Experimental Eye Research 129 (2014) 135–150

Contents lists available at ScienceDirect

Experimental Eye Research

journal homepage: www.elsevier.com/locate/yexer

Review

Oxidative photodegradation of ocular tissues: Beneficial effects of filtering and exogenous antioxidants

Billy R. Hammond [a,*], Bart A. Johnson [b], Eric R. George [b]

[a] Vision Sciences Laboratory, University of Georgia, Athens, GA 30602-3013, USA
[b] Johnson & Johnson Vision Care, Inc., 7500 Centurion Parkway, R&D 3rd Floor W3A, Jacksonville, FL 33256, USA

ARTICLE INFO

Article history:
Received 27 June 2014
Accepted in revised form 13 September 2014
Available online 16 September 2014

Keywords:
Oxidative photodegradation
Proteins
Lipids
Ocular phototoxicity
Filters
Antioxidants

ABSTRACT

The fact that light is necessary for life is generally accepted as an axiom. The extent to which light interacts and influences human biology, however, is often not fully appreciated. Exposure to sunlight, for instance, can both promote and degrade human health. There is now general scientific consensus that, although the eye evolved to respond to light, it is also damaged by excessive exposure. Light-mediated ocular damage is involved in the pathophysiology of many common forms of blindness. The type of ocular tissue damage induced by light exposure depends on the extent of exposure and wavelength. The tissues of the lens, cornea, and retina contain specific chemical moieties that have been proven to exhibit light-mediated oxidative degradation. Proteins and lipids present in the cornea, lens, and retina, meet all of the physical requirements known to initiate the process of oxidative photodegradation upon exposure to solar radiation. As such, different mechanisms have evolved in the lens, cornea, and retina to ameliorate such light-mediated oxidative damage. It appears, however, that such mechanisms are ill-matched to handle modern conditions: namely, poor diet and longer life-spans (and the degenerative diseases that accompany them). Hence, steps must be taken to protect the eye from the damaging effects of light. Preventative measures include minimizing actinic light exposure, providing exogenous filtering (e.g., through the use of protective lenses), and enhancing antioxidant defenses (e.g., through increased dietary intake of antioxidants). These strategies may yield long-term benefits in terms of reducing oxidative photodegradation of the ocular tissues.

1. Introduction

The absorption of visible light in the retina and the subsequent chemical conversions are the first sept in all subsequent visual processing (Wald, 1945; Tang et al., 2013). This very exposure, however, may also be associated with pathological consequences. Actinic light exposure is central to the pathophysiology of the most common forms of blindness (Young, 1992). Age-related cataract, for instance, is the leading cause of blindness in the world and UV-mediated modification of crystalline lens proteins is a primary event in its development. Age-related macular degeneration (AMD) is the leading cause of blindness in the developed world. Epidemiological data in the USA indicate an overall prevalence (>40 years of age) of AMD of 6.5% (Klein et al., 2011). A recent meta-analysis of 14 studies by Sui et al. (2013) showed an average increase of AMD risk due to sunlight exposure of about 38% (OR = 1.379, 95% CI ranging from 1.091 to 1.745, $P = 0.007$).

The very existence of life on earth is dependent upon light from the sun. Not all energy arising from our sun, however, is incident on the planet surface. As shown in Fig. 1, electromagnetic energy from the sun extends from around 200 to over 2500 nm. Exposure to the very high-frequency end of that continuum (cosmic radiation) is a significant factor in the disease risk of astronauts (e.g., Cherry et al., 2012). Fortunately, the earth's magnetic field and atmosphere (ozone) absorb or reflect nearly all of the electromagnetic energy below about 260 nm (Norval et al., 2007). The very energetic waveband between about 260 and 400 nm does make it to the surface (about 97% of that is UVA, 315–400 nm). The amount present at any given time, however, varies dramatically depending on altitude, latitude, time of day, season and local weather conditions. Fig. 2 demonstrates these large changes as measured during different seasons and climate regions in China.

The impact of light on the eye and the ocular tissues affected are influenced by both the degree of UV exposure and the wavelength of the light entering the eye. An immediate challenge when

* Corresponding author.
E-mail addresses: bhammond@uga.edu (B.R. Hammond), EGeorge1@its.jnj.com (E.R. George).

