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NICKEL OXIDE(NiO) NANOTECHNOLOGY FOR ANTI-FUNGAL APPLICATIONS: A COMPREHENSIVE REVIEW OF CURRENT TRENDS AND FUTURE PROSPECTS

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ABSTRACT

Fungal infections are known to be a common global health problem, especially as resistance to conventional antifungal drugs increases. Innovative solutions are needed to overcome this problem. This review aims to explore the potential application of nanotechnology to nickel oxide materials in inhibiting the growth of pathogenic fungi, as well as investigating the ability of nanosized nickel oxide as an innovative option in overcoming antifungal problems. The use of nickel oxide nanomaterial as an antifungal agent can produce efficient healing in treating fungal infections which are currently difficult to treat. Information explaining the potential side effects or long-term effects of this method is essential to ensure that the use of this agent does not harm the patient's health. Nano-sized nickel oxide has the ability to interact with other living things in an ecosystem. Therefore, to understand possible environmental risks, research is needed on the concept of ecological impacts on these materials. To increase awareness of the potential use of nano nickel oxide in the treatment of fungal infections, it is important to make this nickel oxide material available to the general public. Global consistency of patient treatment can be ensured through the establishment of well-defined and standardized protocols for the application of nickel oxide nanoparticles in the treatment of fungal infections.

Keywords : Nickel Oxide, Fungal Infection, Nanotechnology, Anti-Fungal.

ABSTRAK

Infeksi jamur dikenal sebagai salah satu masalah kesehatan global yang umum, terutama seiring dengan meningkatnya kekebalan terhadap obat antijamur konvensional. Solusi inovatif diperlukan untuk mengatasi masalah ini. Tinjauan ini bertujuan untuk mengeksplorasi potensi penerapan nanoteknologi pada bahan oksida nikel dalam menghambat pertumbuhan jamur patogen, serta menyelidiki kemampuan oksida nikel berukuran nano sebagai pilihan yang efisien dan inovatif dalam mengatasi masalah antijamur. Penggunaan nanomaterial nikel oksida sebagai bahan antijamur mampu menghasilkan penyembuhan yang efisien dan inovatif dalam mengatasi infeksi jamur yang saat ini sulit ditangani. Informasi yang menjelaskan bagaimana potensi efek samping atau efek jangka panjang dari metode ini sangat penting untuk memastikan bahwa penggunaan bahan ini tidak membahayakan kesehatan pasien. Oksida nikel berukuran nano memiliki kemampuan untuk berinteraksi dengan makhluk hidup lain dalam suatu ekosistem. Oleh karena itu, untuk memahami kemungkinan risiko lingkungan, diperlukan penelitian tentang konsep dampak ekologis pada material ini. Untuk meningkatkan kesadaran akan potensi penggunaan nano nikel oksida dalam pengobatan infeksi jamur, penting untuk membuat bahan

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nikel oksida ini tersedia untuk masyarakat umum. Konsistensi pengobatan pasien secara global dapat dipastikan melalui penetapan protokol yang terdefinisi dengan baik dan terstandarisasi untuk penggunaan partikel nano nikel oksida dalam pengobatan infeksi jamur.

Kata kunci *: Oksida Nikel, Infeksi Jamur, Nanoteknologi, Anti Jamur.*

Introduction

Fungal infections are often ignored and rarely realized by many people, even though this can cause serious public health problems (Gnat et al., 2021). Fungal infections are an increasingly urgent health problem worldwide. Diseases caused by fungi, or better known as mycosis, can affect various organs and systems in the human body (Brown et al., 2012). Most of these fungal infections are superficial, affecting the hair, skin and nails, but some species are capable of causing life-threatening diseases. The most common of these include Cryptococcus neoformans, Aspergillus fumigatus and Candida albicans. Candidiasis is a primary or secondary infection caused by Candida species. Infection may be limited to the mouth, throat, skin, vagina, fingers, nails, trachea, lung or gastrointestinal tract. During serious damage to the immune system, Candida species can cause invasive candidiasis (IC) includes blood-derived infections (candidemia) and deep-seated tissue infection (Nami et al., 2019). These fungi are typically innocuous and even constitute a part of the human microbiome, but if these pathogens disseminate throughout the body, they can cause fatal infections which account for more than one million deaths worldwide each year. Thus, systemic dissemination of fungi is a critical step in the development of these deadly infections (Strickland et al., 2021). Other pathogenic fungi can also cause serious infections in individuals with weakened immune systems, such as patients with HIV/AIDS or those undergoing chemotherapy (Pappas et al., 2018).

