

Antioxidant Research in Asia in the Period from 2000-2008

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Abstract: Problem statement: Plant antioxidants are natural plant products that inhibit the adverse effects of the Reactive Oxygen Species (ROS) produced in plants. Thus, antioxidants enable plants to survive. Depending on this principle, human beings started using some plants' parts to cure from diseases many centuries ago, even before the discovery of microbes or disclosing the etiology of many human diseases. Shed light on the importance of diet and natural products that have proved of great health impact on human traditionally and scientifically, disclosing the central role of natural antioxidants in this matter. Moreover, this review tried to give an overview on the research has so far done in Asian countries particularly in the field of natural antioxidants during the period 2000-2008. Therefore, the aim of this review is to present a comprehensive index for the antioxidant property of herbs and plants that have been traditionally used as well as experimentally proved beneficial in these countries. **Approach:** We had compared Asian and other nation's diet in the popularity of the traditional medicine and the type of daily meal in respect to their antioxidants contents and valuable health promoting effects. Many literatures had been collected using online search engines and the main library of University Putra Malaysia. The gathered data had been arranged alphabetically in a table depending on the plant's scientific name, common name, the used part(s) and the family name. **Results:** The research had shown that there were seventy-six plants with proved antioxidant activity which had been well studied by Asian scientists in the chosen period of time. **Conclusion:** 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 from all the scientists around the world to explore many underestimated plants with highly effective antioxidant activity.

Key words: Dietary supplements, herbs, medicinal food, natural products, spice

INTRODUCTION

Since antiquity, man has used plants to treat common infectious diseases and some of these traditional medicines are still included as part of the habitual treatment of various maladies^[1]. Virtually all cultures around the globe have relied historically and continue to rely on medicinal plants for primary health care. There is currently a worldwide upsurge in the use of herbal preparations and the active ingredients isolated from medicinal plants in health care^[2].

Long before, mankind discovered the existence of microbes, the idea that certain plants had healing potential, indeed, that they contained what we would currently characterize as antimicrobial principles^[1]. Plant-based drugs have been used worldwide in traditional medicines for the treatment of various diseases. Approximately 60% of world's population still relies on medicinal plants for their primary healthcare. According to a survey by NCI, USA, 61% of the 877 small-molecule new chemical entities introduced as drugs worldwide during 1981-2002 were inspired by

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natural products^[3]. In USA, herbal preparations are becoming more popular and used increasingly^[4]. There is a long history of medicinal use of plants in Asian countries, some of which have proved useful to humans as pharmaceuticals. Therefore Asia seems to be the most promising region for discovering novel biologically-active substances from its flora^[5-7].

There is currently a large and ever-expanding global population base that prefers the use of natural products in treating and preventing medical problems. This has influenced many of pharmaceutical companies to produce new antimicrobial formulations extracted from plants or herbs. Herbs are from natural plants and therefore often considered to be harmless compared with western medicines^[4]. Plant species still serve as a rich source of many novel biologically active compounds. However, very few plant species have been thoroughly investigated for their medicinal properties. Thus, there is renewing interest in phytomedicine during last decade and nowadays many medicinal plant species are being screened for pharmacological activities^[3]. At present, plant and herb resources are unlimited. Natural products from plants have provided the pharmaceutical industry with one of its most important sources of lead compounds and up to 40% of modern drugs are derived from natural sources, using either the natural substance or a synthesized version^[2].

Epidemiological studies have shown an inverse relationship between vegetarian dietary practices and the incidence of cancer, cardiovascular diseases and mortality^[8]. Similar outcomes were also observed in countries where animal-based foods are included in the diet but the intake of plant-based foods was high^[9]. This suggests a potential therapeutic role of edible plants in human health. Traditional Asian diet contains less animal fats and higher plant-based foods as it is compared to western diet. Such a higher consumption of plant foods in Asian countries as a result of their

tropical climates, results in a wider choice of edible plants^[10]. Epidemiological studies suggested that the habit of vegetarian food is associated with reduced risk of cancer, cardiovascular and neurodegenerative disorders^[11]. Consistent with this hypothesis, the incidence of these disorders is least in Asian populations where fruits, vegetables and spices are the major elements in the human diet^[11]. Diet can modify the pathophysiological processes of various metabolic disorders and can be an effective preventive strategy for various disease processes most of which are known to involve oxidative damage^[12].

