

Review article

Photoprotective effects of green tea polyphenols

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Non-melanoma skin cancer is the most common malignancy in humans and is equivalent to the incidence of malignancies in all other organs combined in the United States. Current methods of prevention depend on sunscreens in humans, efficacy of which is largely undetermined for non-melanoma skin cancers. Green tea polyphenols have the greatest effect with respect to chemoprevention and have been found to be most potent at suppressing the carcinogenic activity of UV radiation. They protect against many of the other damaging effects of UV radiation such as UV-induced

sunburn response, UV-induced immunosuppression and photoaging of the skin. They exert their photoprotective effects by various cellular, molecular and biochemical mechanisms in *in vitro* and *in vivo* systems. Green tea polyphenols thus have the potential, when used in conjunction with traditional sunscreens, to further protect the skin against the adverse effects of ultra-violet radiation.

Key words: green tea polyphenols; photoprotection; skin cancer; UV radiation.

Non-melanoma skin cancer is the most common malignancy in humans. In the United States alone, over 1.3 million new cases of cutaneous squamous cell and basal cell carcinomas are diagnosed each year (1). This is equivalent to the incidence of malignancies in all other organs combined. It is predicted that one in five Americans will develop at least one basal cell or squamous cell carcinoma during the course of their lifetime. The vast majority of these – over 90% – are caused by overexposure to ultraviolet radiation (2, 3). Moreover, the incidence of these diseases is increasing rapidly (4–7). Over a 6-year period in Minnesota, there was over a 53% increase in the incidence of squamous cell carcinoma in men and a 115% increase in women (6). Similar increases in the incidence of both cutaneous squamous cell and basal cell carcinoma have been reported from epidemiological studies in New Mexico (7).

Although there are many ways in which non-melanoma skin cancers can be successfully treated, there is increasing interest in developing new and better methods for their prevention. Current methods of prevention include counseling patients to avoid sun exposure during peak hours of ultra violet (UV) intensity, to wear broad-brimmed hats and long-sleeved clothing, and to regularly apply sunscreens. It is important to remember, however, that the efficacy of currently available sunscreens is determined largely by their

ability to protect against UV-induced sunburns, and their chemopreventive activity, at least in humans, is largely undetermined for non-melanoma skin cancers. While not to deny the value of sunscreens in the prevention of UV damage, it is important to note that most sunscreens have only modest efficacy (8); there is inconsistent patient compliance (9, 10); large amounts of sunscreen are required to achieve the full SPF value present on the label of the sunscreen (11); and there is no effect of sunscreens on prior UV damage. For these reasons, other agents are needed that will protect against UV-induced skin cancer development. One agent that has received particular attention in this regard is green tea.

Green tea is manufactured from the fresh leaves of the plant *Camellia sinensis* (12). The leaves of this plant are fermented through a process that, for the most part, prevents oxidation and polymerization of the plant's polyphenols. It is these compounds that are thought to be the major chemopreventive mediators. Green tea contains four major polyphenols: (–)-epicatechin (EC), (–)-epicatechin-3-gallate (ECG), (–)-epigallocatechin (EGC), and (–)-epigallocatechin-3-gallate (EGCG) (Fig. 1). It also contains other agents that have chemopreventive activities. These include caffeine, flavandiol, flavanoids, phenolic acids as well as the alkaloids theobromine and theophylline (13). It is the polyphenols, however, that have

