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Plants with antioxidant activity and their potential use as sun protector agents in Costa Rica

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Summary

Aims: To carry out a bibliographic review related to plants available in Costa Rica that have demonstrated antioxidant power and a sun protection factor (SPF) suitable to be used in sunscreen products. **Methods:** The bibliographic review was carried out using different descriptors and by consulting different databases. **Results**: Information about antioxidant power about acerola, avocado, carrots, passion fruit, moringa, banana, pumpkin and amaranth, guava, matico, ginkgo, blackberry, mango, coffee was obtained. The information obtained suggests that the mentioned plants could be used for the formulation of sunscreens. **Conclusion:** Sun protection products should be used every day to prevent skin damage; some sunscreens produce allergic reactions, so it is necessary to investigate natural options to be used in sun protection products. Some natural products exhibit SPF values that allow their incorporation as sun protection agents, adjuvants, or enhancers in sunscreens.

Keywords: Antioxidant activity, ultraviolet radiation, natural products, sun protection factor, Costa Rica.

Resumen

Plantas con actividad antioxidante en Costa Rica y su potencial uso como protectores solares

Objetivo: llevar a cabo una investigación bibliográfica sobre plantas disponibles en Costa Rica que han demostrado su poder antioxidante y un factor de protector solar (SPF) apto para ser utilizados en protectores solares. **Métodos:** la revisión bibliográfica se realizó utilizando diferentes descriptores y mediante la consulta en diferentes bases de datos. **Resultados:** se obtuvo información sobre el poder antioxidante de las plantas: acerola, aguacate, zanahoria, maracuyá, moringa, banano, calabaza y amaranto, guayaba, matico, ginkgo, mora, mango, café. La información obtenida sugiere que las plantas mencionadas podrían ser utilizadas para la formulación de protectores solares. **Conclusiones:** los protectores solares deben ser utilizados diariamente para prevenir el daño sobre la piel. Algunos de estos productos generan reacciones alérgicas y por esta razón es necesario investigar posibles opciones naturales para ser incorporadas en bloqueadores solares. Algunos productos naturales exhiben valores de SPF que permiten su uso como agentes protectores solares, adyuvantes o potenciadores en los bloqueadores solares.

Palabras clave: Actividad antioxidante, radiación UV, productos naturales, factor de protección solar, Costa Rica.

Resumo

Plantas com atividade antioxidante na Costa Rica e seu potencial uso como protetores solares

Objetivo: realizar uma pesquisa bibliográfica sobre plantas disponíveis na Costa Rica que demonstraram poder antioxidante e um fator de proteção solar (FPS) adequado para uso em protetores solares. **Métodos:** a revisão bibliográfica foi realizada usando diferentes descritores e consultando diferentes bases de dados. **Resultados:** foram obtidas informações sobre o poder antioxidante das plantas: acerola, abacate, cenoura, maracujá, moringa, banana, abóbora e amaranto, goiaba, matico, ginkgo, amora, manga, café. As informações sugerem que as referidas plantas pode-

riam ser utilizadas para a formulação de protetores solares. **Conclusões:** protetores solares devem ser usados diariamente para prevenir danos à pele. Alguns desses produtos geram reações alérgicas e por isso é necessário investigar possíveis opções naturais para serem incorporadas aos protetores solares. Alguns produtos naturais apresentam valores de FPS que permitem seu uso como protetores solares, adjuvantes ou potencializadores em protetores solares.

Palavras-chave: Atividade antioxidante, radiação UV, produtos naturais, fator de proteção solar, Costa Rica.

Introduction

In the past, sunscreen was primarily used for quick burn-free tans. Nowadays, sunscreen daily-use is necessary due to the risk generated by direct exposure to ultraviolet (UV) radiation, related to wrinkles, aging, oxidative stress, immunosuppression, erythema, edema, and even skin cancer [1-3]. UV radiation can be divided into three regions: UVA (320-400 nm), UVB (290-320 nm), and UVC (200-290 nm), and it is crucial to be protected from UVA and UVB since these two types of radiation are not entirely filtered by the ozone layer and can cause the damages mentioned above [4].

Topical sunscreens are the most commonly used products to protect the skin from radiation. These products have active ingredients related to the absorption or dispersion of radiation, protecting the skin from direct damage [5].