The aim of this review is to give a comprehensive outlook on the progress of the medicinal plants' research in the continental Asia on antioxidants, anti-radiation, anti-lipid peroxidation and free radicals scavenging plants as well as focusing on the most important and recent findings. This review has been grouped into two parts; essays and a table. The essays encompass introduction, methodology, impact of alternative medicine in Asia and the world, the importance of plants as a source for antioxidant substances, the plants' components rich in antioxidants, the antioxidants as free radicals scavengers, the anti-lipid peroxidation and immune modulatory effects of antioxidants, two examples on the most researched antioxidant's plants in Asia and finally the role of natural products as radioprotectors. In addition, many examples have been mentioned within the text discussing the biological potential and antioxidant activities of some of the most prominent plants and herbs that were investigated in elegant Asian research. Furthermore, the complete list of research conducted in Asia on antioxidants plants, herbs and natural products' components has been shown in Table 1 which summarizes those studies based on the plant's scientific and common name, the family name as well as the used part(s).

Table 1: Potent antioxidant medicinal plants explored by Asian scientists in the period from 2000-2008. Plants are ordered alphabetically on the families' names

Scientific name	Common name	Family	Used part(s)	Medical usage	Reference no.
<i>Amaranthus gangeticus</i> L.	Red spinach or elephant head amaranth	Amaranthaceae	Leaf	Antioxidant	[99-101]
<i>Amaranthus spinosus</i> L.	Spiny amaranth	Amaranthaceae	Leaf	Antioxidant	[99,102,103]
<i>Anacardium occidentale</i> L.	Cashew	Anacardiaceae	Shoot	Antioxidant	[99,100,104]
<i>Apium graveolens</i> L.	Local celery	Apiaceae	Leaf	Antioxidant	[99,100]
<i>Daucus carota</i> L.	Carrot	Apiaceae	Root	Antioxidant	[99,100,105,106]
<i>Colocasia esculentum</i> var. <i>antiquorum</i> (Schott) F.T. Hubb. and Rehder	Elephant ear	Araceae	Leaf stalk	Antioxidant	[99,100]
<i>Calamus scipionum</i> Lour.	No common name	Arecaceae	Leaf	Antioxidant	[99,100,104]
<i>Elaeis guineensis</i> (L.) Jacq.	African oil palm	Arecaceae	Fron	Antioxidant, vasorelaxation properties and LDLr* modulation effects	[104,107]

