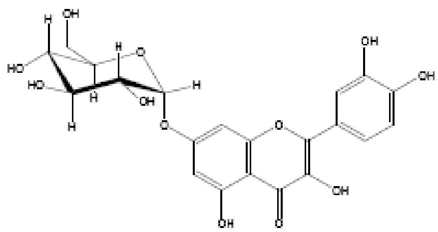
H Apigenin
*Glu-Caf Apigenin 7-*O-*caffeoylglucoside*
*GlcU-GlcU Apigenin 7-*O-*diglucuronide*



Luteolin 7-*O*-4C1-D-glucoside

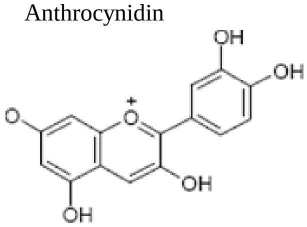


Quercetin 3-*O*-4C1-D-glucopyranoside



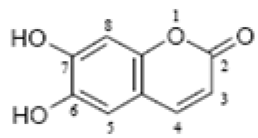
Quercetin 7-*O*-4C1-D-glucoside

Anthrocynidin

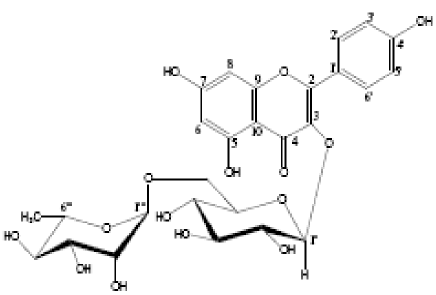


Cyaniding

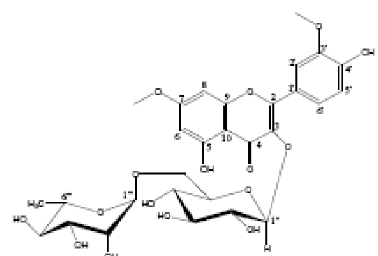
Coumarin



Esculetin

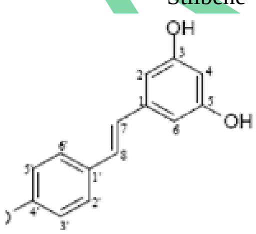


Kaempferol-3-*O*-(6"-*O*-L-rhamnopyranosyl)-D-glucopyranoside (nicotiflorin).



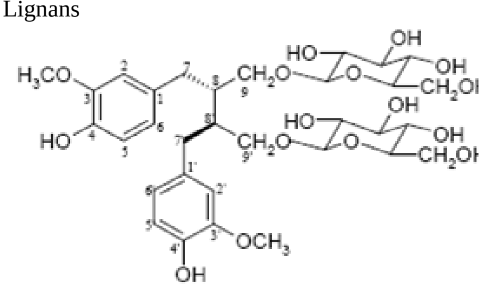
7,3` dimethoxy quercetin 3-*O*-(6"-*O*-L-rhamnopyranosyl)-D-gluco-pyranoside (rhamnazin 3-O-rutinoside)

Stilbene



Resvratrol

Lignans



Secoisolariciresinol diglycoside

Fig. 1: *Continuous….*

that involves, among others, radical scavenging (Bruneton, 999).

Lignin and lignans: Cinnamic acids also feature in the pathways to other metabolites. An important example is the plant polymer lignin, a strengthening material for the plant cell wall which acts as a matrix for cellulose microfibrils. Lignin represents a vast reservoir of aromatic materials, mainly untapped because of the difficulties associated with release of these metabolites. The action of wood-rotting fungi offers the most effective way of making these useful products more accessible. Lignin is formed by phenolic oxidative coupling of hydroxycinnamoyl alcohol monomers, brought about by peroxidase enzymes. The most important of these monomers are 4-hydroxycinnamoyl alcohol (*p*-coumaroyl alcohol), coniferyl alcohol, and sinapoyl alcohol, though the monomers used vary according to the plant type (Dewick, 2002). In what concerns to bioactivity, it is poorly studied and aside from antioxidant activity, the number of studies on this matter are rather scarce. Nevertheless, tyrosine inhibiting activity has been described (Azhar-ul-Haq et al., 2006). Lignans are organic compounds resultant from the establishment of a link between β carbons of the side chain of two 1-phenylpropane derivatives (8-8’ link). Numerous compounds possess cytostatic and antimitotic properties, perhaps the most widely known bioactivity. However, only hemisynthetic derivatives of podophylotoxin (obtained from the rhizome of *Podophyllum peltatum*) have been explored in therapeutics. In addition, several other properties have been reported for lignans: inhibition of AMPc phosphodiesterase and of enzymes from the respiratory chain and antihypertensive activity (Bruneton, 1999).

