REVIEW ARTICLE

Role of Phytochemicals in Neutralizing the Adverse Effects of Ozone Depletion

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ABSTRACT

Ozone layer, a natural sunscreen of earth, shields human beings from harmful ultraviolet radiation of the Sun. Ozone is a toxic, unstable gas and naturally present in the stratosphere zone of atmosphere. Ozone layer absorbs ultraviolet radiation and thus prevent from reaching on the Earth's surface. When destruction of stratospheric ozone increases with respect to its production, this phenomenon alters ozone balance and aggravates ozone depletion.Natural phenomena and man-made compounds such as chlorofluorocarbons cause ozone depletion and thus allow ultraviolet radiation to arrive at earth. Small amounts of ultraviolet radiations are essential in the production of vitamin D but excess exposure develops oxidative stress by generating reactive oxygen species (ROS). These reactive oxygen species has genotoxic and carcinogenic effects and produces various organ disorders. The adverse effect of ultraviolet radiation can be neutralized by phytochemicals. Phytochemicals are non-nutritive plant chemicals (viz. lycopene in tomatoes, isoflavones in soy and flavanoids in fruits) that act as antioxidant and neutralize the free radicals generated during exposure of ultraviolet radiation.

Key Words: Ozone depletion, phytochemicals, reactive oxygen species, ultraviolet radiation.

INTRODUCTION

Ozone denoted as O_3, is a gas naturally present in atmosphere. Ozone is found primarily in two regions of the atmosphere viz. troposphere (10%); the region closest to Earth (from the surface to about 10-16 kilometres) and the remaining ozone (about 90%) resides in the stratosphere between the top of the troposphere and about 50 kilometres altitude. The high concentration of ozone in the stratosphere is referred as *ozone layer*. The ozone layer was discovered in 1913 by the French physicists Charles Fabry and Henri Buisson (ozone.unep.org).

Ozone formation is a multistep chemical process that requires sunlight. In the stratosphere, ozone formation begins with degradation of an oxygen molecule (O_2) by ultraviolet radiation of the sun. In the troposphere ozone is formed by a different set of chemical reactions that involve naturally occurring gases and those from pollution sources.

Ozone formed at Earth's surface in excess of natural amounts is considered as *bad ozone* because of its harmful effect to human, plants, and animals whereas, stratospheric ozone absorbs about 95-99% of destructive ultraviolet radiation emitted by the Sun and thus considered as *good ozone*. But nowadays, depletion of stratospheric ozone is a global environmental problem, increasing incidence of various disorders. For prevention of the adverse effect of ozone depletion, reducing excessive exposure to solar radiation is desirable but this approach is unavoidable. Some novel strategies like use of phytochemicals may be a good approach in minimizing the destructive effect of UV radiation. Phytochemicals are photoprotective in nature because of their potential antioxidant properties.

Ozone depletion

Industrial processes and consumer products result in the emission of ozone depleting substances (ODSs) to the atmosphere. The main ozone depleting substances are chlorofluorocarbons (CFCs), hydrochlorofluor carbons (HCFCs), carbon tetrachloride, halons (brominated fluorocarbons) and methyl chloroform. The chlorofluorocarbons (CFCs) are used in almost all refrigeration and air conditioning systems, and the halons are used in fire extinguishers. Halons can destroy up to 10 times as much ozone as CFCs can. A 1% decrease in the ozone layer is estimated to increase UV-B radiation by 2% (www.enviropedia.org).

The phenomenon of ozone depletion starts with emission of chlorine and bromine containing gases at Earth's surface. These nonreactive gases accumulate in the troposphere and transported to stratosphere in super reactive form by natural air motions and thus destroy ozone layer. Rain and snow removes some reactive chlorine and bromine gases from Earth's atmosphere (www.enviropedia.org).

