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EVALUATION OF PLANT-BASED UV FILTERS POTENTIAL IN MODERN CONCEPT VIEW OF SKIN PHOTOPROTECTION

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A therapeutic plants potential is based on the pharmacological effects due to their phytochemical profile. Today, scientific interest in botanicals is increasing as a result of recent research that looks at the prospect of using these raw materials for the cosmetic industry as a means to protect the skin from the harmful effects of UV rays.

The aim of the study was to evaluate a potential of plant-based UV-filters in modern concept view of skin photoprotection.

Materials and methods. A systematic literature search was carried out using the electronic information arrays PubMed, Scopus, Google Scholar, eLibrary. The search depth was 10 years (the period from 2010 to 2021). The search was carried out by the following keywords: antioxidants, cosmetics, photoprotection, chemical composition, pharmacological action.

Results. In the paper, modern principles of skin photoprotection based on the use of chemical or physical UV-filters are considered and scientifically substantiated A trend for the use of plant-based materials and their components in the formulation of photoprotectors was notified. That is associated with a wide activity spectrum, the absence of a xenobiotic effect, and a high bioavailability of organic plant compounds.

Conclusion. The data analysis from scientific publications demonstrated a potential photoprotective activity of plant-based biologically active substances due to antioxidant, anti-inflammatory and anti-radical effects. The results of the study are a theoretical basis for a further comprehensive experimental study of plant objects in order to obtain a pool of evidence in the field of photoprotection in *in vivo* experiments.

Keywords: plant-based UV filters; photoprotection; concept of modern skin photoprotection

Abbreviations: IPD – Immediate Pigment Darkening; IPF – Immune Protection Factor; NADH – nicotinamide adenine dinucleotide; NADPH – nicotinamide adenine dinucleotide phosphate; PPD – Persistent Pigment Darkening; SPF – Sun Protection Factor; UVA – ultraviolet A rays; UVB – ultraviolet B rays; UVC – ultraviolet C rays; ROS – reactive oxygen species; BASs – biologically active substances; WHO – World Health Organization; DNA – deoxyribonucleic acid; UV rays – ultraviolet rays.

ОЦЕНКА ПОТЕНЦИАЛА РАСТИТЕЛЬНЫХ UV-ФИЛЬТРОВ В СВЕТЕ СОВРЕМЕННОЙ КОНЦЕПЦИИ ФОТОЗАЩИТЫ КОЖИ

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Терапевтический потенциал растений основан на фармакологических эффектах, обусловленных их фитохимическим профилем. Сегодня научный интерес к растительным объектам возрастает в результате последних исследований, в которых рассматривается перспектива применения данного сырья для косметической отрасли в качестве средств для защиты кожи от пагубного воздействия УФ-лучей.

Цель. Оценка потенциала растительных UV-фильтров в свете современной концепции фотозащиты кожи.

Материалы и методы. Систематический поиск литературы проводился с помощью электронных информационных массивов PubMed, Scopus, Google Scholar, eLibrary. Глубина поиска составила 10 лет (период с 2010 по 2021 гг.). Поиск проводили по ключевым словам: антиоксиданты, косметические средства, фотозащита, химический состав, фармакологическое действие.

Результаты. В работе рассмотрены и научно обоснованы современные принципы фотозащиты кожи, базирующиеся на применении химических или физических UV-фильтров. Отмечена тенденция использования растительного сырья и его компонентов в рецептуре фотопротекторов, что связано с широким спектром активности, отсутствием ксенобиотического эффекта и высокой биодоступностью органических растительных соединений.

Заключение. Анализ данных научных публикаций продемонстрировал потенциальную фотопротекторную активность биологически активных веществ растений, обусловленную антиоксидантным, противовоспалительным и антирадикальным эффектами. Результаты исследования являются теоретическим базисом для дальнейшего всестороннего экспериментального изучения растительных объектов с целью получения пула доказательных данных в области фотопротекции в опытах *in vivo*.

Ключевые слова: растительные UV-фильтры; фотопротекция; концепция современной фотозащиты кожи

Список сокращений: IPD – быстрое пигментационное потемнение; IPF – фактор защиты иммунитета; NADH – никотинамидадениндинуклеотид восстановленный; NADPH – никотинамидадениндинуклеотидфосфат; PPD – постоянное пигментационное потемнение; SPF – солнцезащитный фактор; UVA – ультрафиолетовые лучи А; UVB – ультрафиолетовые лучи В; UVC – ультрафиолетовые лучи С; АФК – активная форма кислорода; БАВ – биологически активные вещества; ВОЗ – Всемирная организация здравоохранения; ДНК – дезоксирибонуклеиновая кислота; УФ-лучи – ультрафиолетовые лучи.

INTRODUCTION

Despite the fact that sunlight is an initiator and catalyst of most metabolic processes, ultraviolet radiation, as one of the fragments of the sunlight spectrum, provokes photoaging with multiple exposures to the skin, and also contributes to the development of a number of pathologies, incl. photocarcinogenesis [1].

The effects of harmful UV exposure highlight the need for the skin protection across the full sunlight spectrum. A modern concept of human skin photoprotection involves the use of broad-spectrum cosmetics, which leads to the search for new natural multifunctional ingredients, including those with a photoprotective activity. Components of the plant origin, which, due to the multicomponent chemical composition, have a multi-vector biological effect, are of considerable interest. This factor is primarily due to the presence of active centers of biologically active substances (hydroxo groups of polyphenolic compounds, keto-enol tautomeric groups of ascorbic acid, systems of conjugated bonds, etc.) and contributes to the realization of natural photoprotective properties [2].

The literature [3–5] contains information on the ability of a number of representatives of various botanical classification groups, from algae and lichens to dicotyledonous plants, to exert antioxidant, anti-inflammatory, and immunomodulatory effects in the experiment. In combination, they implement a photoprotection mechanism. Thus, a number of authors [6–10] report the active components ability of *Silybum marianum* L., *Gracilariopsis longissimi* (S.G. Gmelin) M. Steentoft, *Elaeagnus angustifolia* L., *Moringa oleifera Lam.*, *Vitis vinífera* L., *Ruta graveolens* L., *Ginkgo biloba* L., *Dirmophandra mollis Benth.*, to exhibit their photoprotective properties. The literature also presents the results of studying the chemical composition

[11–14] and experimentally proven photoprotective properties [15–17] of rosehip raw materials; the data on a high bioavailability of rosehip oil biomolecules have been generalized [18–21]. Given a low toxicity, the absence of a xenobiotic effect, a relative availability of phytosubstances, a study and evaluation of plant components as potential photoprotectors, are of scientific and practical importance [22].