Table 1: Continued

<i>Bidens pilosa</i> Linn. Var. <i>radiata</i>	Hairy Beggarticks	Asteraceae	Whole plant	Antioxidant and NO** inhibitory	[27]
<i>Diplazium esculentum</i> (Retzius)	Swartz	Vegetable fern	Athyriaceae	Shoot Antioxidant	[99,100,108,109]
<i>Brassica alboglabra</i> Bailey	Chinese kale	Brassicaceae	leaves	Antioxidant	[99,100,110]
<i>Brassica oleracea</i> L.	Cauliflower, Broccoli, Cabbage and Chinese cabbage	Brassicaceae	Flower leaves	Antioxidant	[100]
<i>Raphanus sativus</i> L.	White radish	Brassicaceae	Root	Antioxidant	[99,100,111]
<i>Gynandropsis gynandra</i> (L.)	Briq.	Cat's whisker	Capparaceae Leaf	Antioxidant, LDLr modulation effects and Vascular relaxation properties	[99,100,104,112]
<i>Carica papaya</i> L.	Papaya	Caricaceae	Shoots	Antioxidant, LDLr modulation effects and vasorelaxation properties	[99,100,104,107,112]
<i>Garcinia atroviridis</i> Griff. ex T. Anders	Asam gelugur	Clusiaceae	Fruits	Antioxidant, antitumour and antibacterial, <i>Bacillus subtilis</i> (mutant), <i>B. subtilis</i> (wild-type), methicillin-resistant <i>S. aureus</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> and antifungal <i>Cladosporium herbarum</i>	[99,100,113]
			Leaves	Antioxidant, antitumour and antibacterial, <i>B. subtilis</i> (mutant), <i>B. subtilis</i> (wild-type), methicillin-resistant <i>S. aureus</i> , <i>P. aeruginosa</i> and antifungal <i>C. herbarum</i>	[99,100,113]
			Stem bark	Antioxidant, antitumour and antibacterial, <i>B. subtilis</i> (mutant), <i>B. subtilis</i> (wild-type), methicillin-resistant <i>S. aureus</i> , <i>E. coli</i> and <i>P. aeruginosa</i>	[99,100,113]
			Trunk bark	Antioxidant, antitumour and antibacterial, <i>B. subtilis</i> (mutant), <i>B. subtilis</i> (wild-type), methicillin-resistant <i>S. aureus</i> and <i>P. aeruginosa</i>	[99,100,113]
			Roots	Antioxidant, antitumour and antibacterial, <i>B. subtilis</i> (mutant), <i>B. subtilis</i> (wild-type), methicillin-resistant <i>S. aureus</i> , <i>E. coli</i> and <i>P. aeruginosa</i>	[113,114]
<i>Ipomoea aquatic</i>	Water spinach	Convolvulaceae	Leaf	Antioxidant	[99,100]
<i>Ipomoea batatas</i> L.	Sweet potato	Convolvulaceae	Shoots	Antioxidant and LDLr modulation effects	[99,104,115-119]
<i>Cucurbita maxima</i> Duch. ex. Lam.	Pumpkin	Cucurbitaceae	Fruit	Antioxidant	[99,100,115]
<i>Luffa acutangula</i> Roxb.	Angular loofah	Cucurbitaceae	Fruit	Antioxidant	[99,100,120]
<i>Momordica charantia</i> L.	Bitter melon	Cucurbitaceae	Fruit	Antioxidant	[121-124]
<i>Trichosanthes anguina</i> L.	Snake gourd	Cucurbitaceae	Fruit	Antioxidant	[99,100]
<i>Elaeocarpus kontumensis</i> Gagnep.	No common name	Elaeocarpaceae	Bark	Antimalarial	[125]
<i>Manihot utilissima</i> Pohl.	Cassava	Euphorbiaceae	Shoots	Antioxidant and antitumour	[99,100,108]
<i>Sauropus androgynus</i> (L.) Merr.	Star gooseberry	Euphorbiaceae	Leaf	Antioxidant	[99,100]
<i>Glycine max</i> (Linnaeus) Merrill	Soybean	Fabaceae	Shoot	Antioxidant and antitumour	[108]
			Sprout	Antioxidant	[99,100,126,127]
<i>Pachyrrhizus erosus</i> Linn.	Sinkamas	Fabaceae	Root	Antioxidant	[99,100]
<i>Parkia speciosa</i> Hassk	Stink bean	Fabaceae	Seed/bean	Antioxidant	[99]