Anthocyanins: Anthocyanins are water soluble plant pigments and responsible for the blue, purple and red colors of many plant tissues (Prior and Wu, 2006). These compounds are glycosylated polyhydroxy- and polymethoxy-derivatives of 2-phenylbenzopyrylium (flavylium) salts. The most common sugars are glucose, galactose, rhamnose and arabinose (Wu and Prior, 2005). Despite the knowledge of about 17 anthocyanidins (anthocyanin aglycones), only six of them are all over distributed in nature: cyanidin, delphinidin, petunidin, peonidin, pelargonidin and malvidin. With the exceptions of 3-deoxyanthocyanidins and their derivatives, there is always a glycosyl group in C-3, which means that aglycones are rarely found in nature. The sugar moiety may be acylated by aromatic acids, mostly hydroxycinnamic acids (caffeic, ferulic, *p*-coumaric or sinapic acids) and sometimes by aliphatic acids, namely malonic and acetic acids. The multiple possibilities regarding the identity and position of sugars and acyl moieties, as well as the position and number of hydroxy and methoxy groups on the anthocyanidin skeleton, gives rise to a great number of compounds. In the past few years, more attention has been given to the study of adducts between anthocyanins and several other compounds, such as organic acids, either natural-occurring or synthetic. Pigment, the structure of which corresponded to a pyruvic acid adduct of malvidin 3-glucoside linked to a vinyl phenol group (Mateus et al., 2006). An unusual *C*-glycosyl-anthocyanin has been described from flowers of the toad lily, *Tricyrtis formosana* (Liliaceae) (Tatsuzawa et al., 2004). This species remains the only recorded source of C-glycosylanthocyanins. Recently, significant anti-cancer properties of some anthocyanins against a range of cell lines have been described (Zhang et al., 2008).

Tannins: The designation of tannin includes compounds of two distinct chemical groups: hydrolysable tannins (polymers of ellagic acid, or of gallic and ellagic acids, with glucose) (Bruneton, 1999) and condensed tannins, which result from the condensation of monomers of flavan-3-ol units (Waterhouse. 2002). Tannins are substances that are able to combine with proteins of animal hide preventing their putrefaction and converting them into leather. This ability comprises all kinds of proteins and, therefore, enzymes are included. Given their relationship to phenolic acids and flavonoids, their antioxidant properties are not a surprise: they exert their antioxidant activity by scavenging free radicals, chelating trace metals and by binding proteins with suppression of their enzymatic activity. The scavenging activity of tannins increases with an increase in the number of galloyl groups and molecular weight and in the presence of an *ortho*-dihydroxy structure: the hydroxyl groups are responsible for the chelating and radical scavenging properties of these compounds (Yokozawa et al., 1998). While sharing some antioxidant activities with other phenolics, recent works (Muthusamy et al., 2008) have described the capacity of tannins to enhance glucose uptake and inhibit adipogenesis, thus being potential drugs for the treatment of non-insulin dependent diabetes mellitus. As it was said to flavonoids, the antioxidant properties of tannins are equally responsible for other interesting biological properties. Flavan-3-ols are thought to interfere in the pathogenesis of cardiovascular disease *via* several mechanisms: antioxidative, antithrombogenic, and antiinflammatory. In particular, proanthocyanidins and flavan-3-ol monomers aid in lowering plasma cholesterol levels, inhibit LDL oxidation, and activate endothelial nitric oxide synthase to prevent platelet adhesion and aggregation that contribute to blood clot formation (Bagchi et al., 2003).

Coumarins: To this days, around 1300 coumarins are known, with all of them being derivatives of 5,6-benzo-2-pirone (*α*-chromone). As derivatives of simple coumarins, other compounds are known, such as furanocoumarins, which include a furanic ring, linear pyranocoumarins, angular pyranocoumarins, dimeric coumarins, of which dicoumarol is an example and also furanochromones. The ability of dicoumarol to inhibit blood clotting, that later led to the development of the anticoagulant drug warfarin, was the first call to this class of compounds' biological properties. Several biological activities have been reported in natural-occurring coumarins, from photo sensitizers to vasodilatation. Recently, the interest has been given to synthetic derivatives of coumarins, such as fluorinated and 1-azo coumarins, which displayed moderate analgesia properties, and excellent anti-inflammatory and anti-microbial activities. As demonstrated in this special issue of Molecules, phenolic compounds, themselves, or present in natural matrices, are object of profound interest, in what concerns their chemistry and their interesting biological and pharmacological properties (Proença da Cunha, 2005; Kalkhambkar et al., 2008).