Natural sources present an attractive option for creating products with protective activity against solar radiation since they can be produced at a low cost and are generally easily found. Plants with antioxidant activity and UV absorption properties are candidates for the formulation of sun protector products [3]. Among the most widely used antioxidant compounds are tocopherols, flavonoids, phenolic acids, indoles, alkaloids, amines, amino acids, and monoterpenes [1]. For an antioxidant-based sunscreen, the extracts must have this fairly high activity and must be stable in the formulation [6]. New natural products' research to formulate and develop sunscreens is closely associated with photosensitivity and dermatitis that synthetic-based sunscreen formulations may cause [7]. The main objective of this work is to carry out a bibliographic review related to plant available in Costa Rica that have demonstrated antioxidant power and a sun protection factor (SPF) suitable to be used in sunscreen products.

Natural products with antioxidant activity

Acerola

Acerola or Barbados cherry (*Malpighia emarginata D.C*) is a Central America native fruit and is a high source of vitamin C. Additionally this fruit has other components such as polyphenols, β-carotenes, and folates, which gives it great antioxidant activity [8, 9].

The crude acerola extract was evaluated to study the protection against oxidative stress and cytotoxic damage. A study concluded that acerola has an excellent antioxidant and protective capacity for macromolecules against oxidative damage by increasing antioxidant enzymes' activity and protecting mitochondrial functionality [9].

Another study showed the skin lightening effect of acerola phenol extract in guinea pigs that had been exposed to UV radiation. The results were a lightening of damaged skin and a reduction of melanin in the B16 melanoma cells. It was concluded that this extract's lightening effect might be due to a suppression of melanogenesis by inhibiting tyrosinase activity in melanocytes [10].

Avocado

Avocado (*Persea americana* Mill.) is a plant native to Mexico. It mainly presents phenolic compounds such as catechin in the shell and seed. Also, flavonoids can be found in the peel [11].

A study was carried out in Indonesia using avocado peel ethanolic extracts with concentrations of 5%, 7.5%, and 10% to determine its SPF. No ethanolic extract presented an SPF greater than 15% [12].

Carrot

Carrot (*Daucus carota*) is a root native to the Eastern Mediterranean and Southwestern Asia [13]. It is rich in α and β-carotenes, which, as previously mentioned, are a source of antioxidants with photoprotective properties, that is, with sun protection properties. These properties are related to the extensive system of conjugated double bonds, known as polyene chain, which is the chromophore responsible for absorbing light in the visible region and, consequently, for carotenes' coloration. [14]. A study shows that formulations containing 6% w/v carrot seed oil have SPF values of 6.92 [15].

Passion fruit

Passiflora edulis is native to Brazil's Amazon region; however, it has adapted throughout the tropics and subtropics. The plant has green leaves, stems, a flower with petals, and 4-9 x 4-7 cm oval fruits [16].

The antioxidant capacity and the sun protection factor of the *Passiflora edulis* fruit peel were studied. The peel was extracted with 96, 70, and 45% ethanol and the obtained values were 16.03, 16.23, and 9.06 mg ET/g according to DPPH, respectively. In addition, the 45% extract was used to develop and formulate a cream, which obtained 5.52 SPF [17]. Another study determined the antioxidant capacity and antimicrobial capacity of pulp, leaves, seeds, and rind. The leaves exhibited a higher antimicrobial activity due to the high content of flavonoids, polyphenols, tannins, saponins, proanthocyanidins, among others. [18]. It is important to mention that the photoprotective capacity is dependent on the sunscreen formulation. A study compares the SPF between two formulations, and it indicates that the "mousse formulation" sun protection value doubles in magnitude the liquid base formulation with the following values 15.48 ± 1.60 and 5.88 ± 0.30, respectively. It also indicates the extract's concentration did not show differences between 0.1 and 0.3% [19]. Obtaining methanolic extracts can be carried out utilizing ultrasound techniques, and it is one of the solvents that shows the best results in terms of antioxidant capacity [20].

Moringa

The plant *Moringa oleifera* Lam. has been used in different parts of the world due to its nutritional and medicinal characteristics [21]. Compounds such as beta-carotene, vitamin C, vitamin E, and polyphenols can be found in this plant's leaves. The biological functions that have been described are a high antioxidant capacity and even anti-inflammatory, anti-cancer, hepatoprotective, and neuroprotective [22, 23].

A study was conducted on sunscreen based on extracts of the moringa seed oil. The SPF was calculated for this formulation, and the obtained value was 1.46. The authors conclude that these extracts can be used as adjuvants in formulations to improve their activity [24], but it would not be viable to use as a base for a formulation with adequate sun protection. Another study in which sunscreen was also performed using moringa seed oil obtained similar results, with an SPF of 1.05 [25].