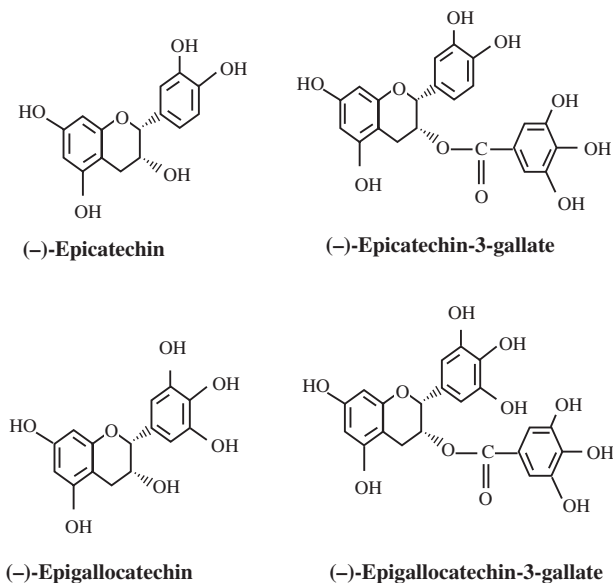


Fig. 1. Chemical structures of major epicatechin derivatives or polyphenols present in green tea.

the greatest effect with respect to chemoprevention. Black and oolong tea, the other two major types of tea, also have chemopreventive activities, which are attributed primarily to the caffeine, theaflavins and thearubigins that they contain (12, 14, 15).

Epidemiologic studies

The stimulus for investigating green tea as a chemopreventive agent in non-melanoma skin cancer was based on a series of epidemiological studies suggesting that green tea prevents cancer in other organ systems (16). For example, in areas of China in which esophageal cancer rates are the highest, tea is infrequently consumed (17). In addition, an inverse correlation has been observed between tea intake and oropharyngeal and esophageal cancers in postmenopausal women in Iowa, where daily tea consumption was associated with a greater than 50% lower risk (18). Tea consumption has also been observed to reduce the risk for cancers of the stomach, bladder and urinary tract, and liver cancer. It is important to note, however, that other studies have shown the opposite effect for some malignancies (16). Green tea compound, ECG and EGCG may be effective in treating human prostate tumors in mice which were actually suppressed by administration of EGCG. Similar EGCG-dependent suppression was also found with human breast tumors growing in mice (19).

Green tea and photocarcinogenesis

The first evidence that green tea polyphenols might have a protective role in UV-induced skin cancer came

from studies by Wang et al., who showed that green tea administered in the drinking water to SKH-1 hairless mice had a dose-dependent prolongation in the mean time of tumor development when they were subjected to a photocarcinogenesis protocol (20). Similar observations were made with respect to topical application of green tea polyphenols (20). A number of other studies have confirmed these results (21–23). Of the four major green tea polyphenols, EGCG has been found to be the most potent at suppressing the carcinogenic activity of UV radiation (21, 22). Moreover, the vehicle into which green tea polyphenols are incorporated has a significant influence with hydrophilic ointment having greater efficacy than other vehicles (22).

The development of UV-induced skin cancers in mice has been divided into the initiation, promotion and progression stages. Green tea polyphenols have been shown to have protective effects during each of these stages (24–26).

Protective effects of green tea polyphenols in other forms of UV damage *in vivo*

Green tea and its polyphenolic constituents protect against many of the other damaging effects of UV radiation. In mice, both systemic and topical administration of green tea polyphenols and EGCG were found to protect against the UV-induced sunburn response (27), UV-induced immunosuppression (27, 28) and photoaging of the skin (29). Similar results with respect to sunburn were observed in human skin that had been pretreated with a crude extract of green tea or with EGCG.

In animal models, green tea polyphenols have an ameliorative effect on photoaging as well (30). In UVA-irradiated SKH-1 hairless mice, there was an observable reduction in the amount of skin wrinkling. Topical application of EGCG has been shown to reduce UV-induced production of matrix metalloproteinases (MMP)-2, -3, -7 and -9, which are known to degrade collagen and lead to photodamage (29). Moreover, it is associated with a decrease in protein oxidation in the skin which also seen with photoaged skin (29).