Assessment of risk factors of these infections such as hospital-acquired fungal infection and environmental factors, including changes in medical practices and epidemiology as well as fungal infection mediated immunomodulation have provided important therapeutic options in the diagnosis of the fungal infections for clinicians (Bajpai et al., 2019). Though there are enormous fungal species across the world, more than 500 species are predicted to be infectious to human. Most of the fungi are present in the environment and also part of the normal flora in humans and animals. The fungal infections in humans can range from common, mild, superficial infections to life-threatening invasive infections, especially in immunocompromised patients (Pathakumari et al., 2020). Fungals can also be a major cause of infection in other organisms. Fungal infections that are being known to have resistants to conventional anti-fungal medications have become a serious problem in clinical practice. The treatment of fungal infections with azoles (such as fluconazole, voriconazole and itraconazole) may lead to the emergence of resistant fungal pathogens due to excessive and frequent use (Di Mambro et al., 2019; Gintjee et al., 2020). Likewise, the traditional treatment procedures including the use of amphotericin (AmB) have been evaluated to be relatively ineffective in most cases due to reactivation of latent fungal infections post medication treatment (Tiew et al., 2020; Brunet et al., 2018). The search for novel effective nanotechnology-enabled antifungals has gained impetus. Therefore, the development of new technologies to solve this problem is

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essentia and has the potential to develop more effective and innovative anti-fungal agents (Alguthaymi et al., 2021).

The anti-fungal properties of bio-inspired nickel oxide nanoparticles have rarely been investigated compared to their antibacterial activity (Berhe et al., 2023). Nickel oxide (NiO) is one of the nanomaterials that attract attention in anti-fungal research. Nickel Oxide itself are acquired for their clinical purpose, as they contains antibacterial, anti-fungal, cytotoxic, anticancer, antioxidant, remediation, and enzyme inhibition properties (Sana et al., 2021). With advances in nanomaterial synthesis, characterization, and understanding of interactions between nanomaterials and pathogenic microorganisms, The antimicrobial properties of NiO have been shown to be effective against various strains of pathogenic fungi (Jha &; Ward, 2020). Nickel Oxide (NiO) Nanotechnology has become an increasing focus of research in anti-fungal applications, having the potential to generate innovative solutions in addressing the increasingly complex challenges of fungal infections. Nickel oxide, specifically NiO, has strong antimicrobial properties against various strains of pathogenic fungi (Yousefzadi et al., 2020). Studies have shown that NiO nano particless are able to inhibit the growth and spread of fungi, even in strains that have shown resistance to conventional anti-fungal agents (Zhu &; Tang, 2020).

Recent researches has provided deep vision about the effectiveness of NiO in inhibiting the growth and spread of pathogenic fungi. The use of nano-sized materials, such as metal nanoparticles of oxides, promises innovative solutions to overcome the problem of fungal resistance to conventional medicines. In addition, nanoparticles can be used for targeted medication delivery, increasing the effectiveness of anti-fungal therapy (Rahman et al., 2019).The unique physical and chemical properties of nanomaterial nickel oxides play a key role in their anti-fungal effects. The very small particle size allows for more effective penetration into the structure of the fungus, allowing for more efficient anti-fungal action to be execute (Tang et al., 2020). In addition, the larger surface of the nanomaterial provides more interaction sites between nickel oxide and microorganisms, significantly improving anti-fungal capabilities (Sun et al., 2018). It is important to consider the potential applications of NiO in the treatment of fungal infections given the increased resistance to conventional anti-fungal agents (Mukherjee et al., 2019). Therefore, a review of current trends and future prospects of NiO in anti-fungal applications is essential for the development of more effective and innovative therapies. Newest researches has also highlighted the need for further clinical trials and more in-depth research on NiO toxicity in humans condition (Zhang et al., 2020). Understanding the long-term impact of NiO use on the human body is an important step in ensuring the safety and effectiveness of this anti-fungal therapy.

Methods

Researchers used several methods in collecting informations from this study. Researchers are using literature methods to navigate through various scientific databases such as Google Scholar, and PubMed. The search focused on scientific articles published after 2018 to keep up with the latest study reports. After collecting several related articles and journals, researchers evaluated and paraphrased each data based on the main topic or atleast fit the context of the study, especially in the context

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of anti-fungal applications. The researchers are also using mixed human and ArtificiaI Intelligence (AI) writing technology features to fulfill this report in order to facilitate and provide accurate data related to the scientific report to be informed and also easy to understand.

Researchers investigated the action of NiO as an anti-fungal agent by reconsidering the molecular interactions between NiO and the fungal cell structure from various papers and with the help of Machine Learning. In addition to anti-fungal effectiveness, researchers also considered the potential toxicity and health impacts based on NiO material and gathering information on how to minimalize it to ensure its safety. The findings from the analysis are compiled and written in a structured report. After completing this report, researchers will conduct a literature review to ensure that all of that informations obtained is accurate. By doing this, researchers will obtained an in-depth potential of this technology in managing the fungal infections.

