Recent Progress on Techniques in the Detection of Aflatoxin B₁ in Edible Oil: A Mini Review

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Abstract: Contamination of agricultural products and foods by aflatoxin B₁ (AFB₁) is becoming a serious global problem, and the presence of AFB₁ in edible oil is frequent and has become inevitable, especially in underdeveloped countries and regions. As AFB₁ results from a possible degradation of aflatoxins and the interaction of the resulting toxic compound with food components, it could cause chronic disease or severe cancers, increasing morbidity and mortality. Therefore, rapid and reliable detection methods are essential for checking AFB₁ occurrence in foodstuffs to ensure food safety. Recently, new biosensor technologies have become a research hotspot due to their characteristics of speed and accuracy. This review describes various technologies such as chromatographic and spectroscopic techniques, ELISA techniques, and biosensing techniques, along with their advantages and weaknesses, for AFB₁ control in edible oil and provides new insight into AFB₁ detection for future work. Although compared with other technologies, biosensor technology involves the cross integration of multiple technologies, such as spectral technology and new nano materials, and has great potential, some challenges regarding their stability, cost, etc., need further studies.

Keywords: aflatoxin B₁; edible oil; chromatographic technology; spectroscopic technology; biosensor technology; recognition elements

1. Introduction

Food security has always been an issue of concern in the international community, and, in recent years, food contamination has become a major factor affecting food security. Contaminated food can not only adversely influence human health (poisoning events, chronic diseases, etc.) but also affect and slow down the economy. When people consume contaminated food, they need to spend a lot of money and time on treatment. There are many factors causing food contamination, such as biological, chemical, and physical factors. Among these, microbial contamination is common and mainly includes contamination by bacteria, fungi, molds, viruses, or their toxins and by-products [1,2]. Mycotoxins are common food contaminants, which can cause changes in the appearance, flavor, smell, and other characteristics of food [3–7]. Mycotoxins are secondary metabolites produced by fungi (e.g., Fusarium, Aspergillus, and Penicillium) that have multiple toxic effects on organisms and contaminate agricultural products (cereals, milk, etc.). More than 400 kinds of mycotoxins have been identified. Among them, aflatoxins (AFs) have become one of the major concerns due to their high toxicity and carcinogenicity, causing approximately 25% of animal deaths [8–12].

Edible vegetable oil plays an irreplaceable role in the human diet. The world oil crop output has increased year by year and had reached 635.5 million tons by 2021 [13]. From the growth of oil crops to the final product, i.e., oil, each link may be affected by external factors (such as mycotoxins), which may affect the quality and safety of edible vegetable oil [14]. This is because most oil crops, such as corn, peanut, soybean, rapeseed, sunflower seeds, olives, and nuts, are seasonal. During the growth process, they will be
affected by climate, pests, and other factors and can be easily be infected by *Aspergillus flavus*. After harvest, the oil may deteriorate or be affected by mildew due to storage conditions (such as temperature and humidity, etc.) and storage methods [15]. At the same time, during the production of edible oil, fresh-pressed edible oil is vulnerable to contamination of raw materials infected with *Aspergillus* by aflatoxin B$_1$ (AFB$_1$) [16–22]. Therefore, contamination of edible vegetable oil products by AFB$_1$ is a serious food safety problem (Figure 1) [20,23–25].

![Diagram of aflatoxins and their effects](image_url)

**Figure 1.** Harmful effects of different types aflatoxins contaminated edible oil.
The presence of aflatoxin is usually detected by using precision instruments, such as high-performance liquid chromatography–mass spectrometry (HPLC–MS), high-performance liquid chromatography–fluorescence detection (HPLC–FD), or other molecular techniques, while rapid detection is mainly realized by enzymatic immunoassay ELISA [26,27]. Although different methods are available for the detection of AFB$_1$ toxicity, these methods require expensive equipment and complex sample pretreatment or can only be performed at relatively high concentrations [28]. Therefore, simple, sensitive, efficient, economical, rapid, and stable AFB$_1$ detection methods are required. Recently, new technologies, such as biosensors, have been applied in many fields, such as health care and food detection. Because of their key advantages, such as convenient operation, rapid response, and excellent portability, these technologies can detect harmful substances in food sensitively and accurately, helping effectively avoid their harmful effects. They have attracted increasing attention of researchers and also promoted the rapid development of biosensors. With progress in nanotechnology, scientists are paying special attention to biosensors based on nanomaterials. These new biosensors or detection systems are sensitive, rapid, consistent, and cost-effective and can be used to detect AFB$_1$ in food [29–33].

Regarding the increased importance of biosensors for accurate detection of AFB$_1$ in edible oil, we have summarized the recent advances in biosensors for AFB$_1$ analysis, specifically from the points of view of the development of novel bioinspired recognition elements and nanomaterials-based electrochemical biosensors.

Therefore, we searched PubMed and web of science for publications describing the detection technology of aflatoxin B$_1$ in edible oil. Search terms were as follows: aflatoxin B$_1$ OR AFB$_1$ OR Aspergillus OR mycotoxins OR AFB$_2$ OR AFG$_1$ OR AFG$_2$ OR AFM$_1$ OR AFM$_2$ OR AF$_s$ OR AFBO OR CYP450 OR edible oil OR vegetable oil OR corn oil OR peanut oil OR soybean oil OR sesame oil OR rapeseed oil OR sunflower seeds oil OR olives oil OR nuts oil OR maize oil OR canola oil OR blend oil OR coconut oil OR almond oil OR rice oil OR palm oil OR tea oil OR chromatographic technology OR spectroscopic technology OR immunological technology OR biosensor technology OR QuEChERS OR Fluorescence spectrophotometry OR Infrared spectroscopy OR Terahertz spectroscopy OR surface-enhanced raman spectroscopy (SERS) OR enzyme-linked immunosorbent assay (ELISA) OR amperometric OR impedometric OR electrochemical impedance spectroscopy (EIS) OR voltammetry (potentiometric) OR Conductometric OR LOD OR chromogenic OR Luminogetic OR Chemiluminescence OR Gravimetric OR Piezoelectric OR Magnetoelectric OR Acoustic OR electrodes (SPEs) OR SRP OR biosensors OR Nanomaterial-based biosensors OR electrochemical biosensors OR bioinspired recognition elements OR antibodies OR aptamers OR molecularly imprinted polymers OR Phylogenetic Evolution of Ligands for Exponential Enrichment (SELEX) OR fluorescence resonance energy transfer (FRET).

Publications until 29 August 2022 were included. This review only had the detection technology targeted at aflatoxin B$_1$ in edible oil, and that had not included other types of toxins or other food carriers. After 4692 publications were searched, 596 full-text articles were reviewed and 132 articles were finally identified to meet our requirements.

