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Real-time Detection of Zeranol in Cereals Using a Terphen[3]arene-Based Optical Sensor Functionalized with Quaternary Ammonium Groups

Beatty Zhang*

Department of Chinese Medicine Modernization, Tianjin University of Traditional Chinese Medicine, Tianjin 301617, China

Introduction

Zeranol is a synthetic estrogenic compound commonly used as a growth promoter in livestock. While it enhances the growth rate and feed efficiency of animals, its presence in food products, including cereals, poses potential risks to human health. Given the potential health risks associated with exposure to endocrine-disrupting chemicals, there is a growing need for reliable, efficient, and real-time methods to detect Zeranol in food matrices like cereals. Traditional methods of detection, such as Liquid Chromatography coupled with Mass Spectrometry (LC-MS), though highly sensitive, are often time-consuming, expensive, and require sophisticated equipment and trained personnel. Therefore, the development of a more accessible and rapid detection system is critical. In this context, the use of terphen[3]arene-based optical sensors functionalized with quaternary ammonium groups has emerged as a promising alternative for real-time detection of Zeranol in cereals. Zeranol, also known as 4-hydroxy-Zeranol, is a synthetic mycoestrogen derived from the fungus Fusarium. It is widely used in veterinary medicine as a growth promoter, particularly in cattle and other livestock, due to its ability to promote muscle growth and increase feed efficiency. However, Zeranol is a potent estrogenic compound and can pose health risks to humans, especially through prolonged exposure to small amounts via the food chain. Chronic exposure to Zeranol has been linked to hormonal imbalances, reproductive issues, and an increased risk of cancers related to hormonal disruption. Cereals, especially those produced from crops like corn, wheat, and barley, are essential food staples consumed globally. However, contamination of these products with Zeranol or other mycotoxins can be harmful, especially in regions where animal feed containing Zeranol is widely used. The detection of Zeranol in such food products is vital to ensure food safety and public health. Conventional detection methods are not ideal for routine or real-time analysis, as they are often slow, require complex sample preparation, and demand expensive equipment [1].

Description

Recent advancements in sensor technology have led to the development of optical sensors that are highly sensitive, portable, and capable of providing real-time results. Optical sensors, particularly those utilizing functionalized organic materials like terphen[3]arene, have shown considerable promise due to their high sensitivity, ease of use, and ability to detect low concentrations of analytes like Zeranol. Terphen[3]arene, a polycyclic aromatic compound, is well known for its unique electronic properties and ability to interact with various molecules. It consists of three benzene rings fused in a particular arrangement, providing a rigid structure that can be functionalized for a range of applications. When functionalized with specific groups, such as quaternary ammonium ions, terphen[3]arene can enhance its binding properties, making it an ideal candidate for sensing applications. In the case of Zeranol detection, the terphen[3]arene structure is functionalized with quaternary ammonium groups, which serve as receptors for the target molecule, Zeranol. The interaction between the quaternary ammonium groups and Zeranol induces a change in the optical properties of the terphen[3]arene, which can be detected in real-time using optical measurement techniques [2].

The principle behind the detection of Zeranol using a terphen[3]arene-based optical sensor functionalized with quaternary ammonium groups is based on the recognition of the analyte (Zeranol) through non-covalent interactions. The quaternary ammonium groups on the sensor surface can interact with the hydroxyl and carbonyl groups present in the Zeranol molecule. These interactions are primarily ionic and hydrogen bonding in nature, which causes a shift in the electronic properties of the terphen[3]arene. The sensor operates through a phenomenon known as fluorescence quenching or Fluorescent Resonance Energy Transfer (FRET). In the absence of Zeranol, the terphen[3]arene exhibits a specific fluorescence signature when excited with light at a particular wavelength. However, when Zeranol is present, it binds to the quaternary ammonium groups on the sensor surface, causing a change in the fluorescence emission pattern. This change is directly related to the concentration of Zeranol in the sample, allowing for quantitative analysis. Since the sensor is designed to respond to the presence of Zeranol in real-time, it offers the advantage of immediate results without the need for sample preparation or complex laboratory equipment. This makes it an ideal solution for monitoring Zeranol contamination in cereals during production, storage, or at the point of sale [3].

The terphen[3]arene-based optical sensor functionalized with quaternary ammonium groups offers several advantages over conventional methods of detecting Zeranol in cereals. One of the most significant benefits of this optical sensor is its ability to detect Zeranol in real-time. The sensor provides immediate results, which is crucial in industries where rapid testing is necessary to ensure the safety of food products. This capability makes it especially valuable in quality control processes during the production and packaging of cereals. The terphen[3]arene-based sensor is highly sensitive and can detect low concentrations of Zeranol in complex food matrices like cereals. The functionalization of the sensor with quaternary ammonium groups enhances its specificity for Zeranol, reducing the chances of false positives from other compounds that may be present in the cereal. Unlike traditional methods such as liquid chromatography or mass spectrometry, optical sensors are relatively inexpensive and do not require expensive reagents or complex laboratory infrastructure. This makes the terphen[3]arene-based sensor an affordable alternative for routine testing of Zeranol contamination in cereals. Non-Invasive and Environmentally Friendly optical sensor does not require the use of harmful chemicals or extensive sample preparation, making it an environmentally friendly option for Zeranol detection. Additionally, the non-invasive nature of the sensor ensures that it can be used without altering or contaminating the cereal sample, which is critical for maintaining the integrity of the food [4,5].

Conclusion

The terphen[3]arene-based optical sensor functionalized with quaternary ammonium groups represents a promising solution for the rapid, real-time detection of Zeranol contamination in cereals. By leveraging the unique

***Address for Correspondence:** Beatty Zhang, Department of Chinese Medicine Modernization, Tianjin University of Traditional Chinese Medicine, Tianjin 301617, China, E-mail: betty@edu.cn*

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properties of terphen[3]arene and functionalizing it with quaternary ammonium groups, this optical sensor offers a sensitive, specific, cost-effective, and portable method for monitoring food safety. The integration of such sensors into food safety systems has the potential to improve the detection of harmful contaminants like Zeranol, ensuring that consumers are protected from the risks associated with endocrine-disrupting chemicals. The future of food safety testing may very well lie in these innovative, real-time, and user-friendly sensor technologies.

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Conflict of Interest

There is no conflict of interest by author.

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