Table 1: Continued

<i>Phaseolus aureus</i> Roxb.	Mung bean	Fabaceae	Sprout	Antioxidant	[99,100,128]
<i>Phaseolus vulgaris</i> Linnaeus	Dwarf bean	Fabaceae	Seed/bean	Antioxidant	[28,99,100,129,130]
<i>Pisum sativum</i> L.	Shelling peas	Fabaceae	Seed/bean	Antioxidant	[99,100,131]
<i>Psophocarpus tetragonolobus</i> DC.	Winged bean	Fabaceae	Seed/bean	Antioxidant	[99]
<i>Sesbania grandifolia</i> (L.) Pers.	Butterfly Tree or agati	Fabaceae	Leaf	Antioxidant	[99,100]
<i>Vigna sinensis</i> (L.) Savi	String bean or green bean	Fabaceae	Seed/bean	Antioxidant	[99,132]
<i>Centella asiatica</i> (L.) Urb.	Pegaga or gotu kola	Hydrocotylaceae	Leaf	Antioxidant	[58,99,100,133,134]
<i>Mentha agrestis</i> Soll.	Japanese mint	Lamiaceae	Leaf	Antioxidant and LDLr modulation effects	[99,100,104,112]
<i>Leea indica</i> (Burm.f.) Merr.	Bandicoot berry	Leeaceae	Whole plant	Antioxidant and NO inhibitory	[135]
<i>Allium odorum</i> L.	Chinese chives	Liliaceae	Leaves	Antioxidant	[99,100]
<i>Allium fistulosum</i> L.	Welsh Onion	Liliaceae	Leaves	Antioxidant	[99,100]
<i>Allium sativum</i> L.	Common garlic	Liliaceae	Root	Antioxidant	[99,100,136,137]
<i>Hibiscus esculentus</i> (L.) Moench	Lady's fingers	Malvaceae	Fruit	Antioxidant	[138]
<i>Hibiscus sabdarifa</i> L.	Roselle	Malvaceae	Calyx	LDL antioxidant and LDLr modulation effects	[104]
<i>Musa sapientum</i> L.	Common banana	Musaceae	Flower	Antioxidant	[139-141]
<i>Psidium guajava</i> L.	Guava	Myrtaceae	Fruit	Antioxidant	[142,143]
<i>Capsicum frutescens</i> L.	Bird chili	Solanaceae	Fruit	Antioxidant, LDLr modulation effects and vasorelaxation properties	[99,100,104,107,112]
<i>Lycium chinense</i> Mill.	Chinese Wolf-berry	Solanaceae	Leaf	Antioxidant	[99,100,144,145]
<i>Solanum melongena</i> L.	Egg plant	Solanaceae	Fruit	Antioxidant	[100,146-149]
<i>Lycium chinense</i> Mill.	Chinese Wolf-berry	Solanaceae	Leaf	Antioxidant	[99,100]
<i>Solanum melongena</i> L.	Egg plant	Solanaceae	Fruit	Antioxidant	[100]
<i>Chasalia chartacea</i>	No common name	Rubiaceae	Whole plant	Antioxidant and NO inhibitory	[135]
<i>Hedyotis verticillata</i> L.	Hedyotis plant	Rubiaceae	Whole plant	Antioxidant and NO inhibitory	[135]
<i>Lasianthus oblongus</i> King and Gamble	No common name	Rubiaceae	Whole plant	Antioxidant and NO inhibitory	[135]
<i>Morinda citrifolia</i> L.	Indian mulberry	Rubiaceae	Leaf (whole leaf)	Antioxidant, LDLr modulation effects and Vascular relaxation properties	[52,53,104,112]
<i>Morinda elliptica</i> Ridley	Magic fruit	Rubiaceae	Leaf	Antioxidant	[51,150]
<i>Psychotria rostrata</i> Blume	No common name	Rubiaceae	Leaf and Stem	Antioxidant	[135,151,152]
<i>Spermacoce articularis</i> L. f.	poaia	Rubiaceae	Whole plant	Antioxidant and NO inhibitory	[135]
<i>Spermacoce exilis</i> (L. O. Williams) C. D. Adams	Pacific false buttonweed	Rubiaceae	Whole plant	Antioxidant	[135]
<i>Citrus hystrix</i> D.C	Kaffir lime	Rutaceae	Leaf	Antioxidant	[99,100]
<i>Thea chinensis</i> Sims.	Green tea	Theaceae	Leaf	Antioxidant	[99,100]
<i>Piper sarmentosum</i> Roxb.	Sireh	Piperaceae	Leaf	Antioxidant	[51,99,100,153]
<i>Polygonum minus</i> Huds.	Small smartweed/ kesum	Polygonaceae	Leaf	Antioxidant	[99,100]
<i>Alpinia hookeriana</i> Val.	No common name	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>Aspergillus ochraceous</i>)	[154]
<i>Alpinia mutica</i> Roxb.	Small Shell Ginger or Orchid Ginger	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>)	[154]
<i>Alpinia nutans</i> Rosc.	Ginger Lily or Shell Ginger	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>)	[154]
<i>Alpinia rafflesiana</i> Wall. ex. Bak.	Raffles' Alpinia	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>)	[154,155]
<i>Alpinia vitellina</i> (Lindl.) Ridl.	No common name	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>)	[154]
<i>Costus discolor</i> Rosc.	Setawar putih	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>)	[154]
<i>Costus megalobractea</i> K. Schum.	No common name	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>)	[154]

Table 1: Continued

<i>Costus spiralis</i> Rosc.	Spiral ginger	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>) ^[154]
<i>Costus villosissimus</i> Jacq.	Spiral flag	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>) ^[154]
<i>Curcuma longa</i> L.	Turmeric	Zingiberaceae	Root	Antioxidant and antitumour ^[99,100,156]
<i>Curcuma mangga</i> Valeton and van Zijp	Mango ginger	Zingiberaceae	Rhizome	Antioxidant, antitumour and antiallergic ^[157,158]
<i>Etilingera elatior</i> (Jack) R. M. Sm.	Torch ginger	Zingiberaceae	Flower	Antioxidant ^[99,100]
<i>Zingiber cassumunar</i> Roxb.	Cassumunar ginger or Thai ginger	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>) ^[154]
<i>Zingiber ottensii</i> Val.	Black cleanser	Zingiberaceae	Rhizome and root parts	Antiallergic ^[158] Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>) ^[154]
<i>Zingiber macroglossum</i> Val.	No common name	Zingiberaceae	Rhizome and root parts	Antioxidant and antibacterial (<i>P. aeruginosa</i> , <i>B. subtilis</i>) and antifungal (<i>A. ochraceous</i>) ^[154]

*: LDLr: Low Density Lipid receptor; **: NO: Nitric Oxide

MATERIALS AND METHODS

The data of this review was collected using Pubmed, Scopus databases and Google scholar search engine. Endnote program was used to edit reference formatting. Moreover, it's worth mentioning that the central library of University Putra Malaysia was as a data source for retrieving books and needed resources.

