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Analysis Based on Three Aspects of Sunscreen

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Abstract:

With the increasing awareness of health, people's awareness of UV protection is also gradually improving. Sunscreen with UV protection has become an indispensable part of people's daily lives. The market size of China's sunscreen market will reach 74.2 billion yuan in 2023, and it is expected to grow to 95.8 billion yuan by 2026. The purpose of this paper is to analyze the safety, effectiveness, and environmental friendliness of sunscreen from three perspectives, and discuss the reliability of SPF human testing, improving the stability of sunscreen use, and the cost of new environmentally friendly materials. Through analysis, it is found that there are still shortcomings in the current SPF testing methods, production costs of environmentally friendly materials, and promotion of correct application methods for sunscreen. Subsequently, appropriate adjustments were made to the testing methods and material formulations of sunscreen, as well as recommendations for the selection and correct application of sunscreen. However, the long-term safety of nanomaterials still needs to be further explored. Due to the rapid development of research technology for sunscreen products and the diversification of market products, it is necessary to review the safety, effectiveness, and environmental friendliness of current sunscreen products.

Keywords: sunscreen; safety; effectiveness; environmental friendliness; SPF

1. Introduction

The skin is the largest organ in the human body, and people are exposed to ultraviolet radiation while traveling or working. Related studies have shown that exposure to ultraviolet radiation in the human body can damage the molecules and structure of skin cells[1]. Long-term exposure to ultraviolet radiation may lead to genetic mutations and the formation of diseases such as melanoma [1]. Therefore, choosing appropriate sunscreen products is very important for human health.

Sunscreen, as one of the sun protection products, has become an indispensable part of people's daily lives. In recent years, with the continuous innovation and development of sunscreen technology, many new sunscreen products with different functions and materials have emerged. Most consumers are not only concerned about the sun protection indicators when purchasing sunscreen products, but also pay more attention to the overall performance of the product. Most people consciously apply or wear sunscreen products when going out. Sunscreen mainly isolates ultraviolet radiation from UVA (320-400nm) and UVB (280-320nm) [1]. With the continuous expansion of the market and the intensification of product competition, as well as in order to reduce carbon footprint and promote sustainable development, the safety, effectiveness, and environmental friendliness of sunscreen have become key areas of concern at present. Therefore, analyzing the current composition of sunscreen is highly worthwhile research. This paper analyzes the safety, effectiveness, and environmental friendliness of sunscreen from three perspectives and proposes some appropriate suggestions.

2. Sunscreen Safety and Regulations

On June 19, 2024, CCTV reported that data showed that the market size of China's sunscreen market in 2023 would reach 74.2 billion yuan, with sunscreen clothing accounting for 57.8%[2]. It is expected that by 2026, the Chinese sunscreen market will grow to 95.8 billion yuan, and the sunscreen industry is forming a market worth billions of yuan[2]. At present, sunscreen is mainly divided into physical sunscreen and chemical sunscreen. The main sunscreen ingredients in physical sunscreen are zinc oxide and titanium dioxide; The main sunscreen ingredients in chemical sunscreens are ethyl hexyl methoxycinnamate (OMC), benzophenones, and ethyl hexyl salicylate[3].

2.1 Safety Analysis of Sunscreen

The safety of sunscreen is the primary consideration for consumers when purchasing and using sunscreen. The safety analysis of sunscreen is a comprehensive and scientific evaluation process of the ingredients, effectiveness, and potential impact on human health contained in sunscreen products. This process aims to ensure that sunscreen provides effective sun protection while reducing adverse effects on human health.

At present, physical sunscreens mainly protect the skin by reflecting and scattering ultraviolet rays[4]. Titanium dioxide and zinc oxide in general physical sunscreens have been proven to be safe, but their particles are larger and may cause discomfort when used. With the increasing demand for sunscreen products and the improvement of product quality requirements from consumers, more and more sunscreen brands are paying attention to the application of nanotechnology. This means that the usage of nanoscale titanium dioxide and zinc oxide in the market may gradually increase.

