Skin Photoprotection by Polyphenols

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Polyphenols are phytochemicals with proven antioxidant and antiinflammatory properties. Premature aging and UV-induced skin conditions could be better overcome by topical polyphenols nanoformulations. Further, polyphenols nanoformulations can be of great interest for the cosmetic industries and any individuals who want to improve their skin appearance. Examples in this regard are provided and the potential toxicity issues related to the use of nanomaterials are highlighted.

Keywords: Nanomaterials ; Nanoparticles ; Nanomedicine ; Bioactive molecules ; Antioxidants ; Antinflammatory ; Dermatology ; Polyphenols ; Cosmetics ; Topical application ; Skin conditions

1. Introduction

For over a decade, reports from animal models and humans have increasingly provided evidence that polyphenols have potential benefits on skin (e.g., photoprotection, anti-aging features), due to their antiinflammatory, antioxidant and dexoxyribonucleic acid (DNA) repair properties. [1][2][3][4][5][6][7]

Polyphenols are represented by a superfamily of various naturally occurring phytochemicals (＞4000) that are abundant in our diet (e.g., vegetables, fruits, nuts, seeds). [8][9] These compounds are divided into three main classes (i.e., flavonoids, stilbenes and lignans), which are further subdivided according to their structural similarities (e.g., number of phenol rings). [1][8][9]

Their chemical structures, molecular mechanisms, metabolism, relative systemic bioavailability, plant source and content of various dietary polyphenols have been reviewed elsewhere. [8][9][10][11][12][13]

Interestingly, a controlled transdermal application of certain polyphenols (e.g., resveratrol and EGCG) for treating skin conditions (e.g., photo-damaged skin), in their bulk- or, preferentially, their nano-forms, usually present the following advantages compared to that of oral or intravenous intake: (1) maximization of local exposure, (2) an increase in the efficacy, (3) improvement of the stability (e.g., decrease of photo-induced polyphenols degradation), (4) minimization of the administered dose, (5) enhancement of the bioavailability at the targeted site (e.g., skin), and (6) reduction of the systemic toxicity (i.e., contribution to the individual's safety). [14][15][16][17][18][19][20]

Chronic exposure or acute high doses of UV, such as solar ultraviolet irradiation (UVR)—especially UV-type A radiation (UVA, 315-400 nm), which constitutes about 95% of the UVR in natural sunlight reaching the earth's surface—is known to induce a series of damage to the skin (e.g., direct molecular damage such as DNA strand breaks and/or oxidative stress-mediated damage such as lipid peroxidation). This, subsequently, can lead to photoaging (aka UV-induced premature/accelerated skin aging) or photo-carcinogenesis (aka skin UV-induced cancers). [21][22][23][24][25] For instance, it is known that after UVR-induced reactive oxygen species (ROS), the metalloproteinases (MMP)-1, -3, -9 levels are increased, causing collagen and elastin degradation before forming coarse wrinkles and sagging skin. [26] However, these overall effects can be reduced by polyphenols (e.g., teaderived catechins), which consequently contribute to a slow-down of the aging process and reduce the incidence of skin cancers (e.g., melanomas or nonmelanomas such as squamous cell carcinoma (SCC) or basal cell carcinoma (BCC)). [1][26][27][28][29][30][31][32][33][34][35][36][37][38]

Therefore, the evaluation of skin polyphenol-based products (e.g., polyphenol-rich sunscreens), [6][29][39][40][41][42][43] as well as the potential benefit of dietary polyphenols, [31][44][45][46][47][48] is promising and remains a challenging field of research.