The immunosuppressive effects of UV radiation on the skin immune system are well recognized, and have been implicated in the pathogenesis of non-melanoma skin cancer (31). Using murine-allergic contact hypersensitivity as a model, topical application of green tea polyphenols, either before or immediately after UV exposure, has been shown to reverse the immunosuppressive effects of UV, whereas topical application of green tea polyphenols

in the absence of UV exposure has no discernable effect on the immune response (27, 28).

Mechanisms of photoprotection by green tea polyphenols

There has been great interest in defining the cellular, molecular and biochemical mechanisms by which green tea polyphenols exert their photoprotective effects. Sunscreens form a physical barrier averting the penetration of ultraviolet radiation into the skin. Green tea polyphenols act in a dissimilar manner, given the fact that there is very little absorption by green tea in the UVB or UVA range; it is effective when given systemically; and protection against at least some of the biological effects of ultraviolet radiation occur when green tea is applied immediately after exposure (27).

Cellular effects

Keratinocytes

Green tea and its polyphenolic constituents reduce the number of sunburn cells, which have been shown to be epidermal keratinocytes that are undergoing apoptosis (32). As expected, direct examination of UV-irradiated skin that had been pre-treated *in vivo* with topical EGCG resulted in a reduction in the number of apoptotic keratinocytes as detected by TUNEL staining (33, 34). The *in vivo* observations are supported by *in vitro* studies in which cultured normal human keratinocytes were exposed to UVB radiation *in vitro* (33, 35). Further analysis showed that this anti-apoptotic effect *in vitro* was caused by an EGCG-induced increase in the expression of the anti-apoptotic molecule Bcl-2 and a decrease in the pro-apoptotic protein Bax (33). In contrast to its effect on normal keratinocytes, EGCG stimulates apoptosis in UV-induced pre-malignant papillomas and invasive squamous cell carcinomas in mice (33, 36). It has been proposed that this differential effect on apoptosis in malignant vs. benign keratinocytes is responsible, at least in part, for the chemopreventive effects of EGCG in photocarcinogenesis.

Inflammatory cell infiltration

Another hallmark of UVB radiation exposure *in vivo* is the development of a profound inflammatory response consisting of the influx of neutrophils and macrophages into the UV-irradiated skin site. The inflammatory response has been shown to contribute to the pathogenesis of the sunburn reaction, photocarcinogenesis, photoaging of the skin and UV immune suppression. Application of green tea

polyphenols to the skin as well as administration of green tea in the drinking water markedly reduces the inflammatory response brought about by UV radiation (37). A similar effect has been observed in humans (38). The effect of EGCG on neutrophil migration was studied *in vitro* in Boyden chambers and *in vivo* in a rat model of allergic inflammation (39). In both assays, EGCG had inhibitory effects.

Another type of cell that migrates into the skin following UV radiation is the CD11b⁺ macrophage (28, 37, 38). The CD11b⁺ macrophage serves as the antigen-presenting cell that is responsible for the presentation of antigen to T lymphocytes that down-regulate immune responses. It is also a potent source of hydrogen peroxide and nitric oxide in UV-irradiated skin (40). Thus, through its ability to deter the movement of CD11b⁺ macrophages into UV-irradiated skin, EGCG reverses UV-induced immunosuppression and reduces the production of reactive oxygen intermediates.

Langerhans cells are bone marrow-derived antigen-presenting cells that reside in the epidermis for long periods of time and serve as the counterpart to CD11b⁺ macrophages; these cells activate cells that serve as effector cells for cell-mediated immunologic processes. Langerhans cells are extraordinarily susceptible to UV injury, and damage to this cell type plays a key role in the development of UV-induced immune suppression. Moreover, the deleterious effects of UV radiation on Langerhans cells are thought to be an important contributing factor to the pathogenesis of UV-induced skin cancer and to the reduction in cell-mediated immune responses to antigens encountered by the skin (34). Studies have shown that application of green tea to human skin before UV radiation leads to an increase in Langerhans cells densities close to that which is seen in normal skin.