Phytochemicals exerting antioxidant actions are largely being recognized as of benefiting human health and disease prevention. These benefits may be a result of concerted actions of well-known antioxidants such as vitamin C, vitamin E and β-carotene. Indeed, phenolic compounds are ubiquitously distributed in the plant kingdom and exhibit a wide range of medicinal properties, including anti-inflammatory, anti-carcinogenic viral, anti-allergic and immune-stimulating agents. These protective effects have been mostly ascribed to their free radical scavenging, metal chelating and chain breaking effects. Many literature reports show a relatively strong correlation between the total phenolic content and the antioxidant capacity of plant extracts (Tawaha et al., 2007). In recent years, intensive research on natural antioxidants derived from plants has grown due to their potential health-benefits in the search for replacements of synthetic antioxidants. The phenolic compounds and their antioxidant properties present (Maisuthisakul et al., 2008). Various parts of many wild plants are traditionally used as food or medicine and may contribute as potential sources for new natural antioxidants. The antioxidant activities of plants are identifying new sources of natural antioxidants (Phomkaivon and Areekul, 2009).

Phenolic compounds are commonly found in both edible and nonedible plants, and have multiple biological effects, including antioxidant activity. Crude extracts of fruits, herbs, vegetables, cereals, and other plant materials rich in phenolics are increasingly of interest in the food industry because they retard oxidative degradation of lipids and improve the quality and nutritional value of food. The importance of the antioxidants in the maintenance of health and protection from coronary heart disease and cancer, and other health effects (Lo-liger, 1991). Flavonoids and other phenolics have play a preventive role in the development of cancer and heart diseases (Carbonneau et al., 1998). Consumption of controlled diets high in fruits and vegetables increased significantly the antioxidant capacity of plasma, and the increase could not be explained by the increase in the plasma R-tocopherol or carotenoid concentration (Cao et al., 1998). Moreover, epidemiological studies have found that significant negative association between the intake of fruits and vegetables and heart disease mortality (Knekt et al., 1996).

Potential sources of antioxidant compounds are several types of plant materials such as vegetables, fruits, leaves, oilseeds, cereals, spices, herbs, and crude plants (Ramarathnam et al, 1995). Flavonoids and other plant phenolics, such as phenolic acids, stilbenes, tannins, lignans, and lignin, are especially common in leaves, flowering tissues, and woody parts such as stems and barks. They are important in the plant for normal growth development and defense against infection and injury. Flavonoids also partly provide plant colors present in flowers, fruits, and leaves. They generally occur as glycosylated derivates, although conjugation with inorganic sulfates or organic acid (Heldt, 1997). The antioxidant activity of phenolics is mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donators, and singlet oxygen quenchers. In addition, they have a metal chelation potential (Rice-Evans et al, 1995). Berries and fruits contain a wide range of Flavonoids and phenolic acids that show antioxidant activity. Main flavonoid subgroups in berries and fruits are anthocyanins, proanthocyanins, flavonols, and catechins. Phenolic acids present in berries and fruits are hydroxylated derivates of benzoic acid and cinnamic acid (Macheix et al, 1990). Studies on antioxidative activities of fruit extracts have been focused mainly on grapes, which have been reported to inhibit oxidation of human lowdensity lipoprotein (LDL) at a level comparable to wine (Meyer et al, 1997). Fresh strawberry extract have 15 times higher antioxidant capacity than trolox in an artificial peroxyl radical model system (Wang et al, 2005). Extracts of blackberries, black and red currants, blueberries, and black and red raspberries possessed a remarkably high scavenging activity toward chemically generated superoxide radicals (Constantino et al, 1992). Hydroxycinnamic acids typically present in fruits have been shown to inhibit LDL oxidation in vitro (Meyer et al, 1998). Also phenolic extracts of berries (blackberries, red raspberries, sweet cherries, blueberries, and strawberries) were shown to inhibit human LDL and liposome oxidation (Heinonen et al, 1998b).

Studies on phenolic composition and antioxidant action of vegetable extracts have been reported recently. Beans (kidney and pinto), followed by beet, corn, and broccoli, showed highest total phenol content per fresh weight among 22 vegetables analyzed. By using a LDL oxidation method and a combined measure of the quality and quantity of phenol antioxidants present in the vegetables (per fresh weight), kidney and pinto beans were also ranked at the top in respect to the antioxidant ability. Garlic, yellow and red onion, asparagus, snap bean, beet, potato, and broccoli were also evaluated among the 10 most potent vegetables (Vinson et al, 1998). Besides flavoring purposes, spices and herbs have been used also for their medical or antiseptic properties. The preservative effect of many spices and herbs suggests the presence of antioxidative and antimicrobial constituents. Rosemary and sage were remarkably effective, and oregano, thyme, turmeric, and nutmeg also showed high antioxidant activity in the ground form and as extracts. Several later studies confirmed that many leafy spices, especially those belonging to the Labiatae family such as sage, rosemary, oregano, and thyme, show strong antioxidant activity (Hirasa and Takemasa, 1998). A number of phenolic compounds with strong antioxidant activity have been identified in these plant extracts (Nakatani, 1997). Cereals contain a wide range of phenolic compounds. A significant amount of phenolic acids such as ferulic, caffeic, *p*-hydroxybenzoic, protocatechuic, *p*-coumaric, vanillic, and syringic acids is typical to cereals. These compounds occur in the grain primarily in the bound form as conjugates with sugars, fatty acids, or protein (White and Xing, 1997). The phenolic antioxidants in oats have been studied extensively since the 1930s, but less attention has been given to other common cereals. Methanolic extracts of oats have been found to have significant antioxidant effects (Tian and White, 1994).