The results of this study are based on a systematic analysis of the latest data from scientific publications and can contribute to the formation of logical-structural interrelations of this kind: "phytochemical composition – spectrum of pharmacological activity – prospects for using a plant to develop original cosmetic products with a photoprotective effect."

THE AIM of the study was to evaluate the potential of plant-based UV-filters in modern concept view of skin photoprotection.

MATERIALS AND METHODS

The study was carried out by the methods of the content analysis and data aggregation. A systematic literature search was carried out using the electronic information databases PubMed, Scopus, Google Scholar, eLibrary. The search depth was 10 years (the period from 2010 to 2021). The reference (key) words for the targeted search were in Russian: photoprotection, antioxidants, cosmetics, chemical composition, pharmacological action. To search for foreign sources, similar queries were used but only in English.

RESULTS AND DISCUSSION

UV characteristics

To date, it seems undeniable that a human body is affected by two spectra of UV rays: medium-waves (UVB) with a wavelength range of 280–320 nm, constituting 5% of ultraviolet, and long-waves (UVA) with a wavelength range of 320–400 nm covering 95% of the UV spectrum. In recognition of the importance of the ultraviolet radiation dose affecting human skin, the World Health Organization (WHO) introduced the UV index, i.e., the index of a daily assessment of the UV rays intensity near the Earth's surface, depending on the weather conditions in a particular area. It should be notified that the intensity of the UVB radiation depends on the angle of the sun above the horizon and increases by 4–10% every 300 meters up and by 3% for every degree of latitude southward. Unlike the UVB, the effect of UVA rays is not softened by the ozone layer, they have a significant penetrating power, pass through clouds, glass, and are emitted constantly throughout the daylight hours [1, 23].

Effect of UV radiation on human skin

Attention is drawn to the fact that human skin perceives the entire spectrum of electromagnetic waves, but reacts to them in different ways. In this case, the interaction of electromagnetic waves with skin structures depends on the energy of its photon, which is inversely proportional to the wavelength. This process is characterized by the parameters of reflection/scattering, absorption, and waves penetration depth. Visualization of the UV rays impact on the skin according to various authors is presented in Fig. 1.

In relation to visible light, the skin is an optically semitranslucent formation. Reflection, scattering, and absorption of waves occur insignificantly on its surface and massively in its thickness. The index of the intralayer reflection is one of the indicators of youthfulness of the skin, because getting older, the proportion of reflected light decreases (Fig. 2) [1, 23].

The studies by Russian and foreign authors have shown that the shorter the wavelength (the greater its frequency and energy), the more tightly it interacts with tissue and cellular formations due to the intense absorption by skin chromophores. As a consequence, such waves realize predominantly a surface action. In the *stratum corneum*, an important and massive absorbing agent is keratin, which absorbs predominantly UVB rays and, to a lesser extent, interacts with the UVA spectrum [23–25]. Along with keratin, keratinocytes, melanocytes, fibroblasts, Langerhans cells and endotheliocytes are also involved in the process of absorption of UV-wave energy. The biological effect of this interaction is accompanied by the production of biological markers, primarily reactive oxygen species (ROS), as well as nitrogen and carbon, including both free radicals and nonradical substances (Table 1) [1, 23].

It is important to note that ultraviolet radiation has a cumulative damaging effect on the skin, i.e. small daily doses accumulate into monthly/yearly ones. In this case, it is not the doses of UV rays that accumulate, but the consequences of their exposure, mainly represented by the oxidative damage to cells and the extracellular matrix. To date, a number of studies have shown that up to 80% of facial skin aging signs are associated with an exposure to UV rays [24–26]. Thus, an increase in the time of the daily skin exposure to sunlight, from 1–2 to 5 hours a day, leads to a loss of moisture in the skin, a

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violation of the capillary tone and an increase in the formation of fine wrinkles by 4.8 times. A daily use of a cosmetic product with a sun protection filter (SPF) 4–10 can reduce the cumulative UV dose by 50% [23].

Considering that there are absorbers for all types of waves in the cells and the extracellular matrix, the biological consequences are multi-vector. The studies of the etiology and pathogenesis of malignant skin diseases testify to the adverse effects of UV rays on the skin. The rays of UVA and UVB spectra lead to the oxidation of lysine, proline and arginine, often found in proteins in cells and matrix. That triggers an irreversible glycation process with the formation of products of completed glycolysis, cross-links of protein fibers inside and outside cells. The latter circumstance leads to pronounced melanogenesis in the epidermis and thinning of the dermis [23, 25]. It is worth emphasizing that the use of cosmetics with SPF 15 in children reduces the risk of skin cancer later in life by 78% [23].

Attention is drawn to the fact that UVB-waves realize their effect exclusively at the level of the epidermis, in which primary lesions are formed. Biologically, the most important absorber of UVB rays is the DNA of keratinocytes of the germ layer of the epidermis, and the target is the adjacent pyrimidine bases of thymine and cytosine, between which pathological covalent bonds arise under the conditions of a UVB photon absorption. As a result of the interaction, two photoproducts are formed: cyclobutane–pyrimidine dimer and a 6–4 photoproduct (Fig. 3) [1, 23]. It should be notified that the formed photoproducts with altered spatial geometry lead to a nucleotide substitution in the newly synthesized chain, and lead to UVB mutations, which occur during UVB irradiation in 85% of cases. In addition, as a result of a massive DNA damage in the epidermis, the first "burn" cells with a characteristic morphology are formed. Thus, pyrimidine dimers and "burn" cells are an early, accurate and informative indicator of the UVB exposure intensity. Immune Langerhans cells, which are extremely sensitive to the effects of UVB rays, are also a marker of the exposure intensity to UVB radiation, since they lose their processes and migrate to regional lymphatic nodes [23].

Despite the fact that UVB-rays practically do not penetrate the dermis, dermal reactions are also indicators of the UVB damage degree, incl. activation of dermal MMP-1, which destroys collagen, reddening the skin and elastolysis, which increases due to the accumulation of a large amount of immature elastin in the papillary dermis [1].

Herewith, the cumulative effect of UVA rays on the human body is manifested by more pronounced destructive changes than UVB radiation. Despite the fact that the UVB rays energy is 1000 times as much as the UVA rays energy, 90% of UVB rays are blocked by the epidermis stratum corneum, while 50–60% of UVA rays are able to penetrate deep into the dermis. It is worth notifying that it is UVA irradiation *in via* the avalanche-like production of a free radicals pool that damage the cells and extracellular structures of the dermis, which determines the manifestation of the skin photoaging picture through the elasticity loss and the wrinkles formation. An indicator of DNA damage during UVA irradiation is the oxidation of DNA in the region of the purine base of guanine with the accumulation of 8-hydroxyguanine. Along with this, an excess of ROS leads to rapid ligand-independent activation of membrane cell receptors for numerous growth factors and interleukins, distortion of gene activity, including AP-1 and NF-kB. These factors ultimately cause inhibition of procollagen synthesis processes, synthesis of products glycation and activation of metalloproteinases MMP-1, -3, and -9, which determine the destruction of dermal matrix structures (Fig. 4, Table 2) [1, 22, 23].