Biochemical effects

Cytokines

Research in the last two decades has shown that the immune suppression induced by UV radiation is mediated at least in part through alterations in the production of a variety of different cytokines derived from the skin and that these effects contribute to UV-induced skin cancer development (41). Because green tea and its polyphenolic constituents have been shown to reverse the immunosuppressive effects of UV radiation, there has been considerable interest in defining the effects of green tea on UV-induced modifications in cytokine production. Of particular interest have been the effects on interleukin (IL)-10 and -12. IL-10

is an 18 kDa cytokine that down-regulates allergic contact hypersensitivity and other cell-mediated immune responses (42). IL-12, on the other hand, facilitates the induction and elicitation of cell-mediated immune responses (43). *In vitro* exposure of keratinocytes to UVB results in the production of IL-10 (44, 45). When injected into mice, IL-10 containing supernatants cause systemic immunosuppression (44, 45). Moreover, systemic administration of anti-IL-10 antibodies to mice blocks UV-induced inhibition of the delayed-type hypersensitivity response (45). On the other hand, IL-12 reverses the immunosuppressive effects of UVB-radiation on cutaneous cell-mediated immune responses (46). For example, administration of anti-IL-12 antibodies *in vivo* before allergen painting prevents sensitization (47) and systemic administration of recombinant IL-12 prevents UV-induced immune suppression and overcomes the hapten-specific tolerance it produces (46, 47). The accumulated evidence thus indicates that UV-induced immune suppression is mediated at least in part by an increase in the production of IL-10 and a reduction in IL-12 levels (28).

EGCG has been shown to change the balance between these two cytokines, reducing IL-10 production and increasing IL-12 (28). As was mentioned, CD11b⁺ macrophages migrate into the epidermis following UVB exposure (48), and EGCG inhibits the migration of these cells into the epidermis (28). In so doing, it limits the amount of IL-10 found in the skin. Topical application of EGCG greatly increases the production of IL-12 in draining lymph nodes compared with mice treated with UVB alone (28). EGCG is not effective at inhibiting the sunburn response and photocarcinogenesis, indicating that the production of this cytokine is a necessary intermediary in the photoprotective effects of green tea polyphenols. Further analysis has shown that in addition to promoting cell-mediated immune responses, EGCG-induced IL-12 augments the synthesis of enzymes that repair UV-induced DNA damage (49).

Angiogenesis

Growing tumors require a continuous supply of nutrients and oxygen that is greater than normal to survive and thrive. To fulfill this requirement, tumors, including UV-induced tumours, develop new blood vessels, a process called angiogenesis. Angiogenic factors such as the matrix metalloproteinases (MMP) and vascular endothelial growth factor (VEGF) are important regulators of tumor growth, both at the primary tumor site and at sites of distant metastasis (50, 51). Recently, it has been shown that topical application of EGCG significantly inhibited

UVB-induced tumor growth, and inhibition of tumor growth was associated with a reduction of MMP-2 and -9 protein expression and activity (52), factors that are known to play a crucial role in tumor growth, invasion and metastasis. Further, treatment with EGCG resulted in an up-regulation of tumor inhibitor of matrix metalloproteinase (TIMP)-1 in tumors compared with mice that were not treated with EGCG. Induction of TIMP-1 may contribute to inhibition of the expression of both MMP-2 and -9 in tumors. EGCG also inhibited the expression of VEGF in UV-induced skin tumors and in the expression of CD31 on the cell surface of vascular endothelial cells (52, 53). CD31 has been implicated in the formation of new blood vasculature in growing tumors (54). Thus, it is reasonable to presume that EGCG inhibits new vessel formation in UV-induced tumors and thus retards tumor growth.