Banana

The banana is a fruit of the genus *Musa*, belonging to the *Musaceae* family. It is grown in the tropics [26] and is one of the most important crops in Costa Rica. Its peel has been used medicinally to treat some ailments, including burns, snakebites, ulcers, and

diarrhea. Among its components, high levels of fiber and 40 different types of phenols have been identified, including flavonoids, hydroxycinnamic acids, and catecholamines. It has an excellent antioxidant, antimicrobial, and antibiotic capacity [27].

The antioxidant power and sun protection factor of the red banana peel, named *Musa accuminata* L, were investigated. The preparation was carried out by chopping the liquefied peel with distilled water into small pieces to remove the sap. The extraction was carried out with methanol, ethanol, and acetone in reflux for two hours. DPPH method was used to evaluate the antioxidant capacity, and the results were related to tannins, flavonoids, and phenols presence. The extraction with ethanol as solvent showed antioxidant activity with higher values, followed by methanol and acetone, in that order. The sun protection factor's determination through spectrophotometry also showed higher values for ethanol with 16.63, followed by methanol with 16.60 and acetone with 15.42 [28].

Another study compared different species of banana; *Musa acuminata* Colla "purple banana", *Musa paradisiaca* L. "Gros Michel banana", "silk banana", "island banana", "purple banana" and "apple tree". The silk banana showed the higher content of phenolic compounds 31.32 ± 0.05 mg EAG/g with an antioxidant potential of 49.13 ± 0.07 mg ET / g (DPPH •) and 97.98 ± 0.3 mg ET/g (FRAP). The island banana sample showed the highest value for the sun protection factor, with 1.03 ± 0.047 [29].

Pumpkin and amaranth

The seeds of amaranth (*Amaranthus cruentus*) and pumpkin (*Cucurbita seed spp*) contain an oil rich in antioxidants. A study investigated lipid nanoparticles' capacity to encapsulate two UVA and UVB filters. It was determined that nanostructures formulation has a high capacity to inhibit short-lived radicals (93-98%). It was shown that the amaranth oil system with 82% squalene was the most effective for scavenging oxygen free radicals, and the one that demonstrated the higher capacity to inhibit cationic radicals was amaranth oil with 34% squalene. It is concluded that the use of these systems improves the performance of commercial sunscreen [30].

Guava

The leaves of *Psidium guajava* L. trees have compounds such as polyphenols, flavonoids, alkaloids, and saponins, and it has been used to prepare functional beverages and infusions with hypoglycemic activity. High antioxidant activity has been related to a large number of polyphenols contained in guava [31].

An investigation used *Psidium guajava* L (guava), *Musa accuminata* (red plantain), and *Pyrus communis* (pear tree) extracts to formulate a sunscreen. The solvent system used in the formulation was 35% methanol, 35% ethanol, and 30% distilled water to maximize the flavonoids extraction from the mentioned fruits. The SPF value was determined, and the obtained value was 3.90 [32].

In Costa Rica, *Psidium friedrichsthalianum* pulp was studied to determine its antioxidant and anti-inflammatory activity related to phenolic compounds. The ABTS and DPPH test was carried out on different extracts, and it was determined that the extract with ethyl acetate as a solvent had a higher antioxidant activity [33].

Matico

Matico (*Piper elongatum*) is a plant native to Mexico, the Caribbean, and South America. It is present in Costa Rica, and antibacterial, anti-inflammatory, and antioxidant properties have been described [34, 35]. An *in vitro* comparison with commercial creams was carried out to determine the plant's antioxidant capacity and the sun protection factor. The methanolic extract samples of the silver leaves were dried using an oven and a rotary evaporator. Creams containing extract 1% were formulated, and the antioxidant capacity was compared against commercial products by DDPH and ABTS methods. The obtained results were 163.919 μM equivalent of Trolox by DDPH method and 121.400 μM equivalent of Trolox by ABTS method. The extract dried by the rotary evaporator method showed a sun protection factor of 5.334; however, the SPF values determined by the Mansur method were not as high as those of the commercial creams, which were 17.489 and 17.554 [34].

Ginkgo

Ginkgo biloba is a native Chinese tree that has been used as a medicinal plant for many years, especially the extract obtained from its leaves [36]. Ginkgo extracts have different compounds such as glucosides and flavone terpenoids, which provide high antioxidant activity [37], and have been used as an anti-aging treatment [38].

The *in vitro* SPF of a dry extract ginkgo was obtained using spectral transmittance and *in vitro* antioxidant activity using DPPH, ABTS, and AAPH. The obtained SPF value was 7.06, and the extract shows the ability to absorb radiation in the 320-400 nm range. In addition, the DPPH, ABTS, and AAPH tests showed an important antioxidant capacity thanks to the plant flavonoids [39].

