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Antimicrobial and Antifungal Potential of Zinc Oxide Particles in Nail Polish Applications

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Abstract

Zinc Oxide particles, on the nanoscale and low-micron scale are widely reported to inhibit harmful bacteria, yeasts, and filamentous fungi. The unique biological and chemical properties of these particles also make them attractive to the fashion industry for use as a promising antifungal agent in a variety of applications including enhanced textiles, cosmetics and nail polishes. Fungal infection on the fingernails and toenails results in yellowing and thickening of the nail bed and can be caused by dermatophytes, non-dermatophyte molds, and yeasts. Experiments were conducted using *Aspergillus Niger* which is a commonly accepted fungus for use in benchmark antifungal testing and is classified as a non-dermatophyte. A variety of antimicrobial and antifungal agents were mixed with a polymer paint base to simulate that of standard commercial nail polish. Results show that the Zinc Oxide particles create a zone of inhibition on 90% of the area on which it was painted/applied. As nanotechnology has manifested technological advancements across a variety of industries such as food, oil and gas, electronics and communications, it now shows promising advances for the fashion industry in the next generation of cosmetics design.

Introduction

Onychomycosis is a fungal infection of the fingernails or toenails that causes discoloration, thickening, and separation from the nail bed. Onychomycosis occurs in 10% of the general population but is more common in older adults [1]. Classic signs of onychomycosis commonly include nail discoloration and yellowing, brittleness, thickening, and lifting away from the nail bed. As the nail changes worsen over time, affected nails can cause local pain in surrounding skin [2]. Onychomycosis is caused by dermatophyte infections approximately 60-70% of the time. These are fungi that require keratin to grow and cause superficial infections in hair and nails [3]. Non-dermatophyte molds and yeasts such as *Aspergillus* are responsible for the remaining 30-40% of infections caused by onychomycosis [1-3]. In this growth scenario, the microbes are attaching to the surface of the nail and then growing together into a widespread infection.

In many industries, antimicrobial paints or coatings are the traditionally accepted method for protecting a surface exposed to harmful bacterial or fungi which can be grouped together as microbes. These coatings are considered to be antimicrobial because they contain materials that inhibit microbial growth which release at a controlled rate to prevent the development of a biofilm on the surface to which they are applied [4-9]. The authors have previously studied the incorporation of antimicrobial materials into the fabrication of polymer structures and examined their efficacies in high-fouling conditions [4-6]. The rate of release of biocides is critical for efficacy; if it is too fast, the antifouling will fail prematurely, especially after a period of intense activity, while if it is too slow, the antimicrobial will be ineffective, particularly in areas with a high microbe count [4-6,10]. The microbial organisms must be prevented from attaching and growing on the surface. Once this happens, growth is extremely rapid and the organisms are beyond the influence of antifungal paints [10].

The versatility of Zinc Oxide (ZnO) particles has allowed them to be incorporated into antimicrobial substances for the inhibition of microbial pathogen growth and metabolism. The antibacterial activity of ZnO and other metal-containing NPs has been reported in a vast number of previous articles [4-9,11-13]. Prevention and control of microbial contamination using advances in technology is a focus of numerous studies using materials such as Titanium Dioxide and Silver Oxide [13-18]. Nanoparticles of zinc oxide have previously been applied to different textiles including cotton to incorporate antimicrobial properties in combination with UV protection properties [19]. Additionally, ZnO particles have been applied to bleached jute fabric and demonstrated an increased resistance to heat and fire [20].

This study will examine the efficacy through zone of inhibition testing of an antifungal paint with potential use on fingernails and toenails. The antifungal paint is developed by mixing established antimicrobial materials in a powder form into a liquid polymer matrix. The results of this laboratory-based, experimental work could be used in future commercial formulations to prevent nail discoloration, thickening, and infection.

Experimental

Experiments were conducted using a derivative of ASTM F895 Standard Test Method for Agar Diffusion Cell Culture Screening for Cytotoxicity. This test method is useful for assessing the cytotoxic potential of new materials and formulations and as part of a quality control program for established medical devices and components. A third-party tester utilized this method to give qualitative results of the potency of antimicrobial powders. The antimicrobial materials used in this study were selected based on their documented bactericidal efficacy as well as their accessibility in powder form which was required for the experimental methodology [4]. These include Zinc Oxide (44 micron, ZoChem, ZOX-800), Silver Oxide (0.5 micron, BTG Products), and Titanium Dioxide (5 micron, Bulk Apothecary). The commercial product ANA (90 micron, BTG Products, MG) is a microbiologically induced corrosion and biofouling inhibitor that is advertised as added directly into a polymer coating or lining during the manufacturing process. This product is patent protected and the technology is proprietary but the data sheets describe it as a powder additive for biofilm prevention. Antimicrobial and control powders are poured into several wells that have been punched into the inoculated agar. The testing wells can be compared to one another based on the zone of inhibition of cell or spore growth each has created.