2. Importance of Aflatoxins

Aflatoxins are a type of mycotoxins. They are highly toxic metabolites of fungi, produced in food and agricultural products. They have severe toxic effects, such as immunosuppressive, nephrotoxic, teratogenic, carcinogenic, and mutagenic, on human and animal health [34–38].

Aflatoxins can be divided into aflatoxin B$_1$ (AFB$_1$), aflatoxin B$_2$ (AFB$_2$), aflatoxin G$_1$ (AFG$_1$), and aflatoxin G$_2$ (AFG$_2$) according to their fluorescence properties and chromatographic mobility (Figure 1) [39–41]. Aflatoxin M$_1$ (AFM$_1$) and aflatoxin M$_2$ (AFM$_2$) are hydroxylated metabolites of AFB$_1$ and AFB$_2$, respectively. AFB$_1$ is the most toxic among all AF species, with a high incidence rate and the most complex detection mechanism (Figure 2) [42].
AFB1 is a powerful carcinogenic, teratogenic, mutagenic, immunotoxic, hepatotoxic, and reproducible poison. Previous studies have shown that the toxicity of AFB1 is 10, 68, and 416 times that of KCN, arsenic and melamine, respectively [43,44] (Figure 2). Therefore, AFB1 has been classified as a class 1 carcinogen by many international authoritative organizations or institutions [45,46]. Due to the structural double bonds in the furan ring, AFB1 has high carcinogenicity and toxicity [17,47]. The lipophilic structure of atrial fibrillation promotes its entry into the blood through gastrointestinal and respiratory tracts [48,49]. Once AFB1 enters blood, it is distributed in various tissues and accumulates in the liver or other organs, resulting in liver cancer (Figure 3). In the liver, AFB1 produces a variety of metabolites through the hydroxylation and demethylation of the first-stage drug metabolism enzymes (for example, cytochrome P450 oxidase and CYP450 superfamily members, such as CYP1A2, CYP3A4, and CYP2A6) [50]. Metabolic reaction (internal and external) activates the final carcinogen AFB1-8,9-epoxy metabolite, which covalently binds to cellular macromolecules (DNA, RNA, or protein) and plays a key role in acute and chronic poisoning. AFB1 residues also destroy the function of tumor suppressor genes (p53 and Rb) in the liver, which affects normal cells and leads to liver injury, increasing the probability of tumor and liver cirrhosis [51–55]. It is estimated that about 30% of liver cancers in the world are caused by AFB1. Its toxicity increases the infection rate of hepatitis B virus (HBV) and the risk of liver cancer [56]. A recent study found that the synergistic effect of AFB1 and HBV leads to liver cancer [50]. The reason is that HBV infection directly or indirectly exposes hepatocytes to AFB1 sensitive to tumors. The toxic effect of AFB1 is also related to dose, age, sex, nutrition, exposure time, and type [57]. In addition, AFB1 can be transmitted to the fetus through the placenta and affect the health of infants [58]. AFB1 exposure also inhibits immunity, thereby increasing the susceptibility to immunodeficiency virus attack and the probability of infection with other infectious diseases [59–63].

![Main mechanisms of toxicity of aflatoxin B1 for humans.](image.png)

**Figure 2.** Main mechanisms of toxicity of aflatoxin B1 for humans.
health of infants [58]. AFB1 exposure also inhibits immunity, thereby increasing the susceptibility to immunodeficiency virus attack and the probability of infection with other infectious diseases [59–63].

Figure 3. Illustration of the mechanism of hepatocellular carcinoma caused by ingestion of AFB1-contaminated foods.

3. AFB1 Regulations on Edible Oil

Because AFB1 poses many hazards to the human body, many governments and international research institutions have made many efforts to control AFB1 pollution in different foods. For example, the FAO and the European Commission and Codex Alimentarius Commission have formulated regulations regarding the content of AFB1 in various foods to ensure consumer safety [64–69].

As for edible oil, most countries have no legislative restrictions and only a few countries, such as China, have effective regulations, laws, and standards for the highest level of
AFB$_1$ in different edible oils (Table 1). Due to some adverse conditions in the traditional oil processing process, AFB$_1$ is usually degraded to the normal level in the extraction and refining process [17,70]. The EU has strict regulatory norms. The total amount of AFB$_1$ and AF allowed in oilseeds is restricted to 2 and 4 µg kg$^{-1}$, respectively. However, the maximum limit of AFs in oils has not been determined. The corresponding regulations in China, the United States, Kenya, and Thailand clearly stipulate the maximum level of total AFs in all edible oils, but the maximum level required is different. It is worth mentioning that in China, the AFB$_1$ limit in corn and peanut oil is stipulated to be 20 µg kg$^{-1}$, which may be because corn and peanut are most vulnerable to aflatoxin pollution [71,72]. See Table 1 for specific differences.

Table 1. The maximum limits (µg kg$^{-1}$) established for major AFB$_1$ in some countries/regions for edible oils.

| Countries/Agencies | Food Products  | Edible Vegetable Oil | Total of AFs (µg kg$^{-1}$) | AFB$_1$ (µg kg$^{-1}$) | Refs. |
|--------------------|----------------|----------------------|-----------------------------|------------------------|-------|
| EU                 | Oil seeds      | -                    | 15                          | 8                      | [32,69] |
| EU                 | -              | Peanut oil           | -                           | -                      | [32,69] |
| EU                 | -              | Others oil           | 4                           | 2                      | [32,69] |
| EU                 | -              | Maize oil            | -                           | 20                     |       |
| China              | -              | Peanut oil           | -                           | 20                     | [73]   |
| China              | -              | Others oil           | -                           | 10                     |       |
| Greece             | -              | Olive oil            | -                           | -                      | [69]   |
| Russia             | -              | Vegetable oil        | -                           | -                      | [64]   |
| France             | -              | Vegetable oil        | -                           | 5                      | [64]   |
| Kenya              | -              | Vegetable oil        | 20                          | -                      | [64,71]|
| Taiwan             | -              | Edible oil           | 10                          | -                      | [65]   |
| Morocco            | -              | Vegetable oil        | -                           | 5                      | [72]   |
| Thailand           | All foods      | Oil and fats         | 20                          | -                      | [64,65,74] |
| USA                | All foods      | -                    | 20                          | -                      | [64,71,75] |
| Brazil             | All foods      | -                    | -                           | 15                     | [76]   |
| India              | All foods      | -                    | -                           | 30                     | [65]   |
| Chile              | All foods      | -                    | -                           | -                      | [76]   |
| Indonesia          | All foods      | -                    | 35                          | 20                     | [65]   |
| Singapore          | All foods      | -                    | 5                           | -                      | [64,65]|
| Australia          | All foods      | -                    | 5                           | -                      | [64,65]|
| Malaysia           | All foods      | -                    | 35                          | -                      | [65]   |
| Japan              | All foods      | -                    | 10                          | -                      | [65]   |
| Vietnam            | All foods      | -                    | 30                          | -                      | [65]   |
| Sri Lanka           | All foods      | -                    | 30                          | -                      | [65]   |

4. Methods for Detecting AFB$_1$ in Edible Oil

The matrix is too complex for edible oil, and the mycotoxin content is relatively low, making it difficult to detect AFB$_1$. Therefore, researchers have developed various traditional and modern methods to detect AFB$_1$ in oil. AFB$_1$ detection technology is mainly divided into chromatographic technology, spectroscopic technology, immunological technology, and biosensor technology [16,77].