Molecular effects

Reactive oxygen intermediates

Excessive exposure to UV radiation overwhelms the body's natural antioxidant defense mechanisms leading to an increase in reactive oxygen intermediates and a depletion in endogenous antioxidant enzymes (22, 55). Reactive oxygen intermediates have also been implicated in photoaging, photocarcinogenesis and sunburn. There is considerable evidence to indicate that green tea polyphenols protect against UV-induced oxidative injury in the skin (22, 29, 37, 55–57). The observations in this regard originated with *in vitro* studies using mouse epidermal microsomes as a substrate. Pretreatment with green tea polyphenols inhibited the UV-induced lipid peroxidation in those organelles (58). In another *in vitro* study in which cultured keratinocytes were treated with EGCG before UVB exposure, EGCG decreased the UVB-induced intracellular release of hydrogen peroxide and inhibited the phosphorylation of MAPK proteins, a reaction that is dependent on hydrogen peroxide (56). The antioxidant effect of EGCG is not restricted to UVB radiation. When the HaCaT human keratinocyte line was treated with EGCG, it had a protective effect against UVA-induced oxidative damage and it reduced DNA single strand breaks at alkali labile sites, a form of DNA damage that is characteristic of UVA-induced oxidative stress (57). One proposed mechanism for the ability of EGCG to protect against oxidative damage to DNA is through the direct scavenging of reactive oxygen species (59). It has also been shown that low concentrations of green tea polyphenols reduce hydroxyl radical-induced base damage and single-strand breaks in DNA by a

mechanism of electron transfer from catechins to radical sites on the DNA (60).

Some studies have suggested that high concentrations of EGCG actually cause an increase in reactive oxygen species in some cells (61, 62). Yamamoto et al. demonstrated that high concentrations of EGCG (200 μ M) produce reactive oxygen species in tumor cells, while reducing reactive oxygen species to background levels in normal epithelial cells (61, 62). If similar actions could be demonstrated *in vivo*, the differential effects of EGCG on normal vs. tumor cells would have obvious dividends for tumor prevention and therapy.

In addition to their *in vitro* effects, green tea polyphenols also inhibit UVB-induced markers of oxidative stress *in vivo* in animal models. When applied topically or given orally to SKH-1 hairless mice, pretreatment with EGCG or green tea polyphenols before UVB radiation protects against depletion of glutathione, the antioxidant enzymes glutathione peroxidase and catalase, decreases UV-induced lipid peroxidation and inhibits UVB-induced protein oxidation (22, 29, 55). EGCG protects against UV-induced oxidative stress in humans as well. When it was applied to the skin of volunteers just before exposure to a four minimal erythema dose (MED) of UVB radiation, it significantly decreased the production of hydrogen peroxide and nitric oxide production as well as lipid peroxidation in the dermis and epidermis (55). At least some of this effect on the production of reactive oxygen intermediates was due to reduced infiltration of CD11b+ macrophages into UV-irradiated skin (37, 38). This is significant because CD11b+ macrophages are a major source of reactive oxygen intermediates following UV radiation (40). In addition, EGCG also inhibits the UV-induced decrease in glutathione and glutathione peroxidase levels in human skin (55).

The biological effects of tea polyphenols observed *in vitro* might not occur *in vivo*. The activities which are affected by lower concentrations of these compounds are more relevant *in vivo* due to their limited bioavailability. Identification of primary events vs. subsequent events and the demonstration of specific mechanisms of action is important in animal models and human tissues (63).

DNA damage

UV radiation to the skin results in DNA damage in skin cells, the most prevalent of which are cyclobutane pyrimidine dimers. Cyclobutane pyrimidine dimers have been shown to be involved in the initiation of UV-induced immunosuppression (64, 65) as well as various forms of skin cancer (66). Several studies have demonstrated the photoprotective effects of green tea

polyphenols on preventing UV-induced DNA damage. In an *in vitro* study using cultured human cells (lung fibroblasts, skin fibroblasts, and epidermal keratinocytes), EGCG resulted in a dose dependent reduction in UV-induced DNA damage in all three cell types (67). Green tea polyphenols also significantly inhibited the UVB-induced DNA damage when applied topically to the mouse epidermis, using a 32 P-postlabelling technique (68).