Physiological mechanisms of the body's protection from UV/UVB rays are represented by the epidermis stratum corneum, able of compaction under the influence of UV/UVB rays, melanin (from Greek the *"melanos"* – "black"), which delays up to 90% of photons, as well as urocaninic acid. When irradiated, the acid transform goes over into a cis form, and in the absence of the UV radiation exposure, the reverse reaction occurs (Fig. 5) [23, 27].

Thus, a multi-vector nature and depth of morphological and functional changes in the skin exposed to the entire spectrum of UV rays, emphasize the importance of photoprotection of the largest organ of the human body.

Characteristics and mechanism of UV protective filters effect

UV filters have a protective effect on UV rays. These are the substances designed to protect the skin from the penetration of UV radiation by absorption, reflection or scattering. The effectiveness of UV filters is measured by the Sun Protection Factor (SPF) and is the ratio of the minimum dose of UV radiation that causes redness of the protected skin to the minimum dose of UV radiation that causes redness of the unprotected skin.

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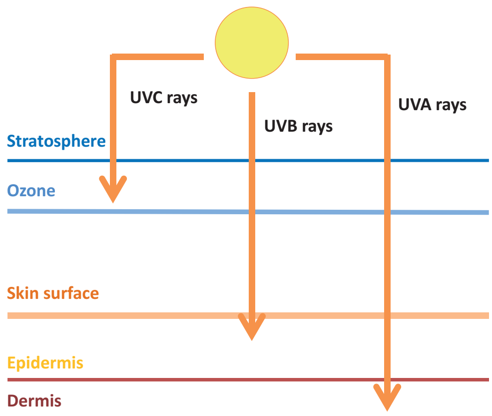

Figure 1 – Scheme of UV rays exposure on human skin[1]

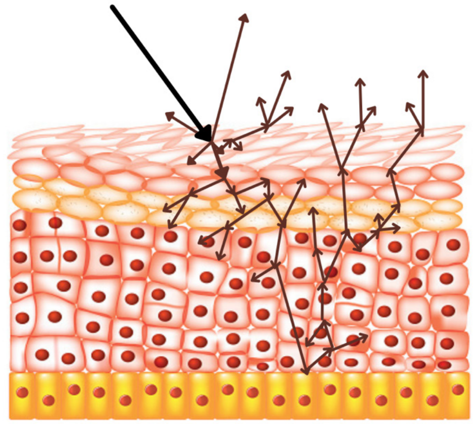

Figure 2 – Propagation of a light wave inside the skin

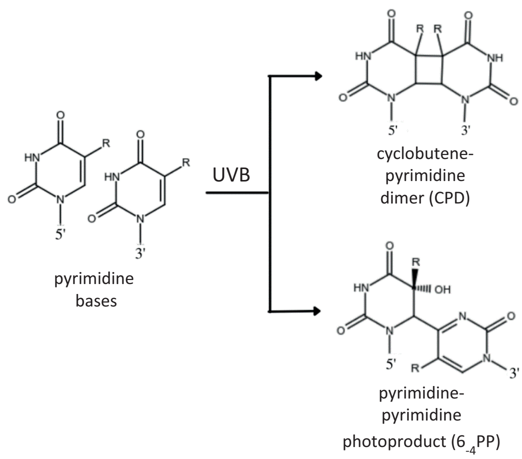

Figure 3 – Transformation of thymine T and cytosine C when absorbing a UVB-wave photon

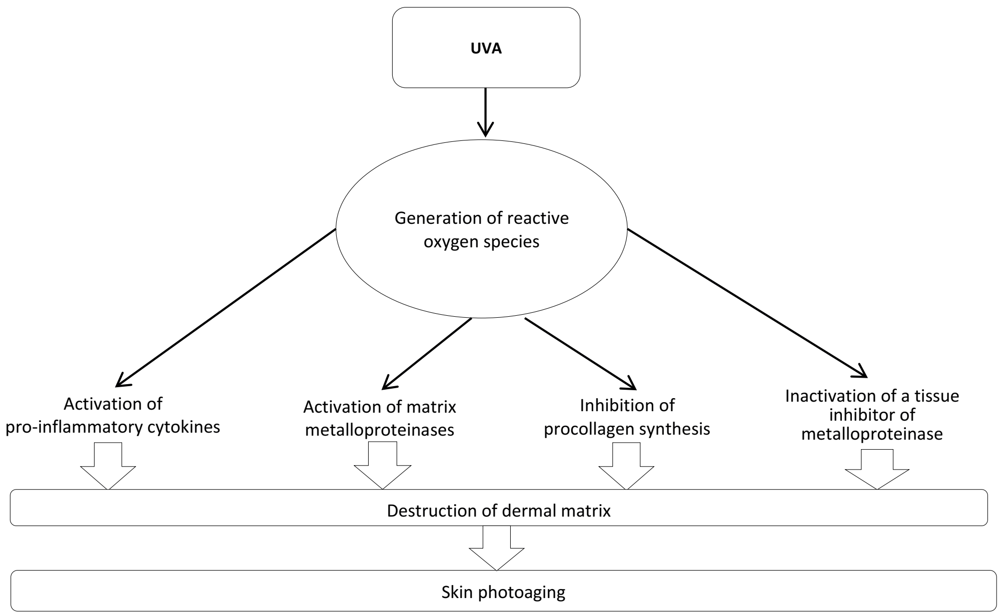

Figure 4 – Skin exposure to UVA rays

[1] Here and below, the figures represent the author's interpretation of references comprehensive analysis on certain aspects of the consideration problem.