Figure 4 briefly summarizes the LOD timelines for AFB$_1$ detection in edible oils published from 2007 to 2022 mentioned in this review. It can be seen from the figure that with the advancement of time, no matter what type of detection technology or which specific detection method is used, the LOD of AFB$_1$ in edible oil tends to be lower. This shows that people have a great interest in the detection of AFB1 in edible oil. At the same time, the wide use of new materials represented by nanomaterials highlights the interdisciplinary characteristics of new sensors. Next is a brief introduction of the identification method of AFB$_1$, including its advantages and disadvantages, combined with actual cases.
4.1. Chromatographic Technology

4.1.1. High Performance Liquid Chromatography (HPLC)

High-performance liquid chromatography is a common official detection method. Many countries and institutions have used it, such as China’s national standard, the European Committee for Standardization (CEN), and the association of analytical organizations (AOAC). One characteristic of the HPLC method is that it can measure multiple targets with high sensitivity [78]. In recent years, researchers have developed new detection strategies combining HPLC with other sensors, such as fluorescence detection (FLD), ultraviolet (UV) detection, diode array detection, and mass spectrometry (MS) [79,80]. Compared to traditional HPLC, this further improves the reliability, sensitivity, and accuracy of target analytes and is widely used to detect harmful substances in food. For example, HPLC combined with FLD is the standard method for detecting AFB₁ in edible vegetable oil [81–86]. HPLC–FLD was able to detect AFB₁ levels as low as 0.01–0.04 µg kg⁻¹ [81] and 0.005–0.03 µg L⁻¹ [82].

Recently, liquid chromatography–tandem mass spectrometry (LC–MS–MS) methods are being increasingly used for the analysis of mycotoxins [85]. They have the advantages of not having a sample purification limitation during extraction, high resolution, high sensitivity, and suitability for various edible vegetable oils [19,87–99]. GC analysis is mostly used for volatile substances, and most mycotoxins are non-volatile, further limiting their application.
the application of GC in mycotoxin detection. A similar procedure to HPLC, UHPLC or UPLC is also used on the column to improve the resolution of AFB$_1$. Hidalgo et al. [100] developed a new analytical method by coupling UHPLC to a triple quadrupole analyzer (UHPLC–QqQ–MS/MS), which was well validated and applied to monitor mycotoxins, including AFB$_1$, in 194 samples of edible vegetable oil.

Many commonly used methods require sample preparation due to the different matrices of edible oil. Currently, a variety of methods are available for the extraction and isolation of mycotoxins from oil, such as liquid–liquid extraction or partitioning (LLE), frequently reported in the literature [101–105]; solid–phase extraction (SPE) [105–109]; immune affinity columns (IACs) [81,94]; IAC combined with dispersive liquid–liquid microextraction (DLLME) [91]; multifunctional cleanup columns [110]; the QuEChERS system [90]; gel permeation chromatography (GPC) [111]; immune assay extraction; and low-temperature cleanup (LTC) [112–115]. However, each method has its advantages and limitations. Thus, which method to choose still depends on the type of food matrix, mycotoxin characterization, and detection techniques [116].

### 4.1.2. Thin-Layer Chromatography (TLC)

Thin-layer chromatography (TLC) is an adsorption thin-layer chromatographic separation method suitable for complex mixed samples [117,118]. Since its development in the 1950s, thin-layer chromatography has been widely used in, for example, biology, medicine, and the chemical industry. It has recently been used in food analysis and quality control and has become a conventional technology in laboratories. Many reports have shown that TLC can be applied to all stages of the food industry, such as the stage of traditional substances, represented by food raw materials, ingredients, and additives, and the stage of unconventional substances, represented by harmful substances and pollutants. The detection and determination of compounds cover almost all substance categories [119–122].

Thin-layer chromatography uses the different adsorption capacities of each component to the same adsorbent so that when the mobile phase (the solvent) is flowing through the stationary phase (the adsorbent), there is continuous adsorption, desorption, readsorption, and redesorption to achieve the mutual separation of each component [123].

Although the TLC method has matured, it still has shortcomings, such as a low detection accuracy, volatility during the experiment being harmful to the experimental operators and the environment, and complex sample pretreatment [124,125]. In recent years, an interdisciplinary approach, such as the combination of TLC with image analysis and with new technologies, such as surface-enhanced Raman spectroscopy, mass spectrometry, and nuclear magnetic resonance, has further promoted the development of thin-layer chromatography and enhanced the practicability of this method in food analysis [126–129]. TLC is used to detect harmful substances in various foods, such as AF in edible oil, making it an effective analytical tool in food science methods [124,130].

### 4.2. Spectroscopic Technology

#### 4.2.1. Fluorescence Spectrophotometry

Spectrum-based sensing technology has been developed and used to assess AFs contamination in food [131]. Among many spectral techniques, fluorescence spectrometry shows certain potential in determining AFs in a variety of agricultural products and foods [125,132,133]. Fluorescence spectrometry uses the target molecules in the sample to absorb ultraviolet or visible light to produce fluorescence and determine its molecular structure. It has excellent detection sensitivity and specificity in the study of AFs and other chemical components [134,135]. The study found that the fluorescence phenomenon is conducive to the characterization and monitoring of target detection objects. For example, AFB$_1$ can emit a specific range of fluorescence (425–500 nm) under the excitation of UV light source (340–400 nm), which provides the possibility of using fluorescence spectroscopy to analyze AFB$_1$ in different foods [135,136]. In recent years, laser-induced fluorescence (LIF) technology has developed rapidly and attracted more attention because it uses a certain
wavelength of laser light source and has better specificity and detection sensitivity. The advantage of LIF is that it can realize online, rapid and nondestructive direct detection according to the characteristic fluorescence peak of AFB$_1$. Researchers have developed a detection model based on LIF, which can quickly and accurately screen AFB$_1$ in different edible oils. The information and conclusions obtained in the study further show that LIF technology can be used for rapid and nondestructive detection of AFB$_1$ in different edible oils [19,137]. However, LIF is also vulnerable to the interference of external factors, such as the power and accuracy of the instrument, the environmental factors of temperature and humidity, and the physical and chemical index factors of the detected object. Although this limits the wide application of LIF technology, researchers are still trying and exploring.

