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Optical properties of bacterial nanocellulose for the replacement of chemical filters with endocrine-disrupting consequences. a natural and sustainable approach

Abstract

In this review, we focus on understanding the optical properties of natural mineral products for incorporation into cosmetics and personal care products. Specifically, we focus on titanium dioxide and bacterial nanocellulose as alternatives to replace endocrine-disrupting molecules present in sunscreens. We want to highlight the importance of replacing benzophenones. These chemicals are known for their UV absorption capacity and their endocrine-disrupting activity. We believe that the complete replacement of benzophenones should be immediate. We propose replacing them with mineral sunscreens, such as those containing titanium dioxide or zinc dioxide. This natural alternative would allow us to add natural nanocellulose (NBC), reinforcing the mechanism of action by increasing the product's refractive capacity. To reach this conclusion, a total of 55 scientific publications were reviewed, covering topics such as toxicity, pharmacodynamics, alternatives, physics, optics, microbiology, and dermatology, among others.

Keywords: bacterial Nano Cellulose, endocrine disrruptors, green aproach, natural products

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Introduction

Bacterial nanocellulose (BNC) is a primary metabolite synthesized by the *Pseudomonas fluorescens* bacteria. BNC possesses distinctive characteristics that allow modifications on its biological, physical, and physicochemical properties. Its versatility stems from the processes involved in its production method. One well-studied and utilized characteristic of BNC are its mechanical strength, biocompatibility and swelling capacity, which reaches approximately 200 times its weight in water.[1] Under special conditions, this makes it a unique model for the design of, films and semi-solid topical pharmaceutical dosage forms. Previous studies conducted in our laboratory allowed us to obtain hydrogels and natural suspensions to carry all types of natural extracts, both oily and aqueous.[2–5] While many laboratories, including ours, are studying the wide range of innovative approaches to developing new nanocellulose-based materials, there is diverse scope for designing new product prototypes involving BNC. One particularly promising characteristic is its optical properties.[1]

Objective

In this review, the focus is on understanding the optical properties of endocrine-disrupting molecules present on cosmetics and personal care products. Specifically, we want to emphasize the importance of replacing benzophenones. These chemicals are known for their UV absorption capacity, but also for their endocrine-disrupting activity. We believe that the complete replacement of benzophenones should be immediate. Therefore, we are considering mineral sunscreens, such as those containing titanium dioxide or zinc dioxide. This natural alternative would allow us to add natural nanocellulose (NBC) by reinforcing the mechanism of action, that is, by increasing the product's refractive capacity.

Endocrine disruptors and their health consequences.[6]

Agrochemicals,[7–12] personal hygiene products such as deodorants, repellents, creams, perfumes, lotions, fabric softener, ultra-processed foods, and fumigated fruits and vegetables are just some of the countless products containing substances known as endocrine disruptors. An endocrine disruptor is any substance that enters our body through ingestion, skin absorption, or inhalation, and although it does not mimic its primary function, it does so by mimicking hormones. The main hormones affected fall into three groups: Estrogens (Xenoestrogens): These are the most frequently mimicked hormones. Compounds such as phthalates,[13] Bisphenol A,[14] benzophenones,[15–17] parabens[6] in cosmetics, and pesticides such as atrazine,[18,19] 2,4-D,[7–11] glyphosate,[12] and all those misnamed "hormone-like" or "plant hormones", al lof them act by mimicking estrogens. Androgens: Certain endocrine disruptors can mimic or antagonize testosterone, affecting reproductive function, especially agrochemicals such as 2,4-D,[7–12] atrazine,[18,21] glyphosate,[12] and the list goes on. Thyroid Hormones:[22,23] Compounds such as triclosan[16] (in soaps/toothpaste) can alter thyroid function and the immune system.