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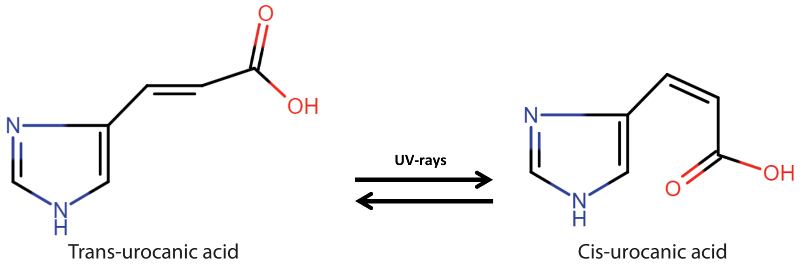

Figure 5 – Isomerization of urocaninic acid by a quantum of light under the conditions of exposure to UV rays

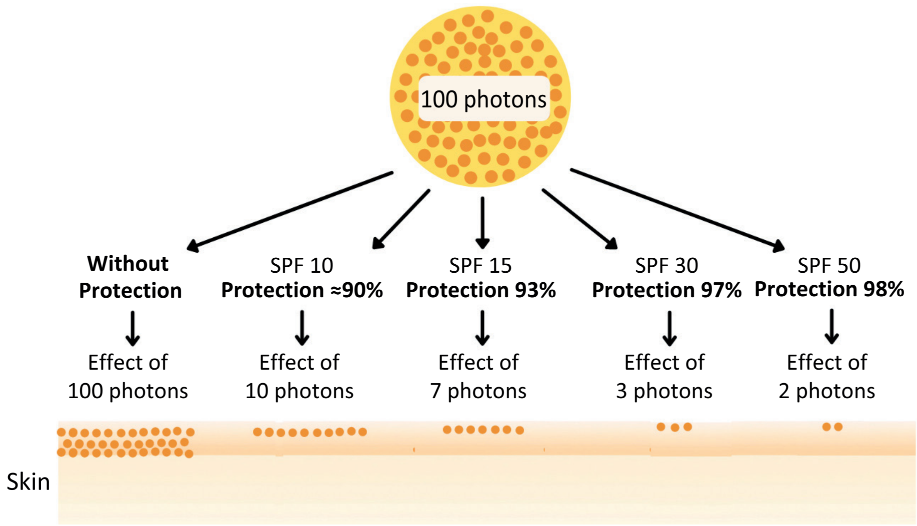

Figure 6 – Principle of calculating SPF value

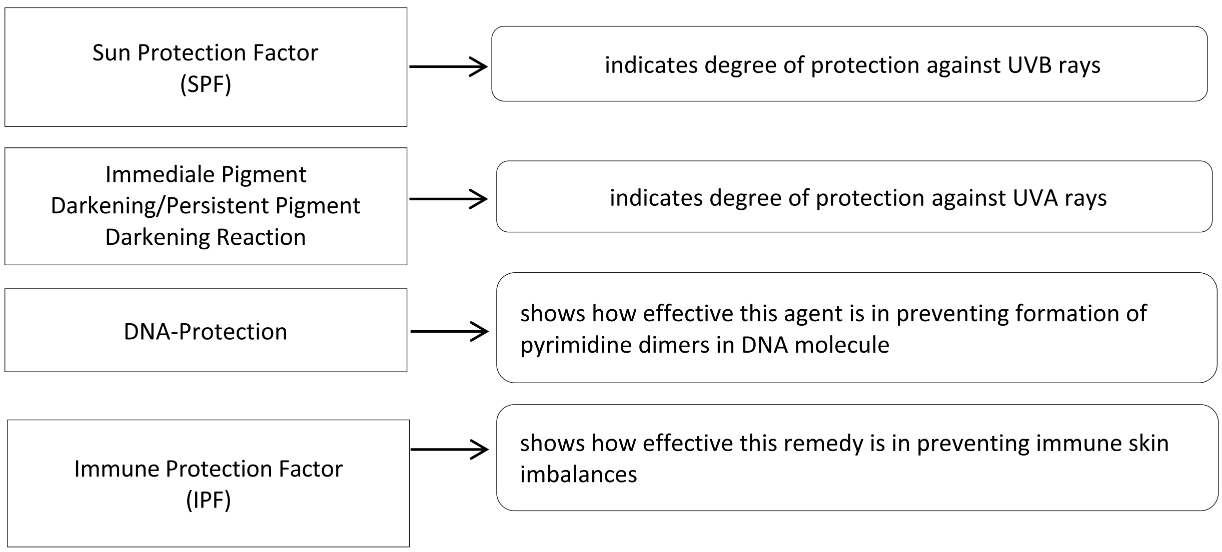

Figure 7 – Methods for testing cellular bioprotection exposed to UV rays

Table 1 – Generation of toxic ROS when interacting with different sunlight spectra

Skin chromophores	Absorption peak, nm	ROS
Bilirubin	400–600	H_2O_2
Collagen/elastin	320–400	H_2O_2
Collagen AGE (pentosidine)	320–400	$\bullet O_2^-$ H_2O_2 $\bullet OH$
Melanin	230–600	H_2O_2
Copper/cytochrome C complex IV (mitochondrion)	770–1400	$\bullet O_2^-$ H_2O_2 $\bullet OH$
NADH, NADPH	290–405	$\bullet O_2^-$ $^1O_2$
2-thioracil/4-thiouridine	290–405	$\bullet O_2^-$ $^1O_2$
Porphyrins	290–700	$\bullet O_2^-$ H_2O_2 $^1O_2$
Tryptophan	300–400	$\bullet O_2^-$ H_2O_2 $^1O_2$
Riboflavin	290–465	$\bullet O_2^-$ $^1O_2$
Urocaninic acid	310	$^1O_2$

Note: $\bullet O_2^-$ – superoxide anion radical; • OH – hydroxyl radical; $^1O_2$ – singlet oxygen; ROS – reactive oxygen species; NADH – nicotinamide adenine dinucleotide; NADPH – nicotinamide adenine dinucleotide phosphate.

Table 2 – Depth of penetration and UVA/UVB rays effect on the skin

Depth of rays penetration	Type of rays	Result of exposure to the skin
Epidermis	UVA+UVB	– keratinocyte lesion поражение меланоцитов – melanocyte lesion – migration of Langerhans cells
Dermis	UVA	– generation of free radicals (including DNA, proteins and lipids, membranes and mitochondria are affected) – decrease in synthetic activity of fibroblasts, disruption of their cell cycle and ability to migrate – violation of the synthesis and destruction of collagen and elastin – infiltration of the circulatory matrix by shaped blood elements
Hypodermis	UVA	– adipocyte damage, including impaired lipid synthesis and decreased triglyceride content – reduction of adiponectin synthesis

Table 3 – Characteristics of photoprotectors with different SPF values

Degree of photoprotection	SPF value	Transmission	Absorption (%)
Low	6	0.167	83.3
Medium	10	0.100	90.0
High	15	0.067	93.3
	20	0.050	95.0
	25	0.040	96.0
Very high	30	0.033	96.7
	50	0.020	98.0
	60 (50+)	0.017	98.3

The solar protection index, e.g. 50, means that a 50 times more UV dose is required to produce erythema with protection than without protection (Fig. 6) [1, 23, 27].

To date, it has been proven that the transmission (transmittance without changing a direction) of UV rays under the conditions of using a photoprotector is inversely related to the absorption value. At the same time, a significant increase in the values of the SPF factor is realized only by a slight increase in the values of the absorption index (Table 3) [1, 27].