4.2.2. Infrared (IR) Spectroscopy

Infrared spectroscopy (IRs) has the characteristics of rapid detection, simple sample preparation process and strong adaptability. It has been widely proven to be an effective food safety detection and control technology. Because IR covers a wide range of electromagnetic spectra (780 to 2500 nm), IR can be applied to the detection of a variety of foods including edible oil, meat, aquatic products, fruits and vegetables [138–144]. When IRs radiation penetrates the sample, the radiation is reflected, absorbed or transmitted by molecular bonds, resulting in the energy change of light, which can reflect some characteristic chemical bonds, thus reflecting the characteristics of the tested product [145,146]. In the application of edible oil, IR shows many abilities, such as distinguishing different kinds of oil, grading the quality of oil, detecting harmful substances in oil, etc. [138,143,147–150]. Using near infrared (NIR) technology to detect mold in edible oil has also been a research hotspot in recent years. Researchers have promoted the further application and development of IR technology by establishing qualitative and quantitative analysis models for AFB$_1$ pollution in edible oil [151–153].

4.2.3. Terahertz (THz) Spectroscopy

With the development of optical and electronic technology, terahertz spectroscopy (THz) has been a revolutionary development, and shows great potential as a new technology tool for nondestructive food testing [154–157]. As a technical information link between microwave spectroscopy and infrared spectroscopy, THz has the characteristics of both, making it widely used in basic research and industrial practice [158,159]. Like other spectral technologies, thanks to the development of chemometrics methods, THz has become a powerful technical tool in the food industry, due to its strong detection and quantification capabilities [156,157,160]. Through the combination of THz and chemometrics methods, researchers have constructed a rapid nondestructive detection model for AFB$_1$ in edible oil. Although the accuracy is slightly lower than other conventional analysis methods, it provides a possibility for THz in food safety detection [161]. In a recent study, researchers further improved the accuracy of THz in detecting AFB$_1$ in edible oil by adding pretreatment and other methods on the basis of predecessors, and reduced the LOD of AFB$_1$ to 1 µg kg$^{-1}$, and the accuracy is improved to more than 90% [161,162]. The cross integration of THz and chemometrics and other disciplines is conducive to promoting its application and development in the detection of AF$_5$ in the edible oil industry. At the same time, the limitations of THz should also be clear, such as the low detection limit and sensitivity advantage are not obvious, the penetration of the detected object is limited, there is scattering effect, the technology is expensive, the database is lack, etc. [163].

4.2.4. Surface-Enhanced Raman Spectroscopy (SERS)

As a complementary analysis technology of IR, the Raman spectroscopy (RS) technology is sensitive to the symmetrical vibration of covalent bonds of non-polar groups (such as C=O, C-C and S-S) [164–166]. Therefore, RS has the advantages of being fast, sensitive and simple in the detection and evaluation system of food [165,167,168]. However, traditional RS has some limitations, such as Raman scattering. Therefore, researchers
have developed SERS signal enhancement technology represented by electromagnetic field enhancement and chemical enhancement [165]. At present, the application of SERS technology in the detection of AFs is still challenging, and the intersection of technology development and multidisciplinarity (such as materials science, stoichiometry, etc.) is the focus of researchers [165]. In recent years, researchers have reported a variety of SERS schemes for AFB₁ detection in edible oil, such as SERS tag detection using antibodies and aptamers, sandwich immunoassay based on SERS, etc. [169–174]. The growing research results show that SERS technology is becoming a powerful tool to ensure the safety development of the food industry, especially in the safety supervision of AFs. However, it cannot be denied that challenges still exist, such as the development of targeted new materials, the optimization of key core technologies, and the practical application of research results [175–177].

4.3. Immunological Technology

Enzyme-Linked Immunosorbent Assay (ELISA)

In recent years, researchers have often used immunochemical methods to determine mycotoxins in food, in addition to traditional chromatographic techniques. The core of immunochemistry is the specific interaction between immunoglobulin (Igs) and antigen (Ag). Several immunochemical methods have been applied to detect mycotoxins in edible vegetable oils, such as enzyme-linked immunosorbent assay (ELISA) and biosensors based on immunoassay.

ELISA is one of the most commonly used methods for detecting mycotoxins [24]. It has been designed and developed on the basis of the principle of specific immune responses between Igs and Ags. The specificity of this immunoassay is due to the use of enzyme-labeled Igs or Ags and solid-matrix-restricted immunoglobulins to capture unlabeled silver in the analyte and detect it with labeled immunoglobulins. Although ELISA is well developed and widely used in food analysis, clinical practice, biotechnology, environmental, chemical, and other industries, it still has several deficiencies, such as excessive dependence on the matrix caused by the interaction between the target antigen and matrix components. The standard ELISA is composed of four main parts (immuno-recognition element, sorbent substrate, enzyme label, and chromogenic reagent), and the deficiency of the central part is the root cause of the limitation of ELISA. In recent years, researchers have used the cross-fusion of multiple technologies to drive the performance of one of the components or the whole ELISA, especially in terms of sensitivity, accuracy, and stability [27].

For mycotoxins, due to the high singularity of ELISA, the developed kit has specific recognition ability and has been widely used in the detection of mycotoxins [70]. For example, Qi et al. [20] used ELISA and UPLC–MS/MS to detect AFB₁ in peanut oil, although the LOD was only 1.08 µg kg⁻¹, much higher than the LOD of UPLC–MS/MS (the LOD is 0.01 µg kg⁻¹) [20]. It has been affirmed because of its accuracy, rapidity, and other advantages. For the actual detection of other harmful substances, such as AFB₁, AFB₂, AFG₁, and AFG₂, in different edible oils (oils of soybean, coconut, peanut, fennel, melon, and palm kernel), ELISA showed satisfactory results and the concentration was lower than the legislative limit [178–180]. On this basis, the researchers developed a commercial ELISA kit that can detect AFB₁, which can be applied to a variety of samples including edible oil, and the detection limit can be as low as 3 ppb. Although the current ELISA technology or kit still has problems such being as time-consuming, high cost, and cumbersome operation, with the advancement of technology, ELISA technology shows strong application potential [27].

4.4. Electrochemical Biosensing Technology

Due to rapidity, small footprint, economy, sensitivity, and unique capabilities, electrochemical biosensing devices have received particular attention in assessing food quality, mainly reflecting AFB₁ levels in food samples [181]. The AFB₁ electrochemical biosensor can produce various types of analytical signals, such as voltage, current, and impedance [182,183].
The standard transduction methods are amperometric, electrochemical impedance spectroscopy (EIS), and voltammetry (potentiometry).