Results and Discussion

Nickel Oxide (NiO) nanoparticles have shown encouraging anti-fungal effects in recent study. Numerous fungi can be effectively inhibited from growing, as studies have shown when NiO is added. This achievement could lead to the creation of more advance antifungal treatments. The way that NiO works includes its molecular interactions with fungus. NiO particles have the ability to pass through fungal cell walls and interfere with reproductive and metabolic functions. As a result, the fungus's capabalities to spread illness are reduced.

One important aspect affecting NiO's efficiency as an anti-fungal medication is its particle size. Because of their larger surface area, particles smaller than a nano particles have an ability to interact with fungal cell walls more effectively. NiO applications that require antifungal properties need to be carefully evaluated for safety. To make sure its use is risk-free and doesn't have any negative side effects, studies to determine how toxic it is to human cells is necessary. In the context of using NiO as an anti-fungal agent, its primarily hazards aspects are related to its physical and chemical properties. The tiny nanoparticles have the potential to cause lung irritation or even inflammation if inhaled. A further concern is that sensitive skin might develop health problem if the NiO particle comes into contact with it. Long-term NiO exposure can damage the nerve system and raise the risk of lung cancer.

Having the abillity to eradicate fungal infections, NiO might also be capable of being applied to building in taking care of fungal growth. Currently, the obtaining of new systems (such as metal oxides and hydroxides) nanoparticles have been used in the last decade to protect building surfaces against biofilm formation (David et al., 2020). Further studies are required to compare which metal oxides including NiO is effective as an option to prevent fungal growth on building. As an anti-fungal agent, nickel oxide (NiO) carries some potential risks that should be minimized by taking some precautions. First and foremost, personnel engaged in the NiO application procedure must be outfitted with personal protective equipment, such as protective goggles, respiration masks, and gloves, to minimize the risk of human exposure. The chance of coming into direct contact with NiO can be reduced by using these tools.

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Furthermore, there should be strict regulation and control over the application of NiO. The risk of exposure to airborne particles can be reduced by using dust extraction equipment or enclosed spaces to help reduce the dispersal of NiO particles in the air. When choosing NiO formulations for buildings, long-term safety should be considered into account. Application techniques should guarantee that risks to the integrity of buildings and human health remain at a minimum level. Additionally, it is essential to keep an eye on the level of NiO in the workplace and to follow all applicable laws and safety precautions. This entails routine air quality checks in the areas where NiO is used at work.

Converting nickel oxide into an anti-fungal agent needs to follow several procedures. This can be done by using methods such as chemical precipitation, sol-gel, thermal decomposition, or other nanoparticle synthesis technique. Conducting an "in vitro" testing can also be done by exposing fungal strains to various concentrations of nanoparticle and examining their inhibiting effect against nickel oxide. Performing the minimum inhibitory concentration, which is determining the lowest concentrations of NiO's nanoparticles are required to ensure and minimalize cost effeciency to inhibit the growth of the target fungus. By doing so, will provides important information about the potency of the anti-fungal agents. The NiO nanoparticles may be further functionalized or even modified to enhance their anti-fungal properties. Such modifications also involved in adding specific chemical components or coatings to improve interactions with the targeted fungal cells. Further experiment like dosage and toxicity testing needs to be done in order to maximize the potential advantages and minimalizing the risks of usage.

As a potential future agent, nickel oxide (NiO) shows promise, especially as an antifungal that may be able to counteract harmful fungal growth. Because of its ability to prevent fungal growth and reproduction, nickel oxide (NiO) has antifungal properties that make it a promising material for a variety of applications, particularly in the building and medical industries. NiO can be applied as a protective layer on surfaces in buildings to stop the growth of fungi. By doing this, the negative impact of fungal growth on building structural integrity and indoor air quality may be minimized. Nanosized nickel oxides have the ability to interact with other living things in an ecosystem. Therefore, in order to understand the possible environmental risks, research on the concept of ecological impact on this material is required. To increase awareness of the potential uses of nano nickel oxide in the treatment of fungal infections, it is critical to make this nickel oxide material available to the general public. Global patient treatment consistency can be ensured through the establishment of a well-defined and standardized protocol for the application of nano particles nickel oxide in the treatment of fungal infections.

Conclusion

NiO's capability to address fungal resistance to conventional medications is another benefit. Particularly when it comes to fungal infections in humans, the emergence of drug-resistant fungal strains has made NiO an effective replacement for more potent treatments. It is important to remember that safety and environmental impact considerations should be taken into account when using NiO. When developing NiO as antifungal agent, prudent use, regulatory oversight, and waste

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management are essential factors to take into account. All things must be considered, nickel oxide offers intriguing potential as an antifungal agent with potentially comprehensive applications in a variety of industries, from healthcare to building. NiO has the potential to be an essential tool in the fight against harmful fungal growth with further research and development.

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