Stratospheric ozone which absorbs the solar ultraviolet radiation is a basic bio-protective filter and its degradation leads to increase of UV radiation level in environment that constitutes a danger for health of the whole human population. Small amounts of UV radiations are essential in the production of vitamin D and thus beneficial for human being. UV radiation is also used to treat several diseases, including rickets, psoriasis, eczema and jaundice. The adverse health effects associated with stratospheric ozone depletion are primarily related to the pulmonary organ, skin, eyes, and immune system (Armstrong, 1994).

Genotoxic effect

The genotoxic potential of ozone is caused by the reaction of ozone and its reactive intermediaries (ORI) with cellular macromolecules. When ozone is dissolved in biological fluids it decomposes and reacts instantly with unsaturated fatty acids in cell membranes generating ORI such as hydrogen peroxide (H_2O_2), aldehydes, ozonides and lipid peroxides. Proteins in plasma and cell membranes are oxidised, mainly in thiol groups. Nucleic acids are unlikely to be damaged by ozone itself, but the cascade of ORI that is generated may have genotoxic effects (Diaz-Llera *et al.*2002).

Carcinogenic effect

In humans, chronic exposure to ultraviolet (UV) radiation induces nonmelanoma skin cancer (NMSC). Wavelength UV-B (290-320 nm) is more harmful as during exposure, it is easily absorbed into skin which results in development of erythema, burns and skin cancer. In UV induced skin carcinogenesis, DNA damage occurs which facilitates incorporation of wrong bases into the genetic material, leading to disruption in cellular processes. This result in mutation which leads to inappropriate expression of affected genes (Ananthaswamy, 2001).

Skin cancer may develop due to mutation in p^{53} protein as it is a tumor suppressor gene and also involved in apoptosis. The p^{53} protein functions as a guardian of the genome by aiding DNA repair of cells with excessive DNA damage (Jankowski and Cader, 1997).

Acute effects of UV radiation include photokeratitis, photoconjunctivitis, DNA damage, lipid peroxidation and protein crosslinking that lead to erythema, sunburn and immunosuppression. Chronic effects include cataract, Pterygium, squamous cell carcinoma of the cornea or conjunctiva and skin cancer (Jankowski and Cader, 1997; www.cheneysd.org).

Effect on pulmonary organ

Ozone is a powerful oxidant and toxic gaseous pollutant. The primary target tissue of ozone is the lung and breathing elevated concentrations of ozone results in a range of respiratory symptoms viz. decreased lung function, increased airway hyper-reactivity, asthma and chronic obstructive pulmonary disease (COPD)(Kosmider *et al.*2010).

After inhalation ozone first reaches to the lung lining fluid compartment, where it reacts with other substrates such as proteins or lipids and thus secondary oxidation products arises which transmit the toxic signals to the underlying pulmonary epithelium followed by initiation of a number of cellular responses. These responses include cytokine generation, adhesion molecule expression and tight junction modification. Together, these responses lead to the influx of inflammatory cells to the lung in the absence of a pathogenic challenge. Moreover, lung permeability is increased and oedema develops (Mudway *et al.,* 2000; Bocci, 2006).

Effect on eyes

UV radiation damages the human eye lens, hastening the deterioration that leads to age related cataract. The effectiveness of UV radiation, causing damage to ocular tissue is wavelength dependent as UV-B radiation at 280-320 nm is an important risk factor for cortical cataract. Additionally, UV-A wavelengths (320-400 nm) and visible radiation have also been implicated in the aetiology of cortical cataract in humans (www.epa.gov).

Effect on skin

Exposure of human skin to UV-B radiation results in excessive generation of reactive oxygen species (ROS) that overwhelms the antioxidant defence system resulting in oxidative stress. Skin related disorders such as photoaging and photocarcinogenesis are mediated by the generation of ROS (Ichihashi, 2009).

Suppression of immune system

UV radiation appears to diminish the effectiveness of the immune system by changing the activity and distribution of the cells responsible for triggering immune responses. Immunosuppression can cause reactivation of the viruses like herpes simplex virus in the lip (Norval *et al*., 2007).

Approaches to combat adverse effects of ozone depletion

For combating the adverse effects of ozone depletion, there is need to reduce the emission of ozone depleting substances and also, adapt the approaches to neutralize them.