Nano titanium dioxide itself is non-toxic, but research on nano titanium dioxide has found that. Part of the nano titanium dioxide will polymerize with each other, and these aggregated particles may cause pore blockage in the skin[3]. There is extensive discussion regarding the permeability of nano zinc oxide.

Mohammed YH et al. proposed to demonstrate the safety of nano zinc oxide sunscreen through multiplex microscopy (MPM). Using MPM to study the permeability of nano zinc oxide in vivo, five imaging methods including fluorescence imaging using spectral filters showed that nano zinc oxide particles are unlikely to penetrate into the outermost layer of the skin. Finally, the permeation effect of nano zinc oxide was studied, and it was confirmed through SHG detection of the skin surface that there was no permeation of nano particles [5]. The safety of nanoscale zinc oxide in terms of permeability has been verified, but no relevant conclusions have been drawn regarding its long-term effects, and further research is still needed.

The detection of chemical sunscreen ingredients such as methoxycinnamic acid ethyl hexyl ester (OMC), benzophenones, and salicylic acid ethyl hexyl ester is mainly carried out by high-performance liquid chromatography (HPLC). This is currently the mainstream method for detecting the content of chemical sunscreens, which can accurately determine the content of various chemical sunscreens. By using the HPLC method, it can be ensured that the content of various chemical sunscreens in sunscreen products meets the standard requirements.

2.2 Standards and Regulations for Sunscreen

The standards and regulations for sunscreen mainly analyze the similarities and differences between relevant standards in the United States, the European Union, and China, and select more suitable products for different environments.

Sunscreen in the United States is defined as over-the-counter (OTC) medication, and all aspects of it are strictly regulated by the FDA[6]. According to the new FDA regulations, existing UV filters are classified into three categories: GRASE (zinc oxide and titanium dioxide), non-GRASE (p-aminobenzoic acid and triethanolamine salicylate), and insufficient safety data to determine GRASE status [6]. The sunscreens allowed by the European Union are listed in Annex VI of the EU Cosmetic Regulation. In the latest regulations on sunscreen, multiple measures for prohibiting and restricting the use of sunscreen ingredients have been mentioned. The latest regulation of the European Commission (EU) 2024/996 changes the scope of use of 4-methylbenzylidene camphor (4-MBC) to a ban; Updated the restricted concentration ranges for two sunscreens, benzophenone-3 and oxytetracycline; Titanium dioxide and zinc oxide have been identified as relatively safe sunscreen ingredients [7].

Sunscreens in China are classified as special-purpose cosmetics. According to their different sun protection mechanisms, they are divided into inorganic sunscreen and organic sunscreen. There are strict regulatory requirements for the use of sunscreen in China, mainly reflected in the "Technical Specification for Safety of Cosmetics"[8]. This specification clearly specifies the types of sunscreen agents that can be used in cosmetics and their usage conditions, including dosage restrictions, scope of use, etc., to ensure the safety and effectiveness of the product. At the same time, sunscreen products also need to go through strict registration and filing procedures, and submit relevant safety assessment reports and other materials[8].

Table 1. Comparison table based on SPF, Test method, Requirement

	China	US	EU
SPF	1~50+	1~60+	No clear upper limit
Test method	Human testing method	Human testing method	In vivo or in vitro testing methods
Requirement	Label SPF value	Requirement	Label SPF value

This article compares the similarities in sunscreen standards and regulations among China, the United States, and the European Union (See Table 1). Currently, the mainstream sun protection factor testing method is still human testing. There are also some differences, which may be due to differences in screening methods, individual differences, instrument accuracy, and UV irradiation intensity in different regions for human testing, resulting in different SPF values. The sun protection factor should be selected according to the different usage environments of sunscreen. SPF15~SPF20 is suitable for indoor work and occasions with less outdoor exposure; SPF20~SPF30 is suitable for daily outings; SPF30~SPF50+is more suitable for prolonged exposure to sunlight or outdoor activities. For areas with more dry skin, sunscreen with a higher SPF value should be chosen to provide a better moisturizing effect. For oily skin, it is recommended to use sunscreen with a lower SPF value to avoid the greasy feeling on the skin caused by SPF sunscreen.