4.4.1. Amperometric Biosensors

The amperometric biosensor is an electrochemical device with high selectivity and sensitivity that takes the change in the measuring current as the analysis signal. Because the change in the current is closely related to the concentration of AFB₁ in food samples and the change can be achieved by maintaining a stable potential, an amperometric biosensor is relatively perfect. A typical amperometric biosensor consists of two- or three-electrode systems (containing a functional electrode, a reference electrode, and an auxiliary electrode), and the analytical performance of the latter is significantly higher than that of the former (Figure 5) [181]. This is because the additional auxiliary electrode not only increases the area of the detection surface but also increases the current between it and the functional electrode, as well as the operating potential between the functional electrode and the reference electrode, thereby enhancing the changes in the detection process of AFB₁ in food in electronic dynamics. On the contrary, the dual-electrode system does not include auxiliary electrodes, which may lose their function at high temperatures. Therefore, amperometric biosensors with dual-electrode systems are not used to analyze the quality of food samples [181].

![Figure 5. Scheme of the two or three-electrode setup used in electrochemical methods.](image)

Even functional electrodes are usually made of inert metal materials (such as platinum, gold) or carbon (graphite, glassy carbon). The main drawback is reproducibility of measurements. Currently, printed electrodes have become a good substitute because their cost and mass production can be controlled [70,78].

Researchers used two kinds of nanomaterials with different charges to deposit on the electrode alternately, obtaining a multilayer electrode with a sandwich structure with excellent conductivity and rich electrochemical active sites [184]. Such a biosensor has good selectivity, reproducibility, and stability. In the subsequent optimization test, the optimized electrochemical biosensor was found to have significant stability and even after being placed for a period of time, it showed good LOD (0.002 ng mL⁻¹). This sensor is believed to be one of the best biosensors for detecting mycotoxins. Researchers applied the electrochemical biosensor to detect AFB₁ in real oil samples and found that it has a good recovery rate (98.11–103.36%).

Xuan et al. [185] developed an integrated AFB₁ detection platform that uses disposable screen-printed electrodes (SPEs), allowing routine detection without electrode modification. According to the SPE used, the platform can simplify the tedious sample processing process through high-throughput processing, reduce operating errors, and improve experimental reproducibility, which can benefit large-scale sample processing. The detectable concen-
tration range of AFB$_1$ was 0.08–800 µg kg$^{-1}$ with a LOD of 0.05 µg kg$^{-1}$. Analysis of real samples and verification of the method showed the results of the new sensor to be consistent with those of the classical method (LC–MS/MS), indicating that the developed method has the potential to monitor AFB$_1$ in peanut oil.

Another study reported a new aflatoxin biosensor based on the AFB$_1$ inhibition of acetylcholinesterase (AChE) [186]. The core of this method is to immobilize choline oxidase on a screen-printed electrode modified with Prussian blue (PB). The electrode used in the biosensor can detect H$_2$O$_2$ at low potential. As per the results, the linear operating range of the biosensor is estimated to be 10–60 ppb and the LOD is 2 ppb. On using real olive oil samples to evaluate the sensor, the recovery rate was found to be 78 ± 9% at 10 ppb.

### 4.4.2. Electrochemical Impedance Spectroscopy (EIS)

Electrochemical impedance spectroscopy (EIS) technology is an effective monitoring tool for identifying and monitoring changes in mycotoxins at the interface between electrode surface modifications. When the target analyte is combined with a biometric element, it generates an electrochemical response by changing conductivity and capacitance through an impedance biosensor [187]. These biosensors monitor the impedance changes caused by the interaction between the target detection object, such as AFB$_1$, and the biometric element fixed on the working electrode, and display the detection results in the form changed electron flow on the working electrode [188,189]. Typical potentiometric sensors are also suitable for the three-electrode system.

The main parameter of the EIS is the charge transfer resistance value (RCT), which is closely related to the reaction between immobilized mycotoxins and the antibody antigen and is also proportional to the target detector/concentration of the target [65,66]. For determining AFB$_1$, Yu et al. [190] reported a sensitive and convenient EIS method involving MWCNT/RTIL/Ab-modified electrodes coated in bare GCE. The experimental results show that the resistance of the MWCNT/RTIL/Ab-modified electrode (605.6 Ω) is higher than that of bare GCE (151.9 Ω). When AFB$_1$ was immobilized on MWCNT/RTIL/Ab-modified electrodes, the increase in the electron transfer resistance (Ret) value was found to be directly related to the AFB$_1$ amount. The specific interaction between AFB$_1$ and Ab causes an increase in the Ret value, which leads to the production of electrically insulating biological conjugates, which will prevent the electron transfer process of redox probes. Therefore, the EIS measurement results are consistent with the above cyclic voltammetry results. Because of its simple characteristics, this method can be widely used to detect various agricultural products and edible oils.

For many researchers exploring mycotoxin detection methods, aptamer-based EIS has become a hot research topic. Aptamer-based impedance biosensors have achieved satisfactory results in detecting mycotoxins in food and have great potential for practical application in edible oils.

### 4.4.3. Voltammetry Biosensors

Voltammetric biosensors solve the problem of obtaining analytical data using ion-selective electrodes. Similar to amperometric biosensors, voltammetry also requires a two- or three-electrode system. When the current is constant, it can detect target analytes, such as AFB$_1$, in food samples by evaluating the change in circuit potential between the functional electrode and the reference electrode [60,191].

Biosensors have also shown promising results in detecting the AFB$_1$ content in edible oils. For example, Wang et al. [192] developed a new disposable electrochemical biosensor based on stripping voltammetry to detect copper ions released from copper apatite. The biosensor uses copper ions as a signal label to immobilize AFB$_1$ antibody on a screen-printed carbon electrode (SPCE) modified by gold nanoparticles. The detection is performed by the voltammetric signal of the dissolution of copper ions released from acid hydrolysis of copper apatite, and copper apatite increases the number of loaded copper ions. The electrochemical signal is further amplified. Peanut oil was used to evaluate the reliability
and application potential of biosensors. Researchers believe that this new method will be applied to many fields in the near future because of its many excellent characteristics (low cost, rapidity, accuracy, and high sensitivity).

4.4.4. Nanomaterial-Based Biosensors

Recently, different nanomaterials, such as carbon and metal, have been used to modify the active surfaces of macroelectrodes and microelectrodes to design electrochemical biosensors for the detection of AFB$_1$ [193–195]. This is because new biosensors directly use nanomaterials or other materials containing nanoparticles that show significant characteristics, such as high sensitivity and specificity for detecting targets, reliability, and consistency of products [181,196,197]. Nanomaterials significantly increase the effective surface area of biosensors and further improve the analytical performance [60,194]. Nanomaterials also enhance some characteristics of biometric elements in biosensor devices in terms of electrical, catalytic, optical, and thermal properties [198]. According to previous studies, some of the key functional enhancements are the enhanced immobilization of biomolecules, generation and expansion of analytical signals, and enhanced usability of fluorescent labels.