The level of photoprotection required by the skin is strictly individual and is determined by the age and characteristics of the body, the type and condition of the skin, the predicted duration of exposure to the sun, and the UV index (0-12) of the region, taking into account cloud coverage. Since UVB rays are more intense, the number on the sunscreen label indicates protection against this type of wave. Weaker UVA rays do not require a very high degree of protection, so protection from them is 1/3 of type B rays. For example, marking SPF 30 means that there will be protection

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Table 4 – Classification and nomenclature of UV filters

Criterium	Physical UV filters	Chemical UV filters
Chemical nature	– Inorganic compounds (used in micronized, ultra-micronized, finely dispersed and nanoparticle forms)	– Organic compounds
Mechanism of action	– They are mineral screens that scatter and reflect sun rays.	– they absorb ultraviolet light and undergo isomerization under quantum of light action
Effect localization	– Surface of epidermis stratum corneum	– epidermis
Advantages	– high level of safety, inertness in relation to UV rays – UVA/UVB – photoprotection – price affordability	– ability to create combinations with minimal "working" concentrations and a wide protective spectrum – compatibility with other recipe components
Disadvantages	– physical particles are removed during the day due to glands activity and other factors – "whitewash effect" – rather high "working" concentrations – difficulties when combined with other recipe components	– likelihood of developing allergic reactions – potential phototoxicity (incl. provocation of photo-contact dermatitis formulation)
Names of filters present in European and Russian cosmetic markets	– zinc dioxide, titanium dioxide	– UVB: p-aminobenzoic acid (PABA) and its derivatives (padimate O), salicylates (homomentyl salicylate, octisalate, trolamine salicylate), cinnamates (octinoxate), camphor derivatives, methoxycinnamic acid derivatives
		– UVA: avobenzone, mexoril, neo heliopan UVA/UVB: octocrylene, benzophenone-3,4,5,8, phenylbenzotriazole sulfonic acid (ensulizol), dioxybenzone, triazines and triazones (tinosorb, juvinul)

30 from UVB, and from UVA, it will be 1/3, i.e., 10^2 [26].

Several tests are used to accurately determine the level of UVA protection. All of them are based on transmission/absorption measurements (Fig. 7). *In vivo* methods such as Immediate Pigment Darkening (IPD) and Persistent Pigment Darkening (PPD) are based on determining the skin response to UVA irradiation (pigmentation and erythema) and then calculating the UVA protective factor, similar to the SPF calculation. Besides, additional tests have now been introduced to assess not only the protective effect against erythema, but also the protection against immunological and mutational effects caused by ultraviolet radiation[3].

The composition of sunscreen preparations includes filters that trap the sun rays (Table 4), the principle of operation of which is based on physical or chemical interaction. Chemical filters capture UV rays and convert them into thermal energy. Physical filters, such as mineral compounds of titanium or zinc, remain on the surface of the skin and block solar radiation by reflecting the rays. Physical filters almost always whiten the skin and are washed off worse, they are suitable for sensitive skin; chemical filters are transparent and invisible on the face, and can have an irritating effect. The list of UV filters approved for use in the European Union is provided in Regulation (EU) 1223/200[4]. The document contains 28 positions of the International Nomenclature of Cosmetic Ingredients (INCI) indicating the absorption area and the maximum allowable concentration. In Russia, the corresponding list is regulated by Technical regulation Commission of the Customs Union, Annex 5 009/2011[5], which also determines the conditions for the use of photoprotectors and the warnings, information about which should be brought to the consumer.

In the light of discussions about the properties of photoprotectors, it is worth notifying photostability, i.e. the ability to maintain its structure and properties under the influence of radiation, as well as the extinction coefficient, which shows how actively the drug absorbs the energy. It is important to emphasize that some

[2] Regulation (Ec) No. 1223/2009 Of The European Parliament And Of The Council of 30.11.2009 on cosmetic products. Official Journal of the European Union. 2009; L.342:59–209.

[3] Commission Recommendation of 22 September 2006 on the efficacy of sunscreen products and the claims made relating thereto. Official Journal of the European Union. 2006; L265:P. 39–42.

[4] Regulation (EC) No 1223/2009 Of The European Parliament And Of The Council of 30.11.2009 on cosmetic products, 2009.

[5] Decision of the Customs Union Commission dated September 23, 2011 No. 799 "On the adoption of the technical regulation of the Customs Union "On the safety of perfumery and cosmetic products" (together with "TR TS 009/2011. Technical regulation of the Customs Union. On the safety of perfumery and cosmetic products"). Russian

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chemical filters undergo photolysis to a large extent. For example, 15 minutes after the exposure to the sunlight, a decrease in the activity is notified: avobenzone – up to 36%, octyl-p-methoxycinnamate – by 4.5%. The values greater than 20 (butylmethoxydibenzoylmethane – 31.0, octyldemethyl p-aminobenzoic acid – 28.4, ethylhexyl-p-methoxycinnamate – 24.2) are considered effective values of the quenching coefficient [27].

Thus, the features of the chemical structure, mechanism of action, the need to maintain stability, efficiency and safety of use determine the range of requirements for a modern photoprotector. They are: the ability to absorb rays in a wide range; photo, thermal and water resistance; low penetrating ability in relation to the epidermis stratum corneum; acceptable safety profile (lack of toxicity, as well as carcinogenic, sensitizing effects); the ability to effectively prevent visible (sunburn) and invisible (photoaging, carcinogenesis) effects of UV radiation [28, 29].

Photoprotective properties of plant-based biologically active substances

A high level of innovation and dynamism in the pharmaceutical and cosmetics industries is reflected in the active search for new multifunctional natural ingredients. Currently, special attention is drawn to the trend of using plant-based materials and their components in the formulation of sunscreens, which is due to a wide spectrum of activity, the absence of a xenobiotic effect, and a high bioavailability of organic plant compounds[6] [30, 31].

Today, it seems undeniable that plants adapt to environmental changes [32–35], incl. the damaging effect of sunlight through the implementation of protective mechanisms, comprising production or activation of the biosynthesis processes of antioxidant molecules [36–38]. Moreover, in a number of studies [22, 24, 26, 30], hypotheses about the potential photoprotective activity of plant compounds have been scientifically substantiated.

At the same time, in a number of works [39, 40], it is notified that plant extracts exhibit a synergistic effect with chemical and physical UV filters, thereby increasing the SPF factor of herbal cosmetic compositions. Moreover, the mechanism of the photoprotective action is different: from its own absorption of UV rays up to antioxidant and anti-inflammatory effects, which indirectly implement photoprotection, leveling the negative effect of the sun.

