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Review Article

Recent advances in nanomaterials-based electrochemical and optical sensing approaches for detection of food dyes in food samples: A comprehensive overview

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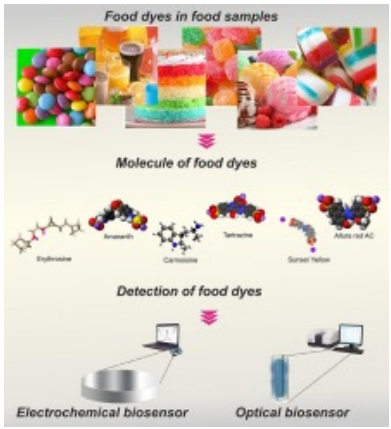
Abstract

In today's world, the stability and affordability of food colorants have caused to attracted considerable attention in the food industry. Food dyes attract the appearance of food by increasing color of that while the harmful effect of these dyes on living organs is undeniable. Synthetic food colors are becoming more common than natural ones via food manufacturers to achieve specific features like high color intensity, low cost, improved appearance, more color uniformity and stability. Varied beverages and foods obtainable in the market might contain synthetic color, which in turn leads to serious health issues such as cancers, mutations, allergic reactions, and reduced hemoglobin concentrations. Thereby, WHO (World Health Organization) highlight the required control of food dyes in food. Up to now, several analytical methods have been developed for different food dyes determination in various food matrixes. On the other hand, the performance of conventional detection platforms has been limited due to many limitations including time consuming and lack of sensitivity. Recently, cost-efficiency, sensitivity and reproducibility of electro-analytical and optico-analytical approaches have led to the development of many of them for food dyes quantification. The nanoprobes have demonstrated satisfactory results in terms of sensitivity and cost. A review of new kinds of nanoprobe consisting of carbon-based, silica-based and metallic-based composites with nanoscale size might open up new opportunities towards the investigation of colorants in food samples by developing a sensor with better analytical performance. Therefore, we attempted to summarize the recent progress of electrochemical and optical sensors in diverse matrices and show how nanoprobes could increase the performance of these approaches.

Graphical abstract



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Introduction

Without a doubt, one of the most pivotal arguments in today's world is food safety [1], [2], [3]. Safe food acts a key role in promoting good health and sustaining life [3], [4], [5]. To elaborate, international organizations, related to public health, have highlighted the safety of food as an international worry for providing nontoxic and innocuous food [6]. In recent years, most studies have introduced fungi, protozoan, toxins, parasites, bacteria, heavy metals, and viruses as the most important food contamination, which can have detrimental impacts on human health [7], [8]. On the other hand, excessive consumption of some additional materials can have a significantly worse effect on living organs, which attracted scanty attention [9]. Food coloring or color additive is any substance or dye that produces color once it is added to foodstuff or beverages or drinks. Food coloring is applied in both domestic cooking and commercial food production purposes. In food technology, food colorants, are chemical materials that are added to food matrices, to sustain or enhance the sensory properties of the foodstuff, which might be influenced or lost throughout storage or processing, and in order to preserve the favorite color appearance [10], [11]. The visual view has an imperative role in the food products selection via modern consumers, color is one of the main components of beverages and food. In recent years, numerous synthetic food dyes are employed as additives to replace ordinary colors, to realize specific characteristics like enhanced appearance, color uniformity, greater color stability, and high color intensity [12], [13]. In comparison to natural dyes, synthetic food colors possess numerous economically significant features, for example, high color stability, low cost, resistance to pH, and light. Synthetic food dyes are substances derived from coal tar derivatives, and most of them have an azo-unite. Synthetic food dyes as one of the most common vital classes of food additives have been exploited in different foods products including drinks, gelatin treats, confectionery products, and snacks in the order to attract more consumers due to better appeal, supplanting their characteristic shading, which can be vanished during the mechanical procedures [14], [15]. Diverse beverages and food products presented in the market might have some non-allowed synthetic colors along with the excessive use of allowed synthetic colors. Various research has proved that artificial food dyes are the main cause of food poisoning and induce serious health issues. Various food additives were widely utilized in the past but are no longer permitted,

because of side effects evidence, toxicity in the long term and medium, along with a great incidence of potential health events [16]. The random use of allowed colors and the use of illegal dyes can pose a great threat to human health. The most relevant food dyes which are permitted for food coloring are tartrazine, sunset yellow, Ponceau 4R, indigo carmine, erythrosine, carmoisine, and Allura Red AC demonstrating the regulation concentration range of them in Table 1. The application of food colorants in foodstuffs accelerates the necessity of the progress of precise, accurate, selective, and sensitive analytical techniques for their quantification and analysis. Over the last few years, capillary electrophoresis [17], HPLC (high performance liquid chromatography) [18], ELISA (enzyme-linked immunosorbent assay) [19], thin layer chromatography [20] and nuclear magnetic resonance [21] methods as classical detection methods have been developed for the analysis of these dyes in different food matrixes. On the other hand, these platforms have suffered from a lack of sensitivity, and also most of them are time-consuming [22], [23]. In addition, most of them need costly instrumentation, proficient personnel to operate the equipment, and multiple-step in sample preparation. From this perspective, several researchers have attempted to introduce more efficient sensing approaches [24]. To elaborate, various types of sensors such as electrochemical [25], optical [26], and QCM (quartz crystal microbalance) based sensors have been developed as useful quantification methods. The term sensor is called a compact analytical device determining qualitative/quantitative signals which are related to the concentration of targets. In recent, sensors have become a hot research topic due to their sensitivity [27], [28]. In detail, the advent of nanotechnology has revolutionized multiple domains in sensing. The application of various types of NMs (nanomaterials) comprising carbon-based, metallic-based, silica-based, polymer, and hybrid NMs can provide several features including high capturing area, biocompatible, high conductive probes, and alongside that specific optical and electronic properties. Besides, a large number of functionalized groups on the surface of NMs can provide an appropriate capturing and immobilization of the surface [29], [30], [31]. Elaborately, the presence of various NMs on the sensing zone of electrochemical sensors can provide a specific capturing surface as well as appropriate nanoprobes in terms of optical sensors that can facile the detection of food dyes. In this perspective, we review recent advanced detection approaches of food dyes in the context of optical and electrochemical sensors to broaden our horizon about efficient sensing zones and nanoprobes. In addition, the advantages and disadvantages of different kinds of sensors to consider the most sensitive platform for food dyes will be debated.

Section snippets

Development of nanomaterials for electrochemical and optical sensing of food dyes

NMs are well-established matrices for the progress of (bio)sensors. Several nanostructures with transduction functions are reported to advance electrochemical, optical, and piezoelectric bio- and chemical probes. The potential application of numerous NMs (like silver nanoparticles, AuNPs (gold nanoparticles), quantum dots, carbon nanotubes (CNTs), and graphene) has been explored for the development of diagnostic substrates that detect a variety of food colorants in various food matrixes.…

Conclusions

Over the last few years, electrochemical and optical sensors as powerful and easy-to-use analytical methods have demonstrated high performance in the detection of various targets. Alongside, many of them have been commercialized in the field of medical diagnostics requiring a border view in technical and nanoscale NMs. On the other hand, there is a shortage in a review of the most important sensors for food dyes, which can detect at low concentrations (micromolar and nanomolar). Besides, the…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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