Characteristic of Nanomaterials Based Electrochemical Biosensors

The role of nanomaterials in biosensors is mainly reflected in the immobilization of biomolecules, signal generator, fluorescent labeling, and signal amplification.

Nanomaterials not only immobilize biomolecules but also increase the interaction between different molecular materials. In addition, nanomaterials enhance the stability of biomolecular immobilization, thereby increasing the signal strength of the immunoassay [31]. Metal nanomaterial particles, such as AgNPs and MOFs, can increase the surface area and biocompatibility of biomolecules bound to the detection target. However, non-metallic nanomaterials show negatively charged functional groups, which can be used as an effective carrier to bind and fix positively charged targets.

Signal Generator

Xue et al. [31] reported that, when the photoelectric signal changes, nanoparticles such as gold and silver can act as a signal generator. By adjusting the fluorescence signal generated by nanomaterials, a new AFB$_1$ nanoprobe can be constructed. In addition, because these nanoparticles can be prepared in different sizes according to need, they have good functionality, stability, and scalability [133,199].

Fluorescent Label

Nanomaterials have unique optical properties that enable them to be widely used in a variety of disciplines, especially in the detection of hazardous substances in food. Nanomaterials can detect AFB$_1$ by sensing optical signals (absorbance, chemiluminescence, fluorescence, etc.) [31]. Some nanomaterials, such as metal nano-ions and quantum dots, have been used as fluorescence quenching agents because of the ability of AFB$_1$ to directly quench or reduce the fluorescence intensity. In addition, quantum dots have transformed fluorescein into a marker element that binds to aptamers or antibodies.

Signal Amplification

Nanomaterials can also be used as functional materials for various electrodes, signal components, etc., to amplify signals in various ways. For example, on the electrode surface of electrochemical sensors, nanomaterials such as gold and silver can amplify the analytical signal by enhancing the redox reaction. Some metal nanoparticles, such as gold, can amplify signals related to their characteristics, such as unique catalytic activity, biocompatibility, and multiple absorption sites. Carbon, graphene, and other non-metallic nanomaterials improve the analytical performance by increasing the surface area.
4.5. Bioinspired Recognition Elements for Biosensors

A biosensor is independent quantitative analysis equipment used to study the analytes required in different types of food samples. A biosensor consists of many parts [29,30] (Figure 6). Biometric elements are the core components of biosensors and can detect specific target analytes. The quality of biometric elements usually determines the specificity and sensitivity of analysis [200,201]. Biorecognition elements, including antibodies, aptamers, molecularly imprinted polymers, and enzymes, have been used to manufacture biosensors [34,64,202]. These elements show increased sensitivity and selectivity for target analytes. Critical biometric elements for developing biosensors to detect AFB$_1$ in edible vegetable oil are elaborated below.

![Figure 6](image-url). Schematic diagram of typical biosensor. Including analyzer, bioreceptor, transducer, electronic system (amplifier and processor), detector (for data processing).

4.5.1. Antibody

Antibodies have been used as recognition elements for developing biosensors because of their specificity and sensitivity [200]. Biosensors that use antibodies as recognition elements are called immunosensors, and their mechanism relies on the specific recognition of aflatoxin epitopes by antibodies.

The first batch of polyclonal antibodies, developed in 1976, became the basis for most mycotoxin detection methods. In the following decades, polyclonal and monoclonal antibodies were the basis for most mycotoxin detection methods [192,200,203]. Today, in addition to monoclonal and polyclonal antibodies, various other types of antibodies are being used to detect target analytes. Researchers have developed an antibody-based immunosensor that can directly recognize AFB$_1$ and is used in peanut oil with a concentration range of 0.001 to 100 ng mL$^{-1}$, with a detection limit of 0.2 pg mL$^{-1}$ [192].

However, the production of monoclonal antibodies and polyclonal antibodies is complex and the antibodies degrade, denature, and aggregate easily [204,205]. In recent years, with the development of protein- and DNA-based new engineering technology, it has become possible to develop modified and recombinant antibodies (RAbs). RAbs integrate many advantages of biosensors, such as simple operation and a high degree of automation, high throughput screening, low requirements for configuration attributes, and the trend of...
more miniaturization [200]. Zhao et al. [206] developed a novel method of MB-dcELISA for AFB$_1$ based on the mimotope of an RAb and nanobody. This study effectively proved that compared with monoclonal antibodies, an RAb is more economical and easier to prepare. Compared with chemically synthesized toxic antigens, immunoassay is safer and performs better in validation studies. In real samples (corn germ oil and peanut oil), the LOD of AFB$_1$ is as low as 0.13 ng mL$^{-1}$. Other researchers also designed an RAb with increased sensitivity to low-molecular-weight hapten, and this RAb was validated in olive oil with a lower LOD (0.03 ng mL$^{-1}$) for AFB$_1$ [190].

Researchers recently found that, by increasing the immobilization of antibodies and giving full play to the characteristics of specific antibodies, the performance of the sensor can be effectively improved, and on this basis, some immuno sensors have been developed for detecting AFB$_1$ in edible oil [133,196]. For example, to determine AFB$_1$, Shi et al. [207] proposed a novel immobilized immunosensor based on graphene supported with hybrid gold nanoparticles-poly4-aminobenzoic acid. In the study, after the reduction in graphene oxide by PABA via an epoxy ring opening reaction, the nanocomposite PABA-r-GO was obtained. Then, gold nanoparticles (AuNPs) were prepared on this basis to form a AuPPABA-r-GO nanohybrid. The final sensor was obtained by the covalent binding of the COOH group of functional nanocomposites with an AFB$_1$-specific antibody. The sensor has good performance (linear range 0.01–25 ng mL$^{-1}$ and LOD 0.001 ng mL$^{-1}$) and has been successfully applied to detect real vegetable oil. This sensor also has good reproducibility and selectivity, especially stability, and can be stored at a low temperature for a long time.

4.5.2. Aptamers

Aptamers are single-stranded RNA or DNA (20–90 oligonucleotide sequences with specific sequences) that can bind to various targets, such as ions, antibodies, proteins, cells, and organic molecules [208]. The particular recognition ability of aptamers relies on the three-dimensional structure of a high-affinity target-induced DNA three-dimensional structure. The researcher procured specific targets for aptamers by screening oligonucleotides using the Phylogenetic Evolution of Ligands for Exponential Enrichment (SELEX) program. Aptamer sensors are biosensors integrated with aptamers developed in the 1990s [200,208–211].