In the series of biologically active substances in plants, researchers attach the greatest photoprotective significance to various classes of phenolic compounds. So, Acevedo A. and his colleagues report that after the introduction of verbascoside and linarin into the composition of a photoprotective cosmetic product, its SPF factor was 24. These compounds are glycosides of caffeic acid and acacetin, which once again confirms the thesis about the pronounced antiradical activity of polyphenolic compounds [41]. Polyphenolic compounds exhibit a wide range of biological properties: antioxidant, anti-inflammatory, hepatoprotective, vasoactive, antithrombotic, antitumor, antibacterial and antiprotozoal. In the work by Velasco M.V.R. et al., the structure similarity of polyphenolic compounds with organic UV filters, for example, ethylhexylmethoxycinnamate and, as a result, the similarity of photoprotective properties, is notified [42].

Photoprotective properties have been studied for many plant phenolic complexes. Thus, the positive effect of polyphenolic compounds of the plantain lanceolate dry extract, was demonstrated in the work of Brazilian scientists [43]. It was shown that the addition of 7% dry extract to the phytocomposition increased the UVA/UVB ratio from 0.49 to 0.52. Silymarin, a complex of *Silybum marianum* L. flavolignan compounds, demonstrates optimal photoprotective properties, which, when added to cosmetic photoprotective agents, provides SPF 13–14 [44]. High photoprotective properties (SPF = 9.9) are also characteristic of the seaweeds phenolic complex [45]. The photoprotective properties of anthocyanins, a separate group of the flavonoid nature compounds, which provide red-violet shades of the aerial parts color (mainly flowers and fruits) of plants, are reported. Cefali L.C. et al showed that oil extracts of raspberry and blueberry anthocyanins exhibit SPF 37 and 54, respectively [46].

Despite the predominant focus on the evidence of the phenolic compounds photoprotective properties, other groups of plant-based biologically active substances are also characterized by a protective action from the sunlight negative effects. The authors [47–49] note a high photoprotective activity of lignin due to its ability to neutralize free radicals. The incorporation of lignin into cosmetic lotions has been notified to increase the UVA/UVB ratio in the range of 0.69–0.72. Publications [50, 51] provide the data on the study of the caffeine photoprotective activity – catechol, chlorogenic and 3,4,5-tricofeylquinic acids isolated from coffee beans. Their effectiveness in the protection of skin aging caused by the exposure to UV rays and a positive effect on damaged DNA has been shown.

[6] Ibid.

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The literature provides an evidence base and shows the possibility of using vegetable oils as natural UV filters: avocado (SPF 4–15), coconut (SPF 2–8), macadamia (SPF 6), shea (SPF 3–6), jojoba (SPF 4). This is due to the presence of residues of polyunsaturated (mainly linoleic and linolenic) acids and their ability to neutralize free radicals, providing antioxidant protection. Plant extracts, e.g., aloe, chamomile, skullcap, grapes, etc., can be considered as complex phytocompositions without individualization of the marker component of the photoprotective action [31, 32].

It should be notified that Russian and foreign authors have studied and experimentally established the photoprotective potential expressed by the antioxidant activity of the wild rose biologically active substances [11–14]. Potential possibilities of using the oil of nuts (fruits) in the development of sunscreens due to the components of the oil – carotenoids, vitamins E and F, triglycerides of polyunsaturated (linoleic and linolenic) acids, which contribute to protection from UV radiation, have been identified. The literature [18, 19] summarizes the data on the high bioavailability of rosehip oil biomolecules, which is determined by its composition similar to the lipid layer of human skin.

The possibility of using secondary plant metabolites – phenolic compounds (including flavonoids, hydroxycinnamic acids, lignans), vitamins, terpenes – can be confirmed by a wide use of the latter in the formulation of photoprotective cosmetics and nutraceutical products [1, 22, 23]. Since the formation of an evidence base for the clinical effectiveness in the field of photoprotection of plant-based sunscreens, which represent a whole complex of biomolecules with antioxidant, anti-inflammatory and anti-radical effects, is complicated by a high labour intensity of isolating and developing the optimal amount of biologically active substances. There are no such positions on the market of cosmetic ingredients today [24].

CONCLUSION

The data analysis from scientific publications demonstrates a potential photoprotective activity of biologically active substances in plants due to antioxidant, anti-inflammatory and anti-radical effects. The results of the study form a theoretical basis for a further comprehensive experimental study of plant objects in order to obtain a pool of evidence in the field of photoprotection in vivo.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

ODN – concept and design of the work, text writing; IIT – materials collection and processing, text writing; ASS – materials collection and processing; AIL – materials collection and processing, text writing; ZBS – materials collection and processing, text writing.

REFERENCES

1. Wolf P. UV-Filter. State of the Art [UV Filters. State of the art]. Hautarzt. 2009 Apr;60(4):285–93. DOI: 10.1007/s00105-008-1623-y. German
2. He H, Li A, Li S, Tang J, Li L, Xiong L. Natural components in sunscreens: Topical formulations with sun protection factor (SPF). Biomed Pharmacother. 2021 Feb;134:111161. DOI: 10.1016/j.biopha.2020.111161
3. Westfall A, Sigurdson GT, Giusti MM. Antioxidant, UV Protection, and Antiphotoaging Properties of Anthocyanin-Pigmented Lipstick Formulations. J Cosmet Sci. 2019 Mar/Apr;70(2):63–76.
4. Korać RR, Khambholja KM. Potential of herbs in skin protection from ultraviolet radiation. Pharmacogn Rev. 2011 Jul;5(10):164–73. DOI: 10.4103/0973-7847.91114
5. Lohézic-Le Dévéhat F, Legouin B, Couteau C, Boustie J, Coiffard L. Lichenic extracts and metabolites as UV filters. J Photochem Photobiol B. 2013 Mar 5;120:17–28. DOI: 10.1016/j.jphotobiol.2013.01.009
6. Vostálová J, Tinková E, Biedermann D, Kosina P, Ulrichová J, Rajnochová Svobodová A. Skin Protective Activity of Silymarin and its Flavonolignans. Molecules. 2019 Mar 14;24(6):1022. DOI: 10.3390/molecules24061022
7. Álvarez-Gómez F, Korbee N, Casas-Arrojo V, Abdala-Díaz RT, Figueroa FL. UV Photoprotection, Cytotoxicity and Immunology Capacity of Red Algae Extracts. Molecules. 2019 Jan 18;24(2):341. DOI: 10.3390/molecules24020341
8. Ahmady A, Amini MH, Zhakfar AM, Babak G, Sediqi MN. Sun Protective Potential and Physical Stability of Herbal Sunscreen Developed from Afghan Medicinal Plants. Turk J Pharm Sci. 2020 Jun;17(3):285–92. DOI: 10.4274/tjps.galenos.2019.15428
9. Baldisserotto A, Buso P, Radice M, Dissette V, Lampronti I, Gambari R, Manfredini S, Vertuani S. Moringa oleifera Leaf Extracts as Multifunctional Ingredients for “Natural and Organic” Sunscreens and Photoprotective Preparations. Molecules. 2018 Mar 15;23(3):664. DOI: 10.3390/molecules23030664
10. Cefali LC, Ataide JA, Fernandes AR, Sanchez-Lopez E, Sousa IMO, Figueiredo MC, Ruiz ALTG, Foglio MA, Mazzola PG, Souto EB. Evaluation of In Vitro Solar