A variety of tree materials are known to be remarkable sources of phenolic compounds. Several phenolics have been isolated and identified from conifer needles; from bark of birch, spruce, and pine (Pan, 1995); and from white birch and silver birch leaves (Ossipov et al, 1996). Pycnogenol (procyanidin extract of the bark of *Pinus maritima*) is probably the most studied phenolic tree extract. It has been shown to scavenge free radicals, including hydroxyl and superoxide anions (Noda et al, 1997), and it may have beneficial effects in preventing atherosclerosis and other age-related diseases (Fitzpatrick et al, 1998). Very scarce data on the quantity of phenolic compounds and the antioxidant activity of phenolic tree extracts in lipid systems have been reported. Even though intensive studies on the phenolic constituents in numerous plant sources have been conducted, the composition data are yet insufficient. Phenolic profiles often have been analyzed after hydrolyzation of the glycosidic bonds in order to simplify the identification process; necessary information of the authenthic structure of the compounds is lost. It is known that the degree of glycosylation significantly affects the antioxidant properties of the compound. For example, aglycones of quercetin and myricetin were more active than their glycosides in bulk methyl linoleate (Hopia and Heinonen, 1999). Also the wide variety of oxidation systems and ways to measure activity used in antioxidant evaluations make it difficult to compare results from different studies. The aim of this study was to screen a large number of plant material extracts of Finnish origin with respect to their total phenolic content and antioxidant activity in order to find new potential sources of natural antioxidants.

It is widely accepted that a plant-based diet with high intake of fruits, vegetables, and other nutrient-rich plant foods may reduce the risk of oxidative stress-related diseases (Johnson.2004). Understanding the complex role of diet in such chronic diseases is challenging since a typical diet provides more than 25,000 bioactive food constituents (Stanner et al, 2004), many of which may modify a multitude of processes that are related to these diseases. Most bioactive food constituents are derived from plants; those so derived are collectively called phytochemicals. The large majorities of phytochemicals are redox active molecules and therefore defined as antioxidants. Antioxidants can eliminate free radicals and other reactive oxygen and nitrogen species, and these reactive species contribute to most chronic diseases. It is hypothesized that antioxidants originating from foods may work as antioxidants in their own right in vivo, as well as bring about beneficial health effects through other mechanisms, including acting as inducers of mechanisms related to antioxidant defense