Recently, aptamers have attracted significant attention in food contamination analysis and are used for various sensing applications due to their inherent benefits: (1) aptamers are obtained from in vitro synthesis, so animals are not necessary; (2) aptamers have lower toxicity, immunogenicity, and production cost; (3) aptamers have enhanced chemical and thermal stability; (4) aptamers have excellent batch-to-batch reproducibility; (5) aptamers have a smaller size and show a remarkable ability to penetrate the tissue and adhere to target molecules; and (6) it is possible to change their structure [193,212,213].

Notably, the immobilization of aptamers is a critical step in biosensor design because it can affect the affinity of aptamers for their targets and their long-term stability in fundamental sample analysis.

Therefore, researchers have developed many strategies to immobilize aptamers: (1) adsorption or π–π stacking interactions between DNA bases and modified graphene oxide (GO) interface [214], (2) aptamers with carboxylic acids on surfaces or nanomaterial covalent bonding of groups [184,215], (3) binding of sulfide aptamer with CdTe quantum dots (QDs) or gold-based materials [216], (4) binding with avidin or other affinity interactions based on biotin streptomycin affinity [200,217,218], and (5) hybridization with partially complementary single-stranded DNA previously fixed on the surface of nanoparticles [219–222].

Table 2 describes some examples of aptasensors recently reported for the detection of AFB$_1$ in edible oils. About half of the previous reports have been based on fluorescent mycotoxin aptamer sensors. Some of them use metal or nanostructured materials, such as gold nanoparticles (AuNPs), GO, single-walled carbon nanotubes, or TiO$_2$ tubes, and are used to prepare aptamer sensors.
Nanometer material has always been the focus of research, and its applications in biosensors are also diverse. Black phosphorus nanosheets (BPNSs) have great application prospects in biosensors due to their unique characteristics [223]. Wu et al. [224] developed a highly specific and sensitive aptamer sensor (UCNPs-BPNSs) based on the team’s research on upconversion nanoparticles (UCNPs) [196]. The research team attached UCNPs to the surface of BPNSs at a very small space distance (less than 10 nm) through glutaraldehyde crosslinking method and π-π stacking effect method, and then constructed the fluorescence resonance energy transfer (FRET) system. This aptamer sensor can effectively detect AFB\textsubscript{1} in peanut oil and other foods quantitatively with good linear range (0.2–500 ng mL\textsuperscript{-1}) and LOD (0.028 ng mL\textsuperscript{-1}).

Xia et al. [225] proposed a label-free, single-tube, homogeneous, and inexpensive assay for AFB\textsubscript{1} based on fine-tunable double-ended stem aptamer beacons (DS) and the effect of aggregation-induced emission (AIE). The structure of the DS aptamer beacon can provide end protection against exonuclease I (EXO I) to the aptamer probe and endow it with specificity and a rapid response to the target AFB\textsubscript{1}. Compared with the traditional molecular beacon structure, the stability of the DS aptamer beacon can be adjusted by adjusting its two terminal stems so that the affinity and selectivity of the probe can be precisely optimized. Using an AIE-active fluorophore, which is illuminated by the aggregation of negatively charged DNA, AFB\textsubscript{1} can be measured label-free. The method has been successfully applied to the analysis of AFB\textsubscript{1} in peanut oil, with a total recovery of 93.59–109.30%. Therefore, beacon-based DS assays may help in real-time monitoring and control of AFB\textsubscript{1} contamination.

Yang et al. [226] first devised a selection method based on rational truncation and post-splicing and developed a bivalent anti-AFB\textsubscript{1} chimeric aptamer (B72) that was measured by micro-thermophoresis (MST) compared to the initial selection. The affinity of the anti-AFB\textsubscript{1} aptamer (B50) increased by 188-fold, and the study also found that B72 has a dual binding site for AFB\textsubscript{1}, which is consistent with the experimental results obtained by isothermal titration calorimetry (ITC) and molecular docking simulations. Therefore, on the basis of the peroxidase-like activity of gold nanoparticles catalyzing 3,3,5,5-tetramethylbenzidine (TMB), an aptamer sensor of gold nanoparticles (AuNPs) was developed by the colorimetric detection of AFB\textsubscript{1}. The assay further validates the practical applicability of the chimeric aptamers. The aptasensor could identify AFB\textsubscript{1} with an excellent linear range (5–5120 nM) and detection limit (1.88 nM) in the corn oil environmental test of H\textsubscript{2}O\textsubscript{2}. Therefore, this study can be called a general selection method for designing high-affinity aptamers and constructing novel aptamer-based biosensing platforms for high-sensitivity and specificity analysis of other targets.

Zhong et al. [227] manufactured an electrochemical aptamer sensor in a similar way for the sensitive detection of AFB\textsubscript{1}. The researchers used electrodeposited AuNPs to prepare AuNPs/ZIF-8 nanocomposites on glassy carbon electrodes (GCEs) decorated with the eight zeolite imidazolate framework (ZIF-8), which increased the surface area of the electro desorption molecular load. Compared with other previously reported sensors, the aptasensor developed under optimized conditions shows a more comprehensive linear range (10.0–1.0 \times 10^5 pg mL\textsuperscript{-1}) and a lower detection limit (1.82 pg mL\textsuperscript{-1}). In addition, the constructed aptasensor possesses excellent selectivity, reproducibility, and stability. Moreover, the aptamer sensor has been successfully used to detect AFB\textsubscript{1} in corn oil and peanut oil samples, and the recovery was between 93.49% and 106.9%, which proves the potential application value of this method. Researchers are very interested in this kind of electrochemical aptamer sensor. Wang et al. [228] also developed an AFB\textsubscript{1} electrochemical aptamer sensor for detecting peanut oil in a similar way. The difference lies in the use of different composite materials (zinc and nickel bimetallic organic skeleton materials).

The hybridization chain reaction (HCR) is a commonly used isothermal nucleic acid amplification technique, and due to the characteristics such as no enzyme, high amplification efficiency etc., HCR is usually used as a new synthetic material technology and is widely used in various sensors. Researchers have fully combined the characteristics of HCR
to build a signal amplification strategy, which has been successfully applied to the sensitive
detection of AFB$_1$ [229–235]. Wang et al. [236] proposed a fluorescent aptamer sensor based
on DNA walker, DNA tetrahedral nanostructures (DTNs) and network HCR. Among them,
DNA walker was used as the signal amplifier induced by AFB$_1$ target, and combined with
self-assembled DTNs. Finally, based on network HCR, signal amplification is realized and
sensitive detection of AFB$_1$ in peanut oil was realized with with LOD of 0.492 pg mL$^{-1}$
and the linear range of 1–1000 pg mL$^{-1}$. In the other report, Zuo et al. [237] combined
DNAzyme with substrate chain (Zn-Sub) and enzyme chain (Zn-Enz) with HCR products
to form a Y-shaped structure, which can significantly enhance the fluorescence intensity
of the detection target. The fluorescent aptamer sensor proposed by researchers shows
excellent performance with LOD of 0.22 nmol L$^{-1}$ and the linear range of 0.4–16 nmol L$^{-1}$.