The alternative medicine in Asia and other parts of the world: India is one of the twelve mega diversity countries in the world. It has a vital stake in the conservation and sustainable utilization of its biodiversity resources^[13]. India has been recognized for its spices and medicinal plants which exhibit a wide range of physiological and pharmacological properties. Herbs and spices 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 on their scientific merits, to provide science-based evidence for the traditional uses and to develop either functional foods or nutraceuticals^[14]. Plant foods contain phytochemicals such as flavonoids, phenolic acids, used to show a remarkable biological activity. Some common foods used in Indian culinary practices were assessed for their anti-oxidant, anti-mutagenic, anti-carcinogenic effects, vitamin D activity and were evaluated for their plausible biological effects^[12]. Away from India, the traditional Korean medicine, So-Cheong-Ryong-Tang (SCRT) also called as Xiao-qing-long-tang or Sho-seiru-to, contains eight species of medicinal plants which have been used for treating allergic diseases,

such as allergic rhinitis and asthma for hundreds of years in Asian countries^[7]. A recent study in Korea revealed that SCRT can correct Th2 dominant condition by affecting directly on the CD4+T cell without significantly depressing general T cell activities^[15]. Malaysia has been found to possess huge biodiversity resources and potential for natural products and is also considered as mega diversity country. These countries together contain at least 60% of the world's known species^[16]. The flora of Malaysia is exceedingly rich and is conservatively estimated to contain about 12,500 species of flowering plants and more than 1,100 species of ferns and fern allies. Many of these species are unique and found nowhere else in the world. Out of the 12,000 species of vascular plants, 10%, or approximately 1200 species, are reported to have medicinal properties^[17]. In Peninsular Malaysia, for example, well over 26% of the tree species are endemic. Higher endemism is expected in the herbaceous flora with some of the larger genera estimated to be endemic in more than 80% of their species. Many endemic plants are localized in their distribution, being found only in a few valleys or mountain tops^[18,19]. Malaysia alone has about 1300 medicinal plant products registered by the Ministry of Health and are available in market^[20]. 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^[18]. In comparison to Asian countries, there are about 1500 species of medicinal and aromatic plants in all

Europe which have been widely used in countries such as Albania, Bulgaria, Croatia, France, Germany, Hungary, Poland, Spain, Turkey and United Kingdom^[21]. Another study found that a total of only 985 species have been catalogued in the Mediterranean countries, of which only 406 have medicinal use^[22]. By this simple comparison we can estimate the huge number of plant species founds in Asia which is astoundingly inspiring for researchers to explore their medicinal benefit.

Countries in Africa, Asia and Latin America use Traditional Medicine (TM) to help meet some of their primary health care needs. In Africa, up to 80% of the population uses traditional medicine for primary health care while in industrialized countries, adaptations of traditional medicine are termed "Complementary "or "Alternative" Medicine (CAM)^[23]. The WHO fact sheet 2003 gave a short description on different countries around the world regarding the practicing of the alternative medicine by their people:

- In China, traditional herbal preparations account for 30-50% of the total medicinal consumption
- In Ghana, Mali, Nigeria and Zambia, the first line of treatment for 60% of children with high fever resulting from malaria is the use of herbal medicines at home
- WHO estimates that in several African countries traditional birth attendants assist in the majority of births
- In Europe, North America and other industrialized regions, over 50% of the population have used complementary or alternative medicine at least once
- In San Francisco, London and South Africa, 75% of people living with HIV/AIDS use TM/CAM
- 70% of the population in Canada have used complementary medicine at least once
- In Germany, 90% of the population has used a natural remedy at some point in their life. Between 1995 and 2000, the number of doctors who had undergone special training in natural remedy medicine had almost doubled to 10,800
- In the United States, 158 million of the adult population use complementary medicines and according to the USA Commission for Alternative and Complementary medicines, US \$17 billion was spent on traditional remedies in 2000
- In the United Kingdom, annual expenditure on alternative medicine is US \$ 230 million
- The global market for herbal medicines currently stands at over US \$ 60 billion annually and is growing steadily^[24]