Table 1: Some antioxidant medicinal plants

Scientific name	Common name Family	Used part (s) Medical usage
Amaranthus gangeticus L.	Red spinach or elephant head amaranth Amaranthaceae	Leaf Antioxidant (Ching, and Mohamed, 2001)
Amaranthus spinosus L.	Spiny amaranth Amaranthaceae	Leaf Antioxidant (Ching, and Mohamed, 2001)
Anacardium occidentale L.	Cashew Anacardiaceae	Shoot Antioxidant (Ching, and Mohamed, 2001)
Apium graveolens L.	Local celery Apiaceae	Leaf Antioxidant (Ching, and Mohamed, 2001)
Daucus carota L.	Carrot Apiaceae	Root Antioxidant (Ching, and Mohamed, 2001)
Colocasia esculentum var. *antiquorum* (Schott) F.T. Hubb. and Rehder	Elephant ear Araceae	Leaf talk Antioxidant (Ching, and Mohamed, 2001)
Calamus scipionum Lour.	No common name Arecaceae	Leaf Antioxidant (Ching, and Mohamed, 2001)
Elaeis guineensis (L.) Jacq.	African oil palm Arecaceae	Frond Antioxidant, vasorelaxation properties and LDLr* modulation effects (Salleh, et al, 2002)
Bidens pilosa Linn. Var. *radiata*	Hairy Beggarticks Asteraceae	Whole plant Antioxidant and NO* inhibitory (Chiang, et al, 2004)
Diplazium esculentum Swartz (Retzius)	Vegetable fern Athyriaceae	Shoot Antioxidant (Ching, and Mohamed, 2001)
Brassica alboglabra	Bailey Chinese kale Brassicaceae	leaves Antioxidant (Miean, and Mohamed, 2001)
Brassica oleracea L.	Cauliflower, Broccoli, Cabbage Chinese cabbage Brassicaceae	Flower leaves Antioxidant (Miean, and Mohamed, 2001)
Raphanus sativus L.	White radish Brassicaceae	Root Antioxidant (Miean, and Mohamed, 2001)
Gynandropsis gynandra Briq. (L.)	Cat's whisker Capparaceae	Leaf Antioxidant, LDLr modulation effects and Vascular relaxation properties (Miean, and Mohamed, 2001)
Carica papaya L.	Papaya Caricaceae	Shoots Antioxidant, LDLr modulation effects and vasorelaxation properties (Miean, and Mohamed, 2001)
Garcinia atroviridis Griff. ex T.	Asam gelugur Clusiaceae	Fruits Antioxidant, antitumour (Miean, and Mohamed, 2001)
Ipomoea aquatic	Water spinach Convolvulaceae	Leaf Antioxidant (Miean, and Mohamed, 2001)
Ipomoea batatas L.	Sweet potato Convolvulaceae	Shoots Antioxidant and LDLr modulation effects (Ching, and Mohamed, 2001)
Cucurbita maxima Duch. ex. Lam.	Pumpkin Cucurbitaceae	Fruit Antioxidant (Ching, and Mohamed, 2001)
Luffa acutangula Roxb.	Angular loofah Cucurbitaceae	Fruit Antioxidant (Ching, and Mohamed, 2001)
Momordica charantia L.	Bitter melon Cucurbitaceae	Fruit Antioxidant (Chandra, et al, 2008)
Trichosanthes anguina L.	Snake gourd Cucurbitaceae	Fruit Antioxidant (Ching, and Mohamed, 2001)
Elaeocarpus kontumensis Gagnep.	No common name Elaeocarpaceae	Bark Antimalarial (Nguyen-Pouplin, et al, 2007)
Manihot utilissima Pohl.	Cassava Euphorbiaceae	Shoots Antioxidant and antitumour (Rahmat, et al, 2004)
Sauropus androgynus (L.) Merr.	Star gooseberry Euphorbiaceae	Leaf-antioxidant Shoot Antioxidant and antitumour (Rahmat, et al, 2004)
Glycine max (Linnaeus)	Soybean Fabaceae	Sprout Antioxidant (Miean, and Mohamed, 2001)
Pachyrrhizus erosus Linn.	Sinkamas Fabaceae	Root Antioxidant (Miean, and Mohamed, 2001)
Parkia speciosa	Hassk Stink bean Fabaceae	Seed/bean Antioxidant (Ching, and Mohamed, 2001)
Phaseolus aureus Roxb.	Mung bean Fabaceae	Sprout Antioxidant (Ching, and Mohamed, 2001)
Phaseolus vulgaris	Linnaeus Dwarf bean Fabaceae	Seed/bean Antioxidant (Miean, and Mohamed, 2001)
Pisum sativum L.	Shelling peas Fabaceae	Seed/bean Antioxidant (Miean, and Mohamed, 2001)
Psophocarpus tetragonolobus DC.	Winged bean Fabaceae	Seed/bean Antioxidant(Ching, and Mohamed, 2001)
Sesbania grandifolia (L.) Pers.	Butterfly Tree or agati Fabaceae	Leaf Antioxidant (Miean, and Mohamed, 2001)
Vigna sinensis (L.)	Savi String bean or green bean Fabaceae	Seed/bean Antioxidant (Ching, and Mohamed, 2001)
Centella asiatica (L.) Urb.	Pegaga or gotu kola Hydrocotylaceae	Leaf Antioxidant (Ching, and Mohamed, 2001)
Mentha agrestis Soll.	Japanese mint Lamiaceae	Leaf Antioxidant and LDLr modulation effects (Miean, and Mohamed, 2001)
Leea indica (Burm.f.) Merr.	Bandicoot berry Leeaceae	Whole plant Antioxidant and NO inhibitory (Saha, et al, 2004)
Allium odorum L.	Chinese chives Liliaceae	Leaves Antioxidant (Miean, and Mohamed, 2001)
Allium fistulosum L.	Welsh Onion Liliaceae	Leaves Antioxidant (Miean, and Mohamed, 2001)
Allium sativum L.	Common garlic Liliaceae	Root Antioxidant (Miean, and Mohamed, 2001)
Hibiscus esculentus(L.)	Moench Lady's fingers Malvaceae	Fruit Antioxidant (Shui, and Peng, 2004)
Hibiscus sabdarifa L.	Roselle Malvaceae	Calyx LDL antioxidant and LDLr modulation effects (Salleh, et al, 2002)
Musa sapientum L.	Common banana Musaceae	Flower Antioxidant (Mohan Kumar, et al, 2006; Dhanabal, et al, 2005)
Psidium guajava L.	Guava Myrtaceae	Fruit Antioxidant (Goel, et al, 2001; Qian, and Nihorimbere, 2004)