Protection Factor (SPF), Antioxidant Activity, and Cell Viability of Mixed Vegetable Extracts from *Dirmophandra mollis* Benth, *Ginkgo biloba* L., *Ruta graveolens* L., and *Vitis vinífera* L. Plants (Basel). 2019 Oct 26;8(11):453. DOI: 10.3390/plants8110453

11. Kiralan M, Yildirim G. Rosehip (*Rosa canina* L.) Oil. Fruit Oils: Chemistry and Functionality. 2019: 803–14. DOI: 10.1007/978-3-030-12473-1_43
12. Fascella G, D'Angiolillo F, Mammano MM, Amenta M, Romeo FV, Rapisarda P, Ballistreri G. Bioactive compounds and antioxidant activity of four rose hip species from spontaneous Sicilian flora. Food Chem. 2019 Aug 15;289:56-64. DOI: 10.1016/j.foodchem.2019.02.127
13. Jiménez PP, Masson SL, Quitral RV. Chemical composition of chia seed, flaxseed and rosehip and its contribution in fatty acids omega-3. Revista Chilena De Nutricion. 2013;40(2):155–60. DOI: 10.4067/S0717-75182013000200010
14. Pashazadeh H, Özdemir N, Zannou O, Koca I. Antioxidant capacity, phytochemical compounds, and volatile compounds related to aromatic property of vinegar produced from black rosehip (*Rosa pimpinellifolia* L.) juice. Food Bioscience. 2021;44(9):101318. DOI: 10.1016/j.fbio.2021.101318
15. Dąbrowska M, Maciejczyk E, Kalemba D. Rose hip seed oil: Methods of extraction and chemical composition. European Journal of Lipid Science and Technology. 2019;121(8):1800440. DOI: 10.1002/ejlt.201800440
16. Duru N, Karadeniz F, Erge HS. Changes in bioactive compounds, antioxidant activity and HMF formation in rosehip nectars during storage. Food and Bioprocess Technology. 2012;5(7):2899–907. DOI: 10.1007/s11947-011-0657-9
17. Kayath H, Dhawan S, Nanda S. *In-vitro* Estimation of Photo-Protective Potential of Rosehip Seed Oil and QbD Based Development of a Nanoformulation. Current Nanomedicine. 2019;9(3):216–31. DOI: 10.2174/246818 7309666190126112141
18. Kulaitienė J, Medveckienė B, Levickienė D, Vaitkevičienė N, Makarevičienė V, Jarienė E. Changes in Fatty Acids Content in Organic Rosehip (*Rosa* spp.) Seeds during Ripening. Plants (Basel). 2020 Dec 17;9(12):1793. DOI: 10.3390/plants9121793
19. Bhave A, Schulzova V, Chmelarova H, Mrnka L, Hajslova J. Assessment of rosehips based on the content of their biologically active compounds. J Food Drug Anal. 2017 Jul;25(3):681–90. DOI: 10.1016/j.jfda.2016.12.019
20. Dubtsova GN, Negmatulloeva RN, Bessonov VV, Baĭkov VG, Sheviakova LV, Makhova NN, Perederiaev OI, Bogachuk MN, Baĭgarin EK. [Composition and content of biologically active substances in rose hips]. Vopr Pitan. 2012;81(6):84–8. Russian
21. Chu CC, Nyam KL. Application of seed oils and its bioactive compounds in sunscreen formulations. Journal of the American Oil Chemists' Society. 2021;98(7):713–26. DOI: 10.1002/aocs.12491
22. Radice M, Manfredini S, Ziosi P, Dissette V, Buso P, Fallacara A, Vertuani S. Herbal extracts, lichens and biomolecules as natural photo-protection alternatives to synthetic UV filters. A systematic review. Fitoterapia. 2016 Oct;114:144–62. DOI: 10.1016/j.fitote.2016.09.003
23. Olisova OY, Vladimirova EV, Babushkin AM. The skin and the sun. Russian Journal of Skin and Venereal Diseases. 2012;15(6):57–62. DOI: 10.17816/dv36783. Russian
24. Sviridova AA, Ischenko AA. Sun protective materials i. classification and interaction mechanism for organic UV-filters. ChemChemTech. 2006;49(11):3–14. Russian
25. Cavinato M, Jansen-Dürr P. Molecular mechanisms of UVB-induced senescence of dermal fibroblasts and its relevance for photoaging of the human skin. Exp Gerontol. 2017 Aug;94:78–82. DOI: 10.1016/j.exger.2017.01.009
26. Wu S, Han J, Laden F, Qureshi AA. Long-term ultraviolet flux, other potential risk factors, and skin cancer risk: a cohort study. Cancer Epidemiol Biomarkers Prev. 2014 Jun;23(6):1080–9. DOI: 10.1158/1055-9965.EPI-13-0821
27. Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol. 1988 Jun;124(6):869–71. DOI: 10.1001/archderm.124.6.869
28. Smanalieva J, Iskakova J, Oskonbaeva Z, Wichern F, Darr D. Investigation of nutritional characteristics and free radical scavenging activity of wild apple, pear, rosehip, and barberry from the walnut-fruit forests of Kyrgyzstan. European Food Research and Technology. 2020;246(5):1095–104. DOI: 10.1007/s00217-020-03476-1
29. Ácsová A, Hojerová J, Janotková L, Bendová H, Jedličková L, Hamranová V, Martiniaková S. The real UVB photoprotective efficacy of vegetable oils: *in vitro* and *in vivo* studies. Photochem Photobiol Sci. 2021 Jan;20(1):139–51. DOI: 10.1007/s43630-020-00009-3
30. Charles Dorni AI, Amalraj A, Gopi S, Varma K, Anjana SN. Novel cosmeceuticals from plants- an industry guided review. Journal of Applied Research on Medicinal and Aromatic Plants. 2017;7:1–26. DOI: 10.1016/j.jarmap.2017.05.003
31. Baumann L. How to Use Oral and Topical Cosmeceuticals to Prevent and Treat Skin Aging. Facial Plast Surg Clin North Am. 2018 Nov;26(4):407–13. DOI: 10.1016/j.fsc.2018.06.002
32. Akbarzadeh A, Rezaei-Sadabady R, Davaran S, Joo SW, Zarghami N, Hanifehpour Y, Samiei M, Kouhi M, Nejati-Koshki K. Liposome: classification, preparation, and applications. Nanoscale Res Lett. 2013 Feb 22;8(1):102. DOI: 10.1186/1556-276X-8-102
33. Fivenson D, Sabzevari N, Qiblawi S, Blitz J, Norton B, Norton S. Sunscreens: UV filters to protect us: Part 2-Increasing awareness of UV filters and their potential toxicities to us and our environment. International Journal of Women's Dermatology. 2021;7(Issue 1. – P. 45–69. DOI: 10.1016/j.ijwd.2020.08.008
34. Takshak S, Agrawal SB. Defense potential of secondary metabolites in medicinal plants under UV-B stress. J Photochem Photobiol B: Biology. 2019;193:51–88. DOI: 10.1016/j.jphotobiol.2019.02.002
35. Shikov AN, Narkevich IA, Akamova AV, Nemyatykh OD, Flisyuk EV, Luzhanin VG, Povydysh MN, Mikhailova IV, Pozharitskaya ON. Medical Species Used in Russia for the Management of Diabetes and Related Disorders. Front Pharmacol. 2021 Jul 20;12:697411. DOI: 10.3389/fphar.2021.697411
36. Li Y, Kong D, Fu Y, Sussman MR, Wu H. The effect of developmental and environmental factors on secondary metabolites in medicinal plants. Plant Physiol Biochem. 2020 Mar;148:80–9. DOI: 10.1016/j.plaphy.2020.01.006
37. Verdaguer D, Jansen MA, Llorens L, Morales LO, Neugart S. UV-A radiation effects on higher plants: Exploring the known unknown. Plant Sci. 2017 Feb;255:72–81. DOI: 10.1016/j.plantsci.2016.11.014
38. Cefali LC, Ataide JA, Moriel P, Foglio MA, Mazzola PG.