Aspergillus Niger was selected for this test as it is a fungus that is easily grown and controlled in a laboratory setting and has been documented to cause fungus infections related to nails [1-3]. This fungi is a conidiophore, or a sexual spore generating aerobic fungus. A more common nail fungus is a dermatophyte which requires keratin to survive. *A.niger* is responsible for a variety of infections, food spoilage and black mold. Although it is primarily a plant pathogen, *A. niger* is known to cause onychomycosis in human nail beds. *A. niger* is a fungus commonly associated with unsightly growth on manufactured goods and is commonly used as a benchmark for fungal resistant testing.

Test fungi was prepared individually, prior to test, by growth on agar plates. The fungi was then spread evenly about the entire surface of the agar and wells were created in the agar using the base of a sterile pipet tip. Each well was punched from the surface of the agar to the bottom of the petri dish and antimicrobial/ antifungal powders and controls were poured at random into the wells. The wells were filled until the powder became even with the surface of the agar. The petri dishes were placed in an incubator at 78°F for three days. The area around each well was then analyzed for any zone of growth inhibition.

Results and Discussion

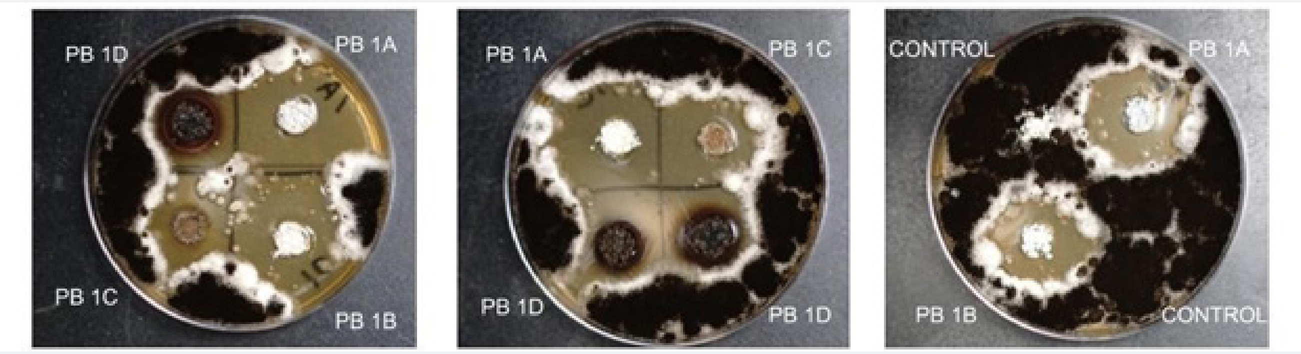

Figure 1: Experimental Results from ASTM F895 Zone of Inhibition Testing
A: Zinc Oxide, B: Titanium Dioxide, C: Silver Oxide, D: ANA.

After the three day incubation period the sections around each well were analyzed for growth. Each of the established antimicrobial materials created their own zone within each of their 1/4 petri dish section. The controls were completely covered with the *Aspergillus Niger* as the spores were able to freely procreate around and on top of the controls. All of the antimicrobial powders created different magnitudes of inhibition. Blend 1A which contains Zinc Oxide consistently produced the best zone of inhibition as it prohibited growth in approximately 90% of its section. Figure 1 shows the test results for ASTM F895 with four antimicrobial agents: Zinc Oxide, Titanium Dioxide, Silver Oxide, and ANA.

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Results from this study can lead to a better understanding of cosmetic solutions that protect the nail surface from common infections that cause unsightly discoloration and thickening of fingernails and toenails. The incorporation of Zinc Oxide (ZnO) into a polymer matrix or nail solution can create an antimicrobial nail polish with little additional cost. The cosmetic industry has embraced the use of ZnO in a variety of products such as sunscreen and face powders and has for years been benefitting from inherent antimicrobial properties. Additionally, incorporating ZnO can be used for eco-fashion garments, protecting the human body from microbial attack and from UV damage. More work needs to be done in testing on infected nails outside of the laboratory setting. The next steps to this work are to evaluate the whitening properties of ZnO on nails that have been infected and experience discoloration. Technological advances in particle development could provide future benefits for a variety of applications in the fashion industry.

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