Application of green tea polyphenols to the skin has proven to be an effective means of protecting against UV-induced DNA damage *in vivo* in human studies as well. When applied topically to human skin 30 min before UV exposure, green tea polyphenols reduced UV-induced DNA damage (34). In another *in vivo* study, human skin was treated with green tea polyphenols before UV exposure. Green tea polyphenol treatment inhibited the UVB induction of cyclobutane pyrimidine dimer formation in the epidermis and the dermis, including the deeper dermis (69). There was a dose-dependent response both for the green tea that was applied and for the UVB dose used to irradiate the skin.

In response to DNA damage, wild-type p53 protein levels increase and induce the synthesis of p21, an inhibitor of cyclin-dependent kinases, leading to arrest of the cell cycle. UVB-induced DNA damage can eventually result in the inactivation of p53, preventing this cascade of events and allowing the replication of the damaged DNA to occur (70). Given the fact that green tea has been shown to inhibit UV-induced DNA damage, an unexpected result was that oral administration of green tea actually stimulated the UV-induced increase in p53- and p21-positive cells in normal mouse skin. This enhancement of the UV-induced increase in p53-positive cells has been postulated to play a role in the chemopreventative and photoprotective properties of green tea (70).

Signal transduction molecules

Several different cellular signal transduction pathways are activated following UV exposure, and, in so doing, UV radiation transmits signals from the plasma membrane to the nucleus, ultimately leading to a cellular response (71). The changes produced by activation of these pathways have been implicated in photoaging of the skin, skin cancer growth and invasion, enhanced cell survival, cell proliferation, and certain types of DNA damage. Green tea polyphenols have been shown to affect multiple steps in various signal transduction pathways. It is thought that inhibition of several of these pathways contributes in a significant

manner to its photoprotective effects in *in vitro* and *in vivo* systems. Among the major signal transduction pathways altered by green tea polyphenols are the p53 and cell cycle regulatory molecules, MAP kinase, NF- κ B, AP-1 and phosphatidylinositol 3-kinase/Akt and p70 S6-K.

Green tea and apoptosis, p53 and cell cycle regulatory molecules

To maintain the integrity of the healthy cells after DNA damage, several cellular responses are activated including removal of damaged DNA, delay in cell cycle progression, and DNA repair by transcriptional activation of p53, p21^{waf1/cip1}, MDM2 and the proteins of the Bcl-2 family of proteins (72–75). The induction of p53 after DNA damage is also associated with enhanced apoptosis, presumably in those cells which are severely damaged. Studies have demonstrated that oral administration of green tea to SKH-1 hairless mice enhanced UV-induced increases in the number of p53- and p21^{waf1/cip1}-positive cells in the epidermis following UV exposure (70). This implies that the photoprotective effect of green tea on UV-induced carcinogenesis may be mediated through stimulation of UV-induced increases in the levels of p53, p21^{waf1/cip1}.

Green tea and mitogen-activated protein kinases (MAPK)

The MAPK, which include the extracellular signal regulated kinase (ERK), c-Jun N-terminal kinase/stress-activated protein kinases (JNK/SAPK) and p38 proteins, are important regulators of the activator protein (AP)-1 and Nuclear factor (NF)- κ B transcription factors (71). As most of the UV radiation-induced adverse biological effects are mediated through the generation of oxidative stress, studies have shown that treatment of normal human epidermal keratinocytes (NHEK) with EGCG inhibits UV-induced phosphorylation of the MAPK family proteins through inhibition of oxidative stress (76). The beneficial effects of green tea were also determined in *in vivo* in animal models. Vayalil et al. have shown that topical application of EGCG to mouse skin resulted in a marked inhibition of UV-induced phosphorylation of ERK1/2, JNK and p38 proteins of MAPK family in a time-dependent manner (22). This response was observed both after a single or multiple exposures to UV radiation. The photoprotective effects of green tea polyphenols also occurred when given to mice in drinking water.