3. Analysis of the Effectiveness of Sunscreen

SPF testing and durability evaluation are two key aspects of the effectiveness of sunscreen, which not only directly affect the UV protection ability of sunscreen, but also determine its practicality and reliability in different usage scenarios. Usually, the evaluation of sun protection efficacy involves using humans as test subjects, applying a limited amount of sun protection product to a certain number of volunteers' skin that meets the testing criteria, and determining the UVA or UVB protection performance of the sun protection product by measuring the amount of time it takes before pigmentation or sunburn occurs when exposed to artificial sun UV sources.

3.1 SPF Testing and Effectiveness

SPF value is an important indicator for measuring the UVB protection ability of sunscreen products, which directly determines the effectiveness of sunscreen products in preventing skin sunburn. Consumers often choose SPF values that are not what they currently need. The determination of SPF value is mainly through the human testing method, which measures the time extension of the skin's resistance to UV sunburn after applying sunscreen products. The data obtained from this test is widely recognized by people, but it has also been questioned by some.

Granger C et al. believe that current SPF testing methods will yield different results in different skin types. Through comparative experiments on the impact of various factors on test values, data analysis revealed that SPF values are influenced by various factors such as season and skin color[9].

SPF value testing may have certain deviations and limitations. By improving the standards and methods of SPF value testing, enhancing the level of in vitro testing technology, and developing membranes that highly approximate the state of human skin, the effectiveness and reliability of SPF value testing can be further improved.

3.2 Durability Evaluation of Sun Protection Effect

Durability assessment is the key to determining whether a sunscreen product can continue to provide effective protection during use. This usually involves simulating the sun protection effect testing in actual usage scenarios to ensure that sunscreen products can maintain stable protective performance under various conditions. This is based on simulated testing, and in fact, besides the durability of the product itself, how to use and apply sunscreen correctly is equally important for the durability of sunscreen.

There are research findings indicating that simply recommending continuous use of sunscreen and cosmetics is a practical and effective way to improve UV protection without adding any additional steps [10]. By ensuring sufficient application amount, even application, avoiding friction damage, and regular reapplication, sunscreen can form an effective sunscreen barrier on the skin, thereby protecting the skin from UV damage for a longer period of time and improving the durability of the sunscreen effect.

4. Application of New Environmentally Friendly Materials in Sunscreen

Synthetic sunscreen is a sunscreen prepared through chemical synthesis, which performs well in sun protection, but its safety has always been a concern. Some synthetic sunscreens may cause skin irritation, allergic reactions, or phototoxicity issues. With the increasing awareness of health and environmental protection among consumers, the demand for sunscreen containing natural ingredients is showing a growing trend. These ingredients themselves also have sunscreen effects, good biocompatibility with human skin, and are easily biodegradable, reducing the environmental pollution and health risks that synthetic sunscreens may bring. This chapter mainly discusses the role of natural ingredients and biodegradable biomaterials in sunscreen.

4.1 The Role of Natural Ingredients in Sunscreen

There are various types of plant extracts in natural sunscreen ingredients, including green tea extract, aloe vera extract, and so on. Related studies have shown that active ingredients in certain plant extracts can directly absorb ultraviolet radiation, especially in the UVA and UVB bands, thereby reducing the penetration and damage of these harmful rays to the skin [11]. Due to the complex composition of plant extracts, there may be more than just sun protection. Aloe vera extract not only has sun protection effects but also has skincare functions, absorbing ultraviolet rays while keeping the skin moist. Aloe gel extract can be added to sunscreen lotion and has the function of preventing the negative effects of sunlight [12]. These types of extracts often have mild and low irritation characteristics, suitable for use on all skin types. Sunscreen containing plant extracts provides more benefits and is more suitable for consumers with sensitive skin.

Resende DISP et al. analyzed and statistically analyzed 444 sunscreen formulations, and found that terrestrial plant ingredients accounted for the majority. There is still great potential for exploring formulations for marine ingredients[11]. From this set of data, it can be seen that the main research object of natural ingredients is still terrestrial plants. The proportion of ocean components may be relatively low due to the current difficulty in exploring the ocean. Due to the current lack of technology to analyze the effects of various substances in plant extracts, further exploration is needed to understand the mechanisms behind these substances. Therefore, there may be a problem where extracts with good effects cannot be applied in sunscreen.