Nevertheless, one should still keep in mind that some polyphenols could be a double-edged sword for the human skin, exerting not only protective (i.e., antioxidation) but also possible damaging actions (e.g., allergic reactions, contact dermatitis, phytodermatoses, and photo-phytodermatoses, enhanced UV-induced apoptosis of "normal" cells) depending on their physico-chemical parameters. [13][14]

2. Skin PhotoProtective Effects of Polyphenols: An Overview

A number of scientific studies with certain phytochemicals such as tea-, grape-, or soy-derived polyphenols, performed in animal models and humans/human cells exposed to UV-induced DNA damage, have provided a molecular basis to mechanistically explain the anti-skin photoaging (e.g., anti-accelerated signs of aging such as reduced wrinkles, improvement in elastic tissue content) as well as the skin photo-chemopreventive effect (e.g., DNA repair and antioxidant activities, anti-photo-induced immune suppression such as anti-depletion of antigen-presenting cells (APC)), suggesting that these natural compounds can serve as alternatives or enhancers to sunscreens or as dietary supplements.

EGCG is a green-tea derived catechin polyphenol (i.e., flavanol). Several studies [27][28][30][32][33][34][35][36][37][38][49][50][51][52][53][54][55] have reported potential benefits of oral administration or topical applications of EGCG for preventing or treating skin conditions (e.g., skin photo-damage) in animals (e.g., usually mice) and humans. Indeed, EGCG displays a number of features such as anti-inflammatory, antioxidant and DNA repair activities. [4]

Resveratrol is a phytoalexin antioxidant derived from natural products such as the skin of red grapes, peanuts, blueberries and cranberries. [8][9] Resveratrol has received extensive attention through the link with the "French paradox," and later with its chemopreventive activity demonstrated in animal cancer models and in humans. [45][56][57][58][59][60][61][62][63][64][65][66][67]

Silymarin consists of a family of flavonoids (silibinin (a major member [68]), isosilybin, silychristin, silydianin, and taxifoline) commonly found in the dried fruit of the milk thistle plant Silybum marianum (L. Gaertner). Silymarin was recently shown to display chemopreventive effects, antioxidant, anti-inflammatory, and immune-modulatory properties. Studies have also revealed that it can be valuable against photo-induced carcinogenesis and premature aging, [68][69][70][71] in various animal tumor models [72][73][74][75][76] and humans. [77][78][79][80] Moreover, silymarin may favorably supplement sunscreen protection. [68][69][70][74]

The soybean isoflavone genistein (aglycone) is a potent antioxidant, a specific inhibitor of protein tyrosine kinase, and a phytoestrogen with photoprotective properties. [81] During the past decade, a series of studies and reports have demonstrated that genistein (as topical, oral or systemic agent) has significant antiphotocarcinogenic and anti-photoaging effects in animal models (e.g., mice, pigs) [82][83] and human cells (e.g., fibroblasts, keratinocytes). [84][85][86][87][88]

Ellagic acid (EA) is a phenolic acid found in a wide variety of fruits and nuts such as raspberries, strawberries, pomegranate, walnuts, grapes, and blackcurrants. [89][90] These molecules are receiving particular attention as agents that may have potential bioactivities preventing skin photo-damage in human cells due to their potent ability to scavenge ROS and reactive nitrogen species (RNS), [90][91][92] decreasing the expression of pro-MMP-2 and pro-MMP-9, precursors of two elastolytic enzymes, [93] and inhibiting cell proliferation. [93]

3. Conclution

Most of the polyphenols presented in this chapter are emerging as efficient skin photoprotectors. Indeed, the overall studies performed in animal models and/or in humans show that these phytochemicals exert skin photoprotective properties, especially through their antioxidant (i.e., as scavengers of free radicals), anti-inflammatory, and antitumoral activities. It is becoming clear that topical/transdermal application of polyphenols (i.e., as cosmeceutics) presents certain advantages (e.g., lower systemic toxicity usually associated with required increased doses to reach a specific tissue) over oral or intravenous administration (e.g., as nutraceutics) of these phytochemicals. Further, polyphenol nano-formulations are proving to have advanced pharmacological effects (e.g., efficacy, safety, selectivity) compared to the therapeutic entities they contain. Evidently, although it appears that the prospects are very bright for the possible use of polyphenols in skin photoprotection, more clinical trials are needed with pure bulk- or nano-polyphenols formulations.

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