Green tea and NF- κ B

UV radiation is a potent stimulus for nuclear factor-kappa B (NF- κ B), a ubiquitously expressed transcription factor that belongs to the Rel family of transcription factors that regulate genes involved in inflammation, immunity, cell cycle progression, apoptosis and oncogenesis (77–79). EGCG inhibits constitutive expression and TNF- α -mediated activation of NF- κ B in the A431 human epidermoid carcinoma cell line more efficiently than in normal human epidermal keratinocytes (80). It has also been shown that EGCG has a protective effect against several of the adverse biological consequences of NF- κ B activation. Treatment of NHEK with EGCG resulted in inhibition of UVB-mediated degradation and phosphorylation of I κ B α and activation of IKK α in a dose-dependent and time-dependent manner (81). *In vivo*, topical application of GTPs to mouse skin resulted in inhibition of UVB-induced activation of NF- κ B, activation of IKK α , and phosphorylation and degradation of I κ B α (82).

Green tea and AP-1

There is growing evidence that the AP-1 family of transcription factors which are involved in cell proliferation and survival through their ability to regulate the expression and function of a number of the cell cycle regulatory proteins, cyclin D1, p53, p21, p19 (83), are ideal molecules to target for the chemoprevention of skin cancer. Treatment of the human keratinocyte cell line, HaCaT, with EGCG inhibited UVB-induced expression of *c-fos*, one of the heterodimers of AP-1 and AP-1 activation (84). Studies by Chen and Bowden (85) have demonstrated that activation of both p38 and ERK are required for UVB-induced *c-fos* expression in HaCaT cells. Therefore, it is likely that inhibition of UVB-induced activation of AP-1 by EGCG is mediated through inhibition of the activation of MAPK proteins.

Green tea and phosphatidylinositol 3-kinase/Akt and p70 S6-K

Phosphatidylinositol 3-kinase and its downstream effectors, Akt, also known as protein kinase B, have been demonstrated to play a crucial role in broad range of biological activities including protein synthesis, cell growth, cell motility and apoptosis (86). UVB radiation results in activation of the epidermal growth factor receptor (EGFR) that triggers phosphorylation of protein kinase B (PKB/Akt) (87). Nomura et al. (86) have demonstrated that EGCG inhibits UVB-induced activation of PI3K, and Akt in mouse epidermal cells. This study also indicated that EGCG has

the ability to directly block UVB-induced p70 S6-K activation.

Green tea and proteasome activation

The 20S proteasome, a constituent of the ubiquitin–proteasome pathway, has also been shown to be a molecular target for EGCG (88). The 20S molecule is responsible for degrading p53, pRB, p21, p27^{Kip1}, IκBα and Bax, proteins which have been implicated in skin tumorigenesis. Evidence has been presented to implicate the chymotrypsin-like activities of this molecule in tumor cell survival. *In vitro* experiments were able to demonstrate that ECG and EGCG does inhibit the activity of the 20S proteasome. This resulted in the accumulation of p27^{Kip1} and IκBα, and, in turn, with growth arrest in the G1 of the cell cycle in the tumor cell lines tested (88). Because many of the molecules that are degraded by the ubiquitin–proteasome pathway regulate the cell cycle and cell death, it has been postulated that irreversible inhibition of the 20S proteasome by EGCG may be one of the upstream events necessary for it to exert its chemopreventive effects (88).

Conclusion

The available evidence indicates that green tea has many biological effects that ameliorate the damaging effects of both UVA and UVB radiation. These biological activities differ from those of traditional sunscreens. Green tea polyphenols thus have the potential, when used in conjunction with traditional sunscreens, to further protect the skin against the adverse effects of ultraviolet radiation.

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