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Inhibiting effects of dietary polyphenols on chronic eye diseases

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A R T I C L E I N F O

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A B S T R A C T

The prevalence of many eye diseases, including cataracts, age-related macular degeneration and diabetic retinopathy, is expected to increase and has become leading causes of irreversible vision loss in the elderly population. Recent experimental and clinical studies have increased awareness of the potential health benefits of polyphenol consumption, including for the prevention of chronic eye diseases. This review focuses on recent findings regarding the beneficial effects of polyphenols for treatment/prevention of cataracts, age-related macular degeneration, diabetic retinopathy and glaucoma, and discusses possible mechanisms of action. The results of studies presented in this review show that polyphenols suppress formation of reactive oxygen species, increase antioxidant defense systems, ameliorate pro-inflammatory cytokines, and decrease vascular endothelial growth factor in retinal cells and ocular tissues. Based on these results, polyphenols may be an effective and safe component of functional foods used to address chronic eye disease.

1. Introduction

As the number of older people increases, so does the incidence of chronic eye diseases, as well as the proportion of the population living with disabilities related to these diseases. The chronic eye diseases, such as cataracts, age-related macular degeneration (AMD) and diabetic retinopathy (DR), have become the leading cause of irreversible vision loss in the elderly population (Pascolini & Mariotti, 2012). Effective treatments are not yet available for the later stages of most these chronic eye diseases, thus, prevention is vitally important. Consumption of fruit and vegetables has been demonstrated to be beneficial for retaining vision or even reversing visual impairment. For example, consumption of oranges and bananas has been associated with a reduced risk of neovascular age-related maculopathy (Cho, Seddon, Rosner, Willett, & Hankinson, 2004) and dietary wolfberry has been shown to restore retinal pigment epithelial integrity and ganglion cell number in db/db mice (Tang et al., 2011). Fruits and vegetables are rich in phytochemicals, including polyphenols, saponine, carotenoids and vitamines (Cho et al., 2004). The beneficial effects for the eye, which are associated with fruit and vegetable consumption, are linked to the bioactive properties of the phytochemical constituents, especially polyphenols (London & Beezhold, 2015; Rhone & Basu, 2008).

There are a lot of herbal polyphenols including proanthocyanidins, anthocyanins (including cyanidin 3-*O*-galactosides, cyanidin 3-*O*-arabinosides, peonidin 3-*O*-galactosides and peonidin 3-*O*-arabinosides), flavonols (including kaempferol, quercetin and myricetin), hydroxycinnamic acids (including caffeic acids, ferulic acids, coumaric acids and sinapic acid), hydroxybenzoic acids (including benzoic acid and gallic acids) and resveratrol (Kowalska & Olejnik, 2016; Shi, Loftus, McAinch, & Su, 2017). The main sources of dietary polyphenols are fruits, vegetables and tea (Hu, Zhang, Chen, & Wang, 2017). Polyphenols are reported to have antioxidant and anti-inflammatory properties along with a host of other beneficial effects (Mohammadian et al., 2016; Shayganni, Bahmani, Asgary, & Rafieian-Kopaei, 2016). Recent studies have shown positive effects of polyphenols on visual function. Ghosh et al. found that bilberry anthocyanins were associated with improvements in night vision (Ghosh & Konishi, 2007) and Matsumoto et al. showed that blackcurrant anthocyanins stimulated regeneration of rhodopsin in frog rod outer segment membranes (Matsumoto, Nakamura, Tachibanaki, Kawamura, & Hirayama, 2003), possibly improving vision. Interest has been growing in natural plant-derived food products rich in polyphenols that are able to counteract chronic eye diseases. Plant food and/or plant extracts that contain multiple phytochemical combinations may have a synergistic effect and act on multiple molecular targets, which is superior to treatment with a single phytochemical (Liu, 2003).

This review included electronic searches of the Web of science, Medline and PubMed databases, using the following search terms: cataract, diabetic retinopathy, age-related macular degeneration (AMD), glaucoma, eye diseases and polyphenols in various combinations, a search using the name of specific polyphenols was also included. These electronic searches were limited to literature within the last 10 years. However, the eye diseases inhibiting activity of polyphenols constitutes an exception since the time-limit was removed. The

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Table 1
Inhibiting effects of some dietary polyphenols on ocular diseases.