http://dx.doi.org/10.1016/j.exer.2014.09.005

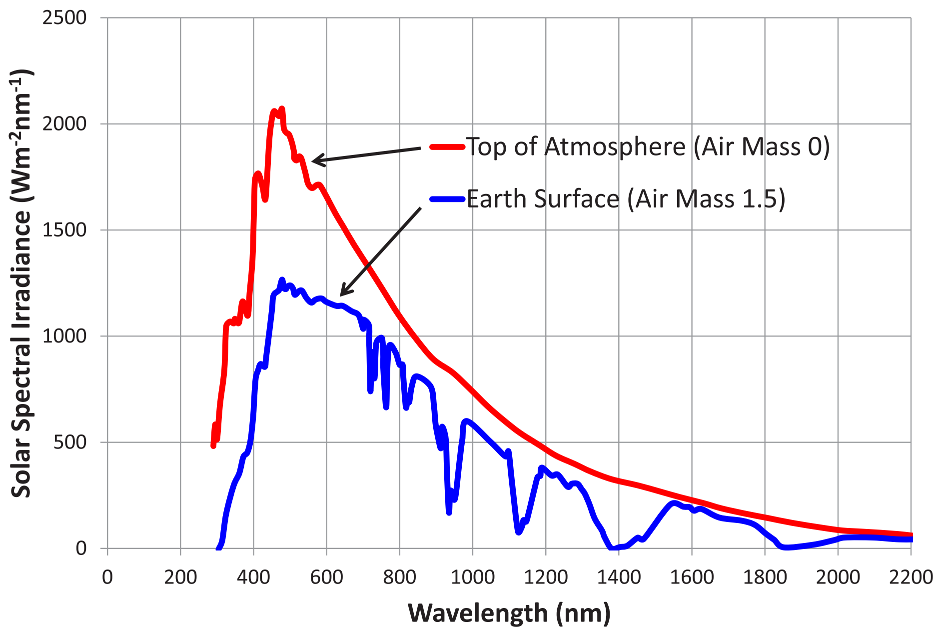

Fig. 1. Solar spectral irradiance (derived from Mecherikunnel and Richmond, 1980).

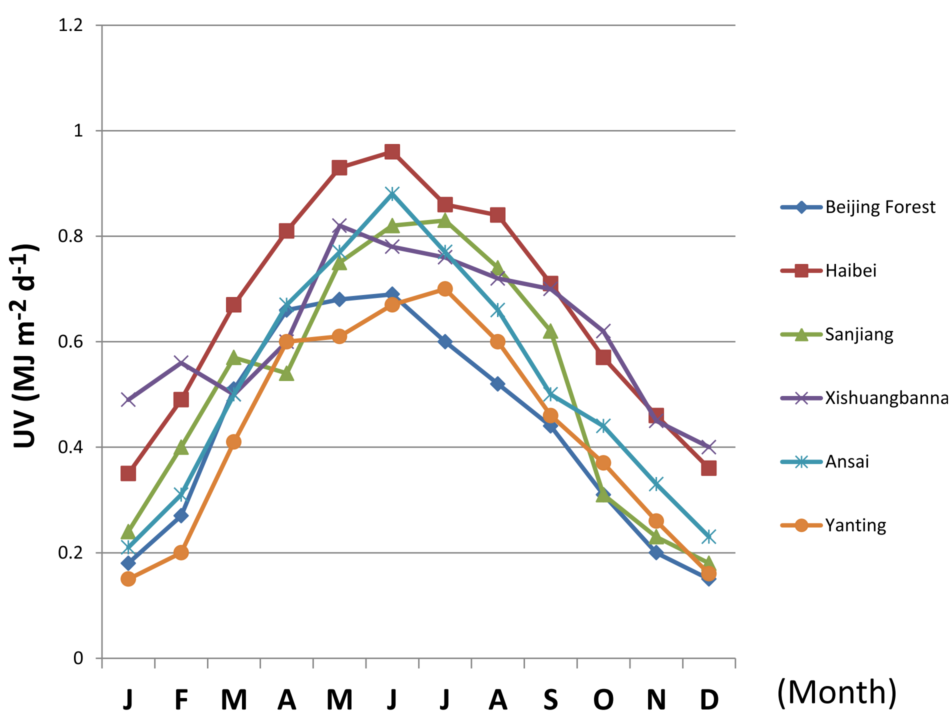

Fig. 2. Monthly average daily UV radiation measured at different locations throughout China (derived from Bo et al., 2010).

evaluating an actinic role of light is quantifying exposures that can vary so tremendously. For example, Sasaki et al. (2011) recently assessed the validity of one common measure of exposure: the solar UV index. They found that the index was, essentially, invalid as a measure of ocular risk because the model is based on such a limited number of dependent variables: exposure estimates, for instance, were limited to ambient solar radiation impinging on an unobstructed horizontal plane (e.g., the top of the head). The timing of the measurement is critical; daily UV exposures vary tremendously by time of year and even throughout the day. For instance, measurements taken in Kanazawa, Japan indicated that the peak ocular exposure occurring for most of the year was not at solar noon, as would be predicted by the UV index, but at mid-morning and mid-afternoon. This is due to the increase in direct and reflected sunlight into the eye at lower solar angles, and the occlusion of the sun at higher solar angles by the superior orbital rim of the eye socket and eyebrow (Merriam, 1996). Fig. 3 summarizes these results and illustrates the inherent photo-protection