Plants' antioxidants:

Why plants are huge source of 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. On the other hand, Oxygen is easily activated by Ultra Violet (UV) radiation and heat from the sunlight to produce toxic Reactive Oxygen Species (ROS)^[25]. 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^[26]. 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 and anti-inflammatory properties appear to contribute to their chemopreventive or chemoprotective activity^[27] which in turn, by the alternative medicine, has been used to the benefit of human beings.

Plants' most abundant antioxidant substances:

Phenolic substances, which are known to 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^[28]. Most of these phenolics are classified into two principal groups of phenol; carboxylic acids and flavonoids, the latter being the most significant^[29,30]. According to Pratt^[31], phenolic compounds are found abundantly 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^[32]. Many phenolic compounds, particularly flavonoids, exhibit a wide range of biological effects, including antioxidant activity, antibacterial, antiviral, anti-inflammatory, anti-allergic, anti-thrombotic, vasodilatory actions and the ability to lower the risk of coronary heart diseases^[33]. The protective effects of diets high in fruits and vegetables have been attributed to the presence of these compounds^[34]. A study on the plant extracts of *Bidens pilosa* L. var. *radiata* (Asteraceae) revealed that it could serve as a good source of caffeoylquinic acid derivatives and flavonoid glycosides which are attributed to *Bidens pilosa* significant antioxidant activity and inhibitory effect on Nitric Oxide (NO) production (an inflammatory mediator) in macrophages. Therefore, the study proposed the potential dietary value and benefits of *Bidens pilosa* extract on the basis of the phytochemical characteristics and the observed bioactive properties^[27]. Another

example of the antioxidant effect of flavonoids, is *Scutellaria baicalensis* Georgi (Lamiaceae); a widely used herb in traditional medical systems of China and Japan. The major constituents of *S. baicalensis* are flavonoids: baicalein, baicalin, wogonin, which have been associated with various properties, for example: Antioxidant, anti-inflammatory, antithrombotic, antibacterial and antiviral^[35].

The antioxidants and free radicals scavenging bioactivity: The term, antioxidant is used to describe a dietary component that can function to decrease tissue damage by reactive oxygen^[36]. A good example of potent plants' antioxidants are anthocyanins, which are water-soluble pigments present in plants^[37]. They are known to be powerful antioxidants that help protect plants from UV damage, particularly, UVB radiation 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^[38,39].

Most living organisms possess enzymatic and non-enzymatic defense systems against excessive production of reactive oxygen species; 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^[40]. The homeostatic balance between Reactive Oxygen Species (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^[41]. 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^[42]. Thus, antioxidants that scavenge reactive oxygen species may be of great value in preventing the onset and propagation of oxidative diseases like autoimmune diseases, cardiovascular diseases, neurovascular diseases^[43]. Recently, more attention has been paid to the role of natural antioxidants, mainly phenolic compounds, which may have higher antioxidant activities than those of conventional vitamins C, E and β -carotene^[44]. Therefore, antioxidants, which can neutralize free radicals, may be of central importance in the prevention of carcinogenicity, cardiovascular and neurodegenerative changes associated with aging^[41,45]. Epidemiological studies showed that the consumption of vegetables and fruits could protect humans against oxidative damage by inhibiting or quenching free radicals and reactive oxygen species^[46].

Fruits and vegetables are rich sources of many food factors including vitamins, minerals and phytochemicals which may act as antioxidants^[47]. 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^[48]. Thus a daily consumption of five or more servings of antioxidant-rich food provides the body with the essential antioxidants needed to prevent degenerative diseases, premature aging symptoms, chronic fatigue and general disability^[49]. Doctors and nutritionist have long known that antioxidants are needed by the human body for optimal well being, especially for maintaining a healthy body system and defense mechanism against cell damage^[50]. Therefore, the more the discovered antioxidant, the more the benefit to human beings has developed.