DOI: 10.19163/2307-9266-2022-10-4-308-319

Plant-based active photoprotectants for sunscreens. Int J Cosmet Sci. 2016 Aug;38(4):346–53. DOI: 10.1111/ics.12316

39. Piovesana de Souza F, Campos GR, Packer JF. Determinação da atividade fotoprotetora e antioxidante em emulsões contendo extrato de *Malpighia glabra* L. Acerola J Basic Appl Pharm Sci. 2013;34(1):69-77.

40. Kumar N, Jose J. Current developments in the nanomediated delivery of photoprotective phytochemicals. Environ Sci Pollut Res. 2020;27(31): 38446–71. DOI: 10.1007/s11356-020-10100-y

41. Avila Acevedo JG, Castañeda CM, Benitez FJ, Durán DA, Barroso VR, Martínez CG, Muñoz LJ, Martínez CA, Romo de Vivar A. Photoprotective activity of Buddleja scordioides. Fitoterapia. 2005 Jun;76(3–4):301–9. DOI: 10.1016/j.fitote.2005.03.009

42. Velasco MVR, Balogh TS, Pedriali CA, Sarruf FD, Pinto CASO, Kaneko TM, Rolim Baby A. Association of rutin with octyl p-methoxycinnamate and benzophenone-3: in vitro evaluation of photoprotective efficacy by reflectance spectrophotometry [Associação da rutina com p-metoxicinamato de octila e benzofenona-3: avaliação *in vitro* da eficácia fotoprotetora por espectrofotometria de refletância]. Lat Am J Pharm. 2008;27(1): 23–7. Portuguese

43. Velasco MV, Sarruf FD, Salgado-Santos IM, Haroutiounian-Filho CA, Kaneko TM, Baby AR. Broad spectrum bioactive sunscreens. Int J Pharm. 2008 Nov 3;363(1–2):50–7. DOI: 10.1016/j.ijpharm.2008.06.031

44. Netto MPharm G, Jose J. Development, characterization, and evaluation of sunscreen cream containing solid lipid nanoparticles of silymarin. J Cosmet Dermatol. 2018 Dec;17(6):1073-1083. DOI: 10.1111/jocd.12470

45. Shanuja SK, Iswarya S, Sridevi J, Gnanamani A. Exploring the UVB-protective efficacy of melanin precursor extracted from marine imperfect fungus: Featuring characterization and application studies under *in vitro* conditions. Int Microbiol. 2018 Jun;21(1-2):59–71. DOI: 10.1007/s10123-018-0005-2

46. Cefali LC, Franco JG, Nicolini GF, Ataide JA, Mazzola P.G. *In vitro* antioxidant activity and solar protection factor of blackberry and raspberry extracts in topical formulation. J Cosmet Dermatol. 2019;18(2):539-44. DOI: 10.1111/jocd.12842

47. Young AR, Narbutt J, Harrison GI, Lawrence KP, Bell M, O'Connor C, Olsen P, Grys K, Baczynska KA, Rogowski-Tylman M, Wulf HC, Lesiak A, Philipsen PA. Optimal sunscreen use, during a sun holiday with a very high ultraviolet index, allows vitamin D synthesis without sunburn. Br J Dermatol. 2019 Nov;181(5):1052–62. DOI: 10.1111/bjd.17888

48. Li SX, Li MF, Bian J, Wu XF, Peng F, Ma MG. Preparation of organic acid lignin submicrometer particle as a natural broad-spectrum photo-protection agent. Int J Biologic Macromolecul. 2019;132:836–43. DOI: 10.1016/j.ijbiomac.2019.03.177

49. Cefali LC, Ataide JA, Fernandes AR, Sousa IMO, Gonçalves FCDS, Eberlin S, Dávila JL, Jozala AF, Chaud MV, Sanchez-Lopez E, Marto J, d'Ávila MA, Ribeiro HM, Foglio MA, Souto EB, Mazzola PG. Flavonoid-Enriched Plant-Extract-Loaded Emulsion: A Novel Phytocosmetic Sunscreen Formulation with Antioxidant Properties. Antioxidants (Basel). 2019 Oct 1;8(10):443. DOI: 10.3390/antiox8100443

50. Cho YH, Bahuguna A, Kim HH, Kim DI, Kim HJ, Yu JM, Jung HG, Jang JY, Kwak JH, Park GH, Kwon OJ, Cho YJ, An JY, Jo C, Kang SC, An BJ. Potential effect of compounds isolated from *Coffea arabica* against UV-B induced skin damage by protecting fibroblast cells. J Photochem Photobiol B. 2017 Sep;174:323–32. DOI: 10.1016/j.jphotobiol.2017.08.015

51. Musazzi UM, Franzè S, Minghetti P, Casiraghi A. Emulsion versus nanoemulsion: how much is the formulative shift critical for a cosmetic product? Drug Deliv Transl Res. 2018 Apr;8(2):414–21. DOI: 10.1007/s13346-017-0390-7

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