A sunscreen was formulated using algae, ginkgo extract, and vitamins A, C, and E. The transepidermal water loss technique in mice and the erythema index were used to

evaluate the formulation's performance. This formulation exhibits the ability to protect the skin from erythema caused by UV radiation [40].

Another study showed that ginkgo extract protects against UV-induced damage to mice's skin. Furthermore, the possibility of protecting lamellar bodies is raised. Other benefits are reduction of dryness and irritation of the skin and reduction of erythema [41].

Blackberry

Blackberries are known to have a high antioxidant capacity due to their high content of flavonoids, more specifically, anthocyanins [42, 43]. These compounds appear on plants' surfaces, flowers, and leaves with pink, red, purple, and blue colorations. Topical formulations with blackberry (*Rubus sp*) and raspberry ethanolic extracts' were analyzed; the antioxidant capacity was measured by the DPPH method and SPF determination by spectrometry [42]. Blackberries had an anthocyanin content of 65.58 mg per 100 g of fruit, and raspberry had an anthocyanin content of 29.93 mg per 100 g of fruit. The obtained SPF values were 54.57 with blackberry formulations and 37.32 with raspberry formulations, indicating that both formulations have potential use as a sunscreen since the FDA specifies that the minimum SPF value is 6.0. This study indicates the formulation process, organoleptic characteristics, and stability of formulation [42].

Mango

Mango (*Mangifera indica* L) is a tropical fruit produced worldwide, just like the banana. Mango peel is a source of consumption and contains fiber, antioxidant minerals, carotenoids, enzymes, vitamins, phenolic compounds, and terpenes [44, 45]. The antioxidant capacity has been evaluated using *in vivo* and *in vitro* techniques. *In vitro* evaluation can be carried out by DPPH, FRAP, TEAC, ABTS methods, and some *in vivo* methods: GSH, catalase, LDL, and TBARS methods. A study analyzed Creole mango samples obtained from different places, one from Trujillo and another from Jaén, known as "Kent" mango and "Edward" mango, respectively. It was determined that Creole mango from Jaén had an SPF value (6,54 ± 0,02) higher than the Creole mango sample from Trujillo, which indicates that the location is decisive. The results suggest a correlation between the fruits' antioxidant capacity and the SPF value, so it could be expected that other plants with antioxidant capacity also have SPF [44].

Coffee

Coffee is a source of antioxidants [46]. It is commonly consumed worldwide, mainly in red coffee beans, because green coffee beans are considered waste and are not consumed; therefore, a study was conducted with green coffee. DPPH or ABTS techniques were used to evaluate antioxidant activity attributed to the presence of tocopherols and

linoleic and palmitic acid. *In vitro* studies for the determination of SPF value were carried out by spectrophotometry in the UV region (290-400 nm) and, like squash and amaranth, by different mechanisms, coffee improves the performance of commercial sunblock products by around 20% [47]. The spent coffee grounds are another waste product, and their antioxidant activity and SPF were evaluated. The obtained results show an antioxidant activity of 18.4 and 23.6 mg of DPPH per 1g extract and SPF value in the range of 2.27 to 2.76 for the ethanolic extracts. These results are related to pharmacological and cosmetic properties and promote the spent coffee grounds use, which benefits the environment due to the waste product reduction and recovery [48]. Another study with the same environmental protection approach promotes sunscreens production with used ground coffee. The results indicate that coffee is a plant that enhances the SPF of sunscreen [49].

Green coffee oil (*C. arabica*) is also a linoleic, palmitic, and oleic acid source, absorbing UVB radiation. The unsaponifiable fraction of the oil is rich in pentacyclic terpenes and tocopherols. The DPPH technique evaluated the antioxidant capacity, and the SPF value was determined by spectrometry; the obtained values were 1.85 to 2.78 [50]. Another study carried out the green coffee oil microencapsulation through the spray drying of an oil-in-water emulsion, which increased antioxidant capacity compared to alpha-tocopherol standard and the same coffee oil [51].

Conclusions

Sun protection is necessary and should be used every day to prevent skin conditions ranging from burns to cancer. However, some sunscreens produce photoallergic reactions, so it is necessary to continue investigating natural options as sun protection agents.

According to the FDA, a compound to be used as a sunscreen must have *in vivo* SPF values higher than 6.0 when only *in vitro* studies are performed. Blackberries, passion fruit, plantain, Ginkgo Biloba, and mango showed promising *in vitro* results. However, many of the plants studied have SPF values lower than 5.0, which indicates that they can be used as adjuvants or enhancers of sunscreen such as acerola, avocado, carrot, moringa, guava, matic, and coffee.

Disclosure statement

The authors have declared no conflict of interest.

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