Why do we use benzophenones in sunscreens?[24]

Benzophenones, particularly oxybenzone (benzophenone-3), are organic chemical compounds used as broad-spectrum sunscreens to absorb UVA and UVB radiation. They are very common in creams and cosmetics. Main characteristics of benzophenones as sunscreens:[25,26] Their action mechanism is the chemical absorption of UV rays, potentially transforming the radiation into energy that is less harmful to the skin.[27] Common uses: They are found in sunscreens,[27] moisturizers,[28] lipsticks, and makeup,[29,30] often referred to as Benzophenone-3 (oxybenzone) or Benzophenone-4. Main

harms of Benzophenones as Endocrine Disruptors: Reproductive and Developmental Disruption:[30–32] They can cause infertility,[33] endometriosis,[34] genital malformations,[35] decreased sperm count, and reduced semen quality.[36] Hormonal Interference: They act as analogs of natural hormones (antiandrogens/estrogens), affecting the endocrine system, including thyroid function.[6] Prenatal and Neonatal Impact: Risks of low birth weight and problems during fetal development.[37,38] Cancer Risk: Benzophenone is identified as a possible human carcinogen, with studies suggesting risks of breast cancer or tumors, ovarian cancer and prostate cancer from chronic exposure.[39–41] Impact on Adolescents: It is associated with risks of obesity,[42,43] non-food allergies,[45] and precocious puberty.[46] Continuous exposure to these compounds, present in sunscreens and personal hygiene products, can be harmful even at low doses.

How can we replace sunscreens that use chemical reactions as a mechanism for absorbing UV light?[47]

One alternative is sunscreens that work through physical methods. Mineral (or physical) sunscreen uses natural ingredients such as titanium dioxide and zinc oxide to create a barrier on the skin's surface that reflects UVA/UVB rays. It is ideal for sensitive, reactive skin or skin with conditions like rosacea,[44–46] as it is not absorbed,[48] offers immediate protection, and is environmentally friendly.[49] Also presents key features and benefits such as; Immediate action: As a physical filter, it works upon application, without needing to wait 30 minutes. Ideal for sensitive skin:[46] It generally does not cause irritation, so it is recommended for intolerant skin, acne-prone skin, or for children. Complete sun protection. It offers broad-spectrum protection."Screen" effect: It can leave a white cast on the skin, although modern formulas have improved this.[47,48] Since the mechanism of action involves a barrier effect through the refraction of sunlight, it is possible to increase the sun protection factor (SPF) of mineral sunscreen.[49] This can be achieved by incorporating a new agent that adds refractive properties, such as BNC. Its optical properties have already been verified by measuring dispersion, refraction, diffraction, transmittance, absorbance, and birefringence.[50] Its action mechanism, in the form of acicular crystals, alters the properties of light upon interaction with an incident light beam.[51–53] The alterations in the properties of light that occur when it interacts with a medium are called the optical properties of that medium.[54] These optical properties are influenced by the physical and medium chemical characteristics, such as surface roughness and dangling bonds.[55] However, measuring optical properties is often simpler and more direct than analyzing physical and chemical properties and their complex correlations with optical behavior. Consequently, optical properties are often studied to better understand the properties of other materials. Some of the most frequently observed optical properties include dispersion, refraction, diffraction, transmission, absorbance, and birefringence.[53] Several laboratories around the world have studied the optical properties of plant-based nanocellulosic material and found encouraging results regarding refractive index and deacresed transmittance in the UV. Our laboratory is conducting similar studies on BNC crystals and flakes, obtained through cleaner physical production methods. Our goal is to increase the sun protection factor (SPF) of titanium dioxide-based sunscreens with a sustainable, biodegradable alternative that has superior optical properties.

Conclution

The benzophenone group, commonly used in sunscreens, is a potent endocrine disruptor with over 12,500 publications to date, including studies in healthy volunteers, patients, and laboratory animals. All publications indicate a serious risk to human and animal health, as well as environmental risks. Our goal is to increase the sun protection factor (SPF) of titanium dioxide-based sunscreens with a sustainable, biodegradable alternative that has superior optical properties. Several studies are necessary before publishing the results to ensure the robustness of this process, but the results obtained so far indicate that the novel production method improves upon the parameters measured to date. Therefore, we can say that it is possible to increase the SPF of titanium dioxide-based sunscreens with a sustainable, biodegradable alternative that offers improved refractive activity.

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Conflicts of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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