Hydrofluorocarbons (HFCs) are strong greenhouse gases and used as substitute for chlorofluorocarbon (CFCs) and hydrochlorofluorocarbons (HCFCs). CFCs and HCFCs are used in vehicle air conditioning and theses gases are powerful destructive factors of ozone (www.enviropedia.org).

Use of Phytochemicals

Phytochemicals are non-nutritive plant chemicals viz. lycopene in tomatoes, isoflavones in soy and flavanoids in fruits, have protective or disease preventive properties. Phytochemicals acts as an antioxidant and thus helps in reducing the free radicals generated during exposure to UV radiation.

Lycopene

Lycopene is a pigment, gives red colour to many fruits and vegetables and also act as an antioxidant, thus prevents destructive effects of free radicals. The lycopene in tomatoes may reduce sun damage by 35 % (www.lycopene.com).

Oral lycopene have a protective effect against UV skin damage. Like sunscreens which provide external protection from UV radiation, lycopene in the diet might provide internal protection from free radicals. Since, lycopene is a lipid, for better absorption, it should be consumed with oil.

Flavonoids

Flavonoids are pigments present in different indispensable components of human diet viz. fruits, vegetables, nuts and beverages. Flavonoids possess antioxidative, anti-cancer, anti-inflammatory and anti-viral properties. Flavonoids are small organic compounds which have been normally absorbed by the human body for long time and thus can be used as safest non-immunogenic drugs. They reduce ozone induced toxicity by working as enzyme inhibitors, antioxidants, hormones or immune modulators (Lee *et al.* 2007).

Isoflavones

Isoflavones are polyphenolic compounds that are capable of exerting estrogen-like effects. Isoflavones have potent antioxidant properties, comparable to that of the well known antioxidant vitamin E. Genistein is the most potent antioxidant among the soy isoflavons, followed by daidzein. It reduces the long term risk of skin cancer by preventing the free radical damage to DNA (Wei *et al.* 1995; 2003). Isoflavones have an anti-aging effect on the UV-damaged hairless mice model, which is partly due to the inhibitory effects on UV-induced MMP-1 (metalloproteinases-1) expression and the subsequent collagen degradation (Kim *et al.* 2004).

Polyphenols

Polyphenols viz. epicatechin (EC), epicatechin gallate (ECG), epigallocatechin (EGC), and epigallocatechin-3-gallate (EGCG) are present in green tea. All of these polyphenols act as potent antioxidants and can scavenge ROS, such as lipid-free radicals, superoxide radicals, hydroxyl radicals, hydrogen peroxide, and singlet oxygen. EGCG has been considered to be the main compound responsible for these effects, constituting approximately 40% of the total polyphenolic mixture (Katiyar *et al.* 2001; Afaq and Mukhtar, 2006).

Polyphenolic compounds viz. anthocyanidins and hydrolysable tannins possess strong antioxidant and anti-inflammatory properties. Pomegranate is a rich source of two types of polyphenols (Afaq *et al.* 2005).

A polyphenolic phytoalexin, resveratrol (trans-3, 4', 5-trihydroxystilbene) is found in the skin and seeds of grapes, nuts, fruits, and red wine. It is a potent antioxidant with anti-inflammatory and antiproliferative properties (Adhami *et al.,* 2003; Afaq *et al.,* 2003). It potentially inhibits generation of hydrogen peroxide, infiltration of leukocytes and skin oedema which occurs due to exposure of UV radiation (Afaq *et al.* 2003).

Other nutrients

Nutrients viz. vitamin E, vitamin C, ratinoids and linoleic acid act as antioxidant and suppresses the effect of UV radiation induced effects in human beings.

CONCLUSION

Thus, many phytochemicals, with antioxidant properties exert anti-inflammatory, cancer-preventive and anti-photoaging effects on the skin. This suggests the possibility of these phytochemicals for the prevention and treatment of a variety of human skin disorders. Theses phytochemicals acts as free radical scavenger that will reduce the adverse effects of UV radiation induced by ozone depletion.

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