Table 1: *Continuous……*

Capsicum frutescens L.	Bird chili Solanaceae	Fruit Antioxidant, LDLr (Ching, and Mohamed, 2001)
Lycium chinense Mill.	Chinese Wolf-berry Solanaceae	Leaf Antioxidant modulation effects and vasorelaxation properties (Ching, and Mohamed, 2001)
Solanum melongena L.	Egg plant Solanaceae	Fruit Antioxidant (Miean, and Mohamed, 2001)
Lycium chinense Mill.	Chinese Wolf-berry Solanaceae	Leaf Antioxidant (Miean, and Mohamed, 2001)
Solanum melongena L.	Egg plant Solanaceae	Fruit Antioxidant (Miean, and Mohamed, 2001)
Chasalia chartacea	No common name Rubiaceae	Whole plant Antioxidant and NO inhibitory (Saha, et al, 2004)
Hedyotis verticillata L.	Hedyotis plant Rubiaceae	Whole plant Antioxidant and NO inhibitory (Saha, et al, 2004)
Lasianthus oblongus King and Gamble	No common name Rubiaceae	Whole plant Antioxidant and NO inhibitory (Saha, et al, 2004)
Morinda citrifolia L.	Indian mulberry Rubiaceae	Leaf Antioxidant, LDLr, modulation effects and Vascular relaxation properties (Zin, et al, 2006)
Morinda elliptica	Ridley Magic fruit Rubiaceae	Leaf Antioxidant (Vimala, et al, 2003, Chong, et al, 2004)
Psychotria rostrata Blume	No common name Rubiaceae	Leaf and Stem Antioxidant (Saha, et al, 2004, Vimala, et al, 2003)
Spermacoce articularis L. f.	poaia Rubiaceae	Whole plant Antioxidant and NO inhibitory (Saha, et al, 2004)
Spermacoce exilis (L. O. Williams) C. D. Adams	Pacific false buttonweed Rubiaceae	Whole plant Antioxidant (Saha, et al, 2004)
Citrus hystrix D.C	Kaffir lime Rutaceae	Leaf Antioxidant (Miean, and Mohamed, 2001)
Thea chinensis Sims.	Green tea Theaceae	Leaf Antioxidant (Miean, and Mohamed, 2001)
Piper sarmentosum Roxb	Sireh Piperaceae	Leaf Antioxidant (Vimala, et al, 2003,, Rukachaisirikul, et al, 2004)
.		
Polygonum minus Huds.	Small smartweed/ kesum Polygonaceae	Leaf Antioxidant (Ching, and Mohamed, 2001)
Alpinia hookeriana Val.	No common name Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)
Alpinia mutica Roxb.	Small Shell Ginger or Orchid Ginger Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)
Alpinia nutans Rosc.	Ginger Lily or Shell Ginger Zingiberaceae	Rhizome and Antioxidant and antibacterial (Habsah, et al, 2000)
Alpinia rafflesiana Wall. ex. Bak.	Raffles' Alpinia Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Mohamad, et al, 2004)
Alpinia vitellina Ridl. (Lindl.)	No common name Zingiberaceae	Rhizome and Antioxidant and antibacterial (Habsah, et al, 2000)
Costus discolor Rosc.	Setawar putih Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)
Costus megalobractea K. Schum.	No common name Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)
Costus spiralis Rosc.	Spiral ginger Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)
Costus villosissimus Jacq.	Spiral flag Zingiberaceae	Rhizome root parts and Antioxidant and antibacterial (Habsah, et al, 2000)
Curcuma longa L.	Turmeric Zingiberaceae	Root Antioxidant and antitumour (Miean, and Mohamed, 2001,156)
Curcuma mangga Valeton and van Zijp	Mango ginger Zingiberaceae	Rhizome Antioxidant, antitumour and antiallergic (Tewtrakul, and Subhadhirasakul, 2007)
Etlingera elatior (Jack) R. M. Sm.	Torch ginger Zingiberaceae	Flower Antioxidant (Ching, and Mohamed, 2001)
Zingiber cassumunar Roxb.	Cassumunar ginger or Thai ginger Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial, Rhizome Antiallergic (Tewtrakul and Subhadhirasakul, 2007)
Zingiber ottensii Val.	Black cleanser Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)
Zingiber macroglossum Val.	No common name Zingiberaceae	Rhizome and root parts Antioxidant and antibacterial (Habsah, et al, 2000)

(Kensler et al, 2007), longevity (Baur et al, 2006), cell maintenance and DNA repair (Astley et al, 2004).

The total antioxidant content of complex diets, identify and rank potentially good sources of antioxidants, and provide the research community with comparable data on the relative antioxidant capacity of a wide range of foods. There is not necessarily a direct relationship between the antioxidant content of a food sample consumed and the subsequent antioxidant activity in the target cell. Factors influencing the bioavailability of phytochemical antioxidants, include the food matrix, absorption and metabolism (Manach et al, 2005). Also, the methods measuring total antioxidant capacity do not identify single antioxidant compounds, and they are therefore of limited use when investigating the mechanisms involved.