Vimala *et al.*^[51] found that the daily consumption of *Piper sarmentosum* Roxb. (kadok, Piperaceae) and *Morinda elliptica* Ridley (mengkudu jantanm, Rubiaceae) leaves, edible medicinal plants commonly used in Malaysian traditional medicine, can help maintain energy, general ability and fitness even during aging. Their findings were based on the truth that Naringenin, a naturally occurring antioxidant superoxide scavenger, was found in the methanolic leave extracts of *P. sarmentosum* and *M. elliptica*. Thus these plants could be considered as potent antioxidant food. Therefore if consumed daily, they could scavenge access free-radicals in the human biological system and could prevent oxidative related diseases^[51]. 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. In a similar study Zin *et al.*^[52,53], found that the consumption of *Morinda citrifolia* L. (Rubiaceae); locally known as (mengkudu), may have potential health effects. All the examined fractions, demonstrated high antioxidative activity; the potency of some of these compounds could provide a scientific basis for the health benefits claimed for *M. citrifolia* in folk medicine^[52,53].

Some of the Korean medicinal plants and their isolated polyphenols have exhibited effective radical-scavenging activity and may act as promising agents for scavenging free radicals and treating diseases associated with excess free radicals. For example the Rosaceae, *Rosa rugosa* Thunb. and *Rosa davurica* Pall. showed strong radical-scavenging activity. The most effective medicinal plant from families other than Rosaceae was *Cedrela sinensis* Juss. (Meliaceae), followed in order by *Nelumbo nucifera* Gaertn.

(Nelumbonaceae), *Eucommia ulmoides* Oliver (Eucommiaceae), *Zanthoxylum piperitum* DC. (Rutaceae), *Cudrania tricuspidata* (Carrière) Bureau (Moraceae) and *Houttuynia cordata* Thunb. (Saururaceae)^[54].

It is worth mentioning that synthetic antioxidants were found to be harmful to health while most of the natural antioxidants from plant source proved to be safer for health and possess better antioxidant activity^[55]. This fact could explain our finding that most Asian scientists have focused their research on the antioxidant activity of the studied plants rather than the antimicrobial and antitumor or other biological activities. Nevertheless, the antioxidant activity of these plants could be considered as the basis for further possible investigations on their additional properties.

The anti-lipid peroxidation and immune modulatory effects of antioxidants: As an example for the indirect antioxidant effect of plants, the antioxidant potential in herbal barks extract of five therapeutically important medicinal plants native to India was investigated. They are *Crataeva nurvala* Buch.-Ham. (Capparidaceae), *Buchanania lanzan* Spreng. (Anacardium), *A. marmelos* (L.) Corr. (Rutaceae), *Dalbergia sissoo* Roxb. ex DC. (Fabaceae) and *Cedrela toona* Roxb. (Meliaceae). All of them 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 nurvala* has the highest antioxidant capacity^[56].

Spices and herbs which are abundant in the daily meals of Asian countries have been proved to possess high antioxidant activity that can be applied for preservation of lipids and reduce lipid peroxidation in biological systems^[57]. The antioxidant activity of spice extracts are retained even after boiling for 30 min at 100 degrees C, indicating that the spice constituents are resistant to thermal denaturation^[58]. 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^[59].

Some of the dietary constituents commonly used in Indian foods such as cloves (*Syzygium aromaticum* (L.) Merrill and Perry, Myrtaceae), licorice (*Glycyrrhiza glabra* L., Fabaceae), mace (aril of *Myristica fragrans* Houtt., Myristicaceae) and greater cardamom (*Amomum subulatum* Roxb., Zingiberaceae), were selected as the test samples to find their effect on the inhibition of lipid peroxidation in rat liver homogenate^[60]. The results showed that spices used in this study have 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^[60]. A second example of bioactive effects of spices and herbs is a study by^[58] in which they used water and alcoholic extract (1:1) of commonly used spices (garlic, ginger, onion, mint, cloves, cinnamon and pepper). Their result 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^[58].

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^[61]. 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^[62]. In addition to delivering 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. As 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 oxidation warrants further attention^[60,63].

In the functioning processes of the immune system, such as phagocytosis, reactive oxygen and nitrogen species are generated^[64]. The generation of Reactive Oxygen Species (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^[65]. Dietary supplementation with antioxidants may greatly help in such conditions. There are some indications of possible benefits of antioxidant supplementation. Polyphenols have a well-known antioxidant-based immunomodulatory activities which can be as therapeutic agents in the inflammation-driven damaging oxidant load^[66,67].