4.2 The Role of Biodegradable Biomaterials

The application of biodegradable biomaterials in sunscreen has been an important innovation in the fields of environmental protection and cosmetics in recent years. By combining biodegradable materials with existing sunscreen ingredients, both environmentally friendly and efficient sunscreen products can be developed. This innovative formula provides consumers with safer sun protection options. From an environmental perspective, biodegradable biomaterials play a significant role in reducing environmental pollution and promoting sustainable development. There are currently many new research schemes for biodegradable materials.

Lorquin et al. concluded through a series of safety analyses such as SPF testing of lignosulfonates that they can effectively enhance SPF values [13]. Lignin is a natural component and one of the most abundant biopolymers on Earth. It has biocompatibility, biodegradability, and human safety for use, as well as a certain degree of UV absorption. Lignosulfonate is lignin treated with sulfite and is a good biomaterial[13]. Lignosulfonates have good effects on sunscreen, but they still face some challenges in practical applications. For example, the darker color of lignosulfonates may affect the appearance and consumer acceptance of sunscreen; In addition, the compatibility issue between lignosulfonates and sunscreen matrices also needs further research and resolution.

Infante VHP et al. studied a formula mainly composed of starch and PEG-75 lanolin. The formula was validated to enhance antioxidant capacity through methods such as electron paramagnetic resonance (EPR) spectroscopy and UV/VIS spectroscopy[14]. This formula plays a significant role in the development of environmentally friendly sunscreens, but PEG-75 lanolin may cause allergic reactions in populations with sensitive skin. Therefore, in developing environmentally friendly sunscreen, more attention should be paid to the properties and potential functions of the materials themselves.

However, the current high production cost of biodegradable biomaterials has led to higher prices for environmentally friendly sunscreens in the market, which to some extent limits their popularity. At present, regulations and standards regarding the combination of biodegradable biomaterials with sunscreen have not been fully developed. This may lead to significant differences in product quality in the market, making it difficult for consumers to judge the quality of the product. Moreover, its performance stability may be slightly inferior to traditional sunscreen, and further formula optimization is needed to improve its stability.

5. Conclusion

Sunscreen protects people's skin exposed to ultraviolet rays to a great extent, which is an important skin protection barrier and even reduces people's risk of illness. From a safety perspective, the improvement of relevant standards and regulations, as well as the application of nanotechnology, effectively ensure the safety and comfort of sunscreen. However, the long-term impact of nanotechnology requires continuous and close attention. From the perspective of effectiveness, SPF testing provides people with references for different usage environments. Due to SPF's current reliance on human testing, it may be subject to various factors of interference. It is necessary to improve the accuracy of SPF values from the perspective of in vitro testing by developing more complex in vitro skin culture techniques and studying the effects of various factors. At the same time, by applying sunscreen correctly, the durability of sunscreen in outdoor environments can be improved, that is, by evenly applying sunscreen with the appropriate SPF value to maximize the sun protection effect. Precautions can be added to the packaging of sunscreen to remind consumers to make correct choices and use. From an environmental perspective, sunscreen with natural ingredients is highly sought after by consumers. By studying the sun protection effects and additional functions of various plant extracts, they are applied to sunscreen. These types of extracts usually have mild and low irritation characteristics, and have high adaptability to people with sensitive skin. However, the specific components and mechanisms of its function still need to be further explored. Degradable biomaterials provide a new approach to making environmentally friendly sunscreens, further enhancing the sun protection effect through the combination of existing sunscreen ingredients and natural substances. It is of great significance for sustainable development. Due to its high production cost, it is necessary to optimize the formula or choose more economical materials to achieve the goal of reducing costs. With the continuous advancement and development of nanotechnology, detection technology, and new environmentally friendly materials, more safe, effective, and multifunctional new products will emerge in the future. Diversified products will provide consumers with more choices while balancing high quality.

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