Food samples with high antioxidant content are identified, but further investigation into each individual food and phytochemical antioxidant compound is needed to identify those which may have biological relevance and the mechanisms involved. The foods to identify total antioxidant capacity of fruits, vegetables, beverages, spices and herbs in addition to common everyday foods (Carlsen et al, 2010). The categories "Herbal / traditional plant medicine" and "Vitamin and dietary Supplements" some products may rightfully be classified as both an herbal medicine and a supplement, but are still assigned to only one category. All berries, fruits, and vegetables were fresh samples unless otherwise noted in the database (Halvorsen et al, 2006; Dragland et al, 2003).

DISCUSSION

With this study we present a comprehensive survey of the total antioxidant capacity in foods. Earlier small-scale studies from other laboratories have included from a few up to a few hundred samples (Pellegrini et al, 2006; Lee et al, 2003; Richelle et al, 2001). These studies have been done using different antioxidant assays for measuring antioxidant capacity making it difficult to compare whole lists of foods, products and product categories. Still, a food that has a high total antioxidant capacity using one antioxidant assay will most likely also be high using another assay (Miller et al, 2000; Pellegrini et al, 2003; Pellegrini et al, 2006). Consequently, the exact value will be different but the ranking of the products will be mainly the same whichever assay is used. In the present extensive study, the same validated method has been used on all samples, resulting in comparable measures, thus enabling us to present a complete picture of the relative antioxidant potential of the samples. When classifying the samples into the three main classes the difference in antioxidant content between plant- and animal-based foods become apparent. The results here uncover that the antioxidant content of foods varies several thousand-fold and that antioxidant rich foods originate from the plant kingdom while meat, fish and other foods from the animal kingdom are low in antioxidants. Diets comprised mainly of animalbased foods are thus low in antioxidant content while diets based mainly on a variety of plantbased foods are antioxidant rich, due to the thousands of bioactive antioxidant phytochemicals found in plants which are conserved in many foods and beverages. Most of the spices and herbs analyzed have particularly high antioxidant contents. Although spices and herbs contribute little weight on the dinner plate, they may still be important contributors to our antioxidant intake, especially in dietary cultures where spices and herbs are used regularly. We interpret the elevated concentration of antioxidants observed in several dried herbs compared to fresh samples, as a normal consequence of the drying process leaving most of the antioxidants intact in the dried end product. This tendency is also seen in some fruits and their dried counterparts. Thus, dried herbs and fruit are potentially excellent sources of antioxidants. Herbal and traditional plant medicines emerged as many of the highest antioxidant-containing products in our study. The high inherent antioxidant property of many plants is an important contributor to the herb's medicinal qualities. The sap from the tree trunk of the species *Croton lechleri* sampled has exceptional high antioxidant content. This sap has a long history of indigenous use for wound healing and as an antifungal, antiseptic, antiviral and antihaemorrhagic medicine. Proanthocyanidins are major constituents of this sap (Cai et al, 1991) and studies have shown that limits the transcription of a wide range of pro-inflammatory cytokines and mediators and accelerates the healing of stomach ulcers (Miller et al, 2001) and promotes apoptosis in cancer cells (Sandoval et al, 2002). Other extreme antioxidant rich herbal medicines are Triphala, an Indian Ayurvedic herbal formulation, shown to have anti-inflammatory activity (Rasool and Sabina. 2007), antibacterial and wound healing properties (Kumar et al, 2008) and cancer chemopreventive potential (Deep et al, 2005). Arjuna, another Auyrvedic formula, has been shown to have health beneficial activities (Manna et al, 2007) while Goshuyu-tou, a traditional Chinese kampo medicine has been shown to significantly reduce the extracellular concentration of NO in the LPS-stimulated Raw 264.7 cells (Okayasu et al, 2003). With their high content of phytochemicals such as flavonoids, tannins, stilbenoids, phenolic acids and lignans (Maatta-Riihinen et al, 2004) berries and berry products are potentially excellent antioxidant sources. The phytochemical content of berries varies with geographical growing condition, and between cultivars (Scalzo et al, 2005) explaining the variations found in our study. During the processing of berries to jams, total phenol content is reduced (Amakura et al, 2000) resulting in lower antioxidant values in processed berry products than in fresh berries. Nuts are a rich source of many important nutrients and some are also antioxidant-rich. The observed increase in antioxidant content in nuts with pellicle compared to nuts without pellicle is in good agreement with earlier studies showing the flavonoids of many nuts are found in the nut pellicle (Chen et al, 2005). After water, tea and coffee are the two most consumed beverages in the world, although consumption patterns vary between countries. Because of the fairly high content of antioxidants and the frequent use, coffee and tea are important antioxidant sources in many diets. Several different compounds contribute to coffee's antioxidant content, e.g, caffeine, polyphenols, volatile aroma compounds and heterocyclic compounds, (Gonthier et al, 2003). Many of these are efficiently absorbed, and plasma antioxidants increase after coffee intake (Illy. 2002). In green tea, the major flavonoids present are the monomer catechins, epigallocatechin gallate, epigallocatechin, epicatechin gallate and epicatechin. In black tea the polymerized catechins theaflavin and thearubigen predominate in addition to quercetin and flavonols (McKay and Blumberg. 2007).