The two most researched plants with antioxidant activity in Asia: A prominent example of 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 anti-inflammatory effects^[14,68]. Studies in India have explored its anti-inflammatory, cholekinetic and antioxidant potentials^[69-71]. The recent investigations have focused on its preventive effects on precarcinogenic, anti-inflammatory and anti atherosclerotic effects both *in vivo* and *in vivo* conditions in animals and humans. 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^[14]. 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^[72,73]. *In vivo*, curcumin exhibits anti-parasitic, antispasmodic, anti-inflammatory and gastrointestinal effects; and also inhibits carcinogenesis and cancer growth^[73-76]. *In vivo*, there are experiments showing the anti-parasitic, anti-inflammatory potency of curcumin and extracts of *C. longa* L. by parenteral and oral application in animal models^[74,77]. 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^[77,78]. Curcumin can also downregulate the expression of various proinflammatory cytokines including TNF, IL-1, IL-2, IL-6, IL-8, IL-12 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^[68].

The second example, *Panax ginseng* C.A. Meyer (Araliaceae) is a well-known medicinal herb native to China and Korea and has been used as a herbal remedy in Eastern Asia for thousands of years and is now a popular and worldwide used natural medicine. The active ingredients of ginseng are ginsenosides which are also called ginseng saponins^[79]. 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^[80]. Modern pharmacological experiments have proved that ginseng possesses multiple constituents (ginsenosides, polysaccharides, peptides, polyacetylenic alcohols), with actions (potent antioxidant activity, central nervous system 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^[81]. A recent study demonstrated the potential anti-rheumatoid activity of *Panax ginseng* C.A. Meyer head part and suggested that it has potential analgesic and anti-inflammatory activities^[82]. Ginseng has also been studied on its effect mainly on physical, psychomotor performance and cognitive function^[83,84], immunomodulation, diabetes mellitus^[85], cardiovascular diseases^[86]. Nevertheless, equivocal results have been demonstrated for many of these indications due to the poor quality of most clinical trials on ginseng^[79]. Therefore, reliable clinical data in humans are still lacking and broader understanding of medical knowledge and reasoning on ginseng, is necessary^[87]. A complete list of antioxidant plants researched in Asia is shown in Table 1.

The role of 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^[88]. No ideal and safe synthetic radioprotectors are available to date. So, the search for alternative sources, including plants, has been on going for several decades. In Ayurveda, the traditional Indian system of medicine, several plants have been used to treat free radical-mediated ailments and, therefore, it is logical to expect that such plants may also render some protection against radiation damage^[89]. A systematic screening approach can provide leads to identifying potential new candidate drugs from plant sources, for mitigation of radiation injury^[89]. The currently available radioprotectors have many drawbacks including high cost, side effects and toxicity^[90]. Some antioxidant nutrients and phytochemicals have the advantage of low

toxicity although they are generally protective when administered at pharmacological doses^[91]. A number of phytochemicals, including caffeine, genistein and melatonin, have multiple physiological effects, as well as antioxidant activity, which resulted in radioprotection *in vivo*^[91]. Several novel approaches are on the track to locate a potent radioprotector from plants. These include mimics of antioxidant enzymes^[92], nitroxides, melatonin^[93], growth factors^[94], gene therapy^[95] and natural products^[92,96]. The latter has several advantages since they are non-toxic with proven therapeutic benefits. Results from animal experiments indicated that 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^[88]. As India and many Eastern countries have an enormous heritage of vast natural dietary and time tested medicinal resources; therefore, it is worth to explore the possibility of developing efficient, economically viable and clinically acceptable radioprotectors for human application from these resources^[88]. For instance, *Rosemarinus officinalis* L. (Lamiaceae) leave extract and *Zingiber officinale* Roscoe (Zingiberaceae) have been demonstrated to be good radioprotectors. The latter possesses antioxidant and neuromodulatory properties that can be effectively utilized for behavioral radioprotection^[97,98].

CONCLUSION

As mentioned, the Reactive Oxygen Species (ROS) or oxidants, which are formed in the human body due to exogenous and endogenous factors, are found to be responsible for many diseases. Day by day, a lot of research have shown the potential of phytochemical antioxidants as health benefactors because of their ability to neutralize free radicals, reactive oxygen species, or oxidants responsible for the onset of cell damage. Taken together, it was concluded that first, 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 second main conclusion is that 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 and to counteract the rapid emergence of multi-drug resistant microbes against the commonly used antimicrobial agents. Apart from the huge number of research studies in the filed of antioxidants discovery, this field still needs more attention from scientists around the world.

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