Polyphenols	Dose	Testing systems	Activity in chronic eye diseases	Reference
Quercetin	10 μM for 6 h	SD rat lens	Inhibits hydrogen peroxide induced cataract	Cornish, Williamson, and Sanderson (2002), Sanderson et al.(1999);
Quercetin	25 or 50 mg/kg body weight for 6 months	Streptozotocin-induced diabetic Wistar rats	Inhibits diabetic retinopathy	Kumar et al. (2014)
Catechin derivatives	200 mg/kg body weight	SD rats	Inhibits *N*-methyl-*N*-nitrosourea induced cataract	Lee et al. (2010)
Ellagic acid	200 mg/kg body weight for 30 days	Wistar rats	Inhibits selenite-induced cataractogenesis	Sakthivel, Elanchezhian, Ramesh, Isai, and Jesudasan (2008)
Curcumin	200 μM for 12 days	Wistar rat lens	Inhibits selenium-induced oxidative stress in the eye lens	Manikandan et al. (2009)
Caffeic acid	15 μmol/kg body weight for several weeks	SD rats	Inhibits sodium-selenite-induced cataract	Doganay et al. (2002)
Chlorogenic acid	50 mg/kg for 2 weeks	50% galactose-fed SD rats, an animal model of sugar cataract	Inhibits cataractogenesis	Kim et al. (2011)
Cinnamic acid, Ferulic acid	14.8 nM	Human lens	Inhibits diabetes induced cataract	Chethan, Dharmesh, and Malleshi (2008).
Myricetin	5×10^{-6} M	*In vitro* assay of aldose reductase	Inhibits diabetes induced cataract	Ongand and Khoo (1997)
Rutin	10–1000 μM for 3 weeks	Goat lens	Inhibits diabetes induced cataract	Muthenna, Akileshwari, Saraswat, and Reddy (2012)
Silybin	231 mg/day for 4 weeks	Human patient	Inhibits diabetes induced cataract	Zhang et al. (1995)
Eriodictyol	0.2 mg/ml	*In vitro* assay of advanced glycation end production	Inhibits diabetes induced cataract	Morimitsu et al. (1995)
Pelargonidin	n.i.	Diabetic hamsters	Inhibits diabetes induced cataract	Ghosh and Konishi (2007)
Peonidin	100 μg /ml	SD rat lens	Inhibits diabetes induced cataract	Morimitsu et al. (2002)
Cyaniding	0.5% w/w for 10 weeks	SD rats	Inhibits diabetes induced cataract	Osakabe et al. (2004)
Genistein	15 mg/kg body weight for 4 weeks	SD rats	Inhibits galactose induced cataract	Huang et al. (2007)
Anthocyanin monomers isolated from grape skins: Malvidin 3-glucoside, Delphinidin 3-glucoside, Cyanidin 3-glucoside, Petunidin 3-glucoside and Peonidin 3-glucoside	n.i.	SD rat lens	Inhibit diabetes induced cataract	Morimitsu et al. (2002)
Grape seed proanthocyanidin extract	100 mg/kg body weight for 3 weeks	SD rats	Inhibit selenite-induced cataractogenesis	Durukan et al. (2006)
Blueberry and black currant extracts rich in anthocyanins	100 μM	Retinal pigment epithelium (ARPE-19)	Inhibit age-related macular degeneration	Jang et al. (2005), Milbury et al. (2007)
Ginkgo biloba extracts rich in flavonoids	n.i.	Human patient	Inhibit age-related macular degeneration	Evans (2000)
Resveratrol	2–3 years	Human patient	Inhibits age-related macular degeneration	Richer et al. (2014);
Resveratrol	20 mg/kg body weight for 4 weeks	C57BL/6 mice	Inhibits age-related macular degeneration	Richer et al. (2014)
Resveratrol	5 mg/kg body weight	Streptozotocin-induced diabetic SD rats	Inhibit diabetic retinopathy	Khaled et al. (2016)
Hesperetin	24 weeks	Streptozotocin-induced diabetic SD rats	Inhibits diabetic retinopathy	Kumar et al. (2013)
Genistein	n.i.	Streptozotocin-induced diabetic SD rats	Inhibits diabetic retinopathy	Sulaiman et al. (2014)
Curcumin	n.i.	Streptozotocin-induced diabetic SD rats	Inhibits diabetic retinopathy	Sulaiman et al. (2014)
Decursin	n.i.	Streptozotocin-induced diabetic SD rats	Inhibits diabetic retinopathy	Sulaiman et al. (2014)
Zingiber zerumbet extracts rich in flavonoids	200, 300 mg/kg body weight for 3 months	Streptozotocin-induced diabetic SD rats	Inhibit diabetic retinopathy	Tzeng et al. (2015)
Polygonum cuspidatum extracts rich in resveratrol, emodin and their derivatives	100 or 350 mg/kg body weight for 16 weeks	Streptozotocin-induced diabetic SD rats	Inhibit diabetic retinopathy	Sohn et al. (2016)
Plantaginis semen extracts rich in flavonoids	100, 200 or 300 mg/kg body weight for 8 weeks	Streptozotocin-induced diabetic SD rats	Inhibit diabetic retinopathy	Tzeng et al. (2016)

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