Interestingly, the antioxidant content in human breast milk is comparable to that in pomegranate juice, strawberries and coffee and on average higher than the antioxidant content observed in the commercially available infant formulas analyzed in our study. Breakfast cereals are also potential important sources of antioxidants; some of these products have antioxidant contents comparable to berries, which are fairly high, compared to other grain products and may be due to antioxidants added to the products in fortification process. Chocolate have for several years been studied for its possible beneficial health effects (Cooper et al, 2008). Our results show a high correlation between the cocoa content and the antioxidant content, which is in agreement with earlier studies (Lee et al, 2003). As demonstrated in the present study, the variation in the antioxidant values of otherwise comparable products is large. Like the content of any food component, antioxidant values will differ for a wide array of reasons, such as growing conditions, seasonal changes and genetically different cultivars (Scalzo et al, 2005), storage conditions (Xianquan et al, 2005) and differences in manufacturing procedures and processing (Hartmann et al, 2008; Ismail and Lee. 2004). Differences in unprocessed and processed plant food samples are also seen in our study where processed berry products like jam and syrup have approximately half the antioxidant capacity of fresh berries. On the other hand, processing may also enhance a foods potential as a good antioxidant source by increasing the amount of antioxidants released from the food matrix which otherwise would be less or not at all available for absorption (Lindsay and Astley. 2002). Processing of tomato is one such example where lycopene from heat-processed tomato sauce is more bioavailable than unprocessed tomato (Unlu et al, 2007). The large variations in antioxidant capacity observed in the present study emphasize the importance of using a comprehensive antioxidant database combined with a detailed system for food registration in clinical and epidemiological studies. Initial studies have been carried out to examine the association between intake of antioxidant rich foods and their health effects (Mullen et al, 2007). Some of these studies describe a beneficial effect on oxidative stress related chronic diseases, e.g. from intake of nuts (Ros et al, 2004), pomegranates (Adhami and Mukhtar. 2007), tomatoes, coffee (Andersen et al, 2006), tea (Cabrera et al, 2006), red wine (Klinge et al, 2008) and cocoa (Cooper et al, 2008). The highly reactive and bioactive phytochemical antioxidants are postulated to in part explain the protective effect of plant foods. An optimal mixture of different antioxidants with complementary mechanisms of action and different redox potentials is postulated to work in synergistic interactions. Still, it is not likely that all antioxidant-rich foods are good sources and that all antioxidants provided in the diet are bioactive. Bioavailability differs greatly from one phytochemical to another (Williamson and Manach. 2005), so the most antioxidant rich foods in our diet are not necessarily those leading to the highest concentrations of active metabolites in target tissues.

CONCLUSION

As mentioned, the ROS or oxidants, which are formed in the human body due to exogenous and endogenous factors, are found to be responsible for many diseases. A lot of researchs have shown the potential of natural antioxidants as health benefactors because of their ability to neutralize free radicals, ROS, or oxidants responsible for the onset of cell damage. Antioxidant components of the natural products constitute the major source of human health promotion and maintenance. Moreover, antioxidant activity of the natural products includes detoxifying toxins, scavenging free radicals; wipe out the excess ROS and anti-lipids peroxidation. Indirectly, antioxidant components are useful as anticancer, anti-inflammatory, antimicrobial, antilipids, antiallergic and antidiabetics. The nature is still the perfect source for health promotion and for the supplementation of safe drugs. Moreover, natural products and their antioxidant activity might represent the best solution to prevent the side effects of many commercially available drugs (Hafidh et al, 2009; Pereira et al, 2009). The Antioxidant is a valuable research contribution, expanding the research evidence base for research and may be utilized in epidemiological studies where reported food intakes can be assigned antioxidant values. It can also be used to test antioxidant effects and synergy in experimental animal and cell studies or in human clinical trials. The ultimate goal of this research is to combine these strategies in order to understand the role of dietary phytochemical antioxidants in the prevention of cancer, cardiovascular diseases, diabetes and other chronic diseases related to oxidative stress. In addition, there may be some interference rising from other chemical components present in the extract, such as sugars or ascorbic acid. Further work is under way to confirm the antioxidative effect of these promising plant extracts by using other types of lipid models and to characterize the active phenolic antioxidants, their mechanism of action, and their possible interactive antioxidant effects together with other antioxidants in different lipid environments. In addition, more work on the effect of intraspecies variation, i.e, different cultivars and growing conditions, is in progress.

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