The emerging quantum dots (QDs), represented by carbon quantum dots (CQDs),
graphene quantum dots (GODs) etc., have attracted great attention and are widely used
in various sensor fields since their discovery because of their excellent optical properties,
low toxicity, stability and low cost etc. [238–240]. QDs-based sensors can adopt different
working mechanisms and be applied to detect different substances, including AF$_3$ in edible
oil [51,173,238]. According to the characteristics of QDs, Xuan et al. [185] and Ye et al. [241]
developed and constructed different magnetic control pretreatment platforms, which were
actually applied to the detection of AFB$_1$ in peanut oil and agricultural products, and
both showed good detection characteristics. Other researchers used a quencher system
composed of quantum dots and graphene oxide to detect AFB$_1$ in peanut oil, which also
showed good detection characteristics [242].

SERS

As mentioned above, SERS is a promising analytical tool with many advantages over
traditional AFB$_1$ detection methods, including high sensitivity, easy sample preprocessing,
and non-destructive testing [166,174,243]. Compared with antibodies, aptamers have
the advantages of low cost, easy synthesis, good stability and strong specificity to target
molecules. With the mature development of aptamer manufacturing technology, they have
gradually become one of the most potential recognition elements in SERS labeling detection.

Recently, several authors have combined advanced composite materials with SERS
aptamer sensors to develop new procedures for AFB$_1$ detection. For example, on the
basis of the combination of a multifunctional capture probe (Fe$_3$O$_4$@Au report the strong
Raman signal of probe 1 (AU)-4MBA@AgNSs-Apt), an ultrasensitive assay was successfully
developed for a high-performance SERS aptamer sensor of AFB$_1$. He et al. [174] reported
that, in the presence of AFB$_1$, the probe was released from the capture probe, resulting in a
decrease in SERS intensity, possibly due to the specific binding affinity between the aptamer
and AFB$_1$. For AFB$_1$ detection, a wide linear range, from 0.0001 to 100 ng mL$^{-1}$, was
obtained, with an R$^2$ of 0.9911, and the LOD was calculated as 0.40 pg mL$^{-1}$. Finally,
after extracting AFB$_1$ from peanut oil samples, the SERS aptamer sensor was successfully applied
to the analysis of AFB$_1$, and the recovery was between 96.6% and 115%. Therefore, the novel
SERS aptamer sensor is a promising analytical tool for detecting AFB$_1$ in actual samples.

In the report by Yang et al. [169], with the help of the specific interaction between AFB$_1$
and aptamer, a novel SERS-based universal aptamer sensor platform was constructed to
detect AFB$_1$. First, gold nanotriangle (GNT)-DTNB@Ag-DTNB nanotriangles (GDADNTs)
were synthesized and used as SERS active substrates. These magnetic beads and amino-
terminal-aptamer-conjugated magnetic beads (CS-Fe$_3$O$_4$) were then used as capturer and
reporter of AFB$_1$, respectively. Finally, the platform showed excellent sensitivity under
optimized assay conditions, with a lower LOD (0.54 pg mL$^{-1}$) and a more comprehensive
linear range (0.001–10 ng mL$^{-1}$). In addition, the high stability of SERS substrate activity
was maintained for at least three months, with an RSD of ~5%, which has good selectivity
for general coexistence interference. The excellent sensitivity and selectivity of micro-AFB$_1$
detection are mainly due to the substantial Raman-enhancing effect of GNTs as the core
of GDADNTs, which results from the bilayer of reporter molecules, aptamer specificity,
and the super-paramagnetic CS-Fe₃O₄, respectively. The researchers also evaluated and confirmed that the established SERS aptamer sensor can be used to detect AFB₁ in peanut oil samples.

In a subsequent study, on the basis of previous research, another simple and sensitive SERS aptamer sensor was developed for detecting AFB₁ in peanut oil [170]. In this study, the researchers used an aminoterminal AFB₁ aptamer (NH₂-DNA1) as a SERS aptamer sensor, magnetic beads conjugated to a thiol-terminal-complementary AFB₁ aptamer (SH-DNA2) (CS-Fe₃O₄) as enrichment nanoparticle probes, and AuNR@DNTB@Ag nanorods (ADANR) as reporter nanoprobes. 5,5′-Dithiobis (2-nitrobenzoic acid) (DNTB) is embedded in gold and silver core/shell nanorods as a Raman reporter molecule, which has a large Raman scattering cross section and no fluorescence interference. Furthermore, CS-Fe₃O₄ has good biocompatibility and superparamagnetism, which can quickly enrich signals. Therefore, NH₂-DNA1-CS-Fe₃O₄ and SH-DNA2-ADANRs were prepared by a mixed reaction between aptamers and complementary aptamers. When present, AFB₁ will compete with NH₂-DNA1-CS-Fe₃O₄ to induce SH-DNA2-ADANRs to dissociate from CS-Fe₃O₄, further reducing SERS signals. According to the SERS aptamer sensor, the lower detection limit of AFB₁ is 0.0036 ng mL⁻¹ and the correlation coefficient is as high as 0.986. The effective linear detection range is 0.01–100 ng mL⁻¹, obtained with a correlation coefficient as high as 0.986. Finally, the specificity and accuracy of the SERS aptasensor were proved by detecting AFB₁ in natural peanut oil.

Similar research strategies are reflected in other reports. Jiao et al. [244] developed a gold-silver core-shell nanoparticles (Au@Ag CSNPs) SERS sensor decorated with 5-aminotetramethylrhodamine (NH₂-Rh). Based on the optimization of experimental conditions, the sensor can be combined with solid phase extracts of peanut oil, hazelnut, and other samples to achieve a quantitative analysis of AFB₁ with detection range and LOD 0.1–5.0 ng·mL⁻¹ and 0.03 ng·mL⁻¹, respectively.

Various AFB₁ sensors are also identified in edible vegetable oil by electrochemical detection, which has some unique advantages, such as low cost, high sensitivity, and the possibility of micromachining. For example, Xiong et al. [245] revealed a highly innovative method based on dual-DNA-tweezer nanomachines to detect AFB₁ in olive and peanut oils. Wu et al. [246] presented a method based on ferrocene and β-cyclodextrin (β-simple electrochemical aptamer sensor for host–guest recognition between CD) to detect AFB₁ in peanut oil, with a low LOD (0.049 pg mL⁻¹).

4.5.3. Molecularly Imprinted Polymers (MIPs)

MIPs have been used as recognition elements to develop biosensors, and synthetic polymers have displayed precise target recognition [133,202,247]. These artificial materials can recognize specific targets in complex mixtures because of specific recognition sites for binding or catalysis and functional groups with shapes and geometries complementary to those of the template molecule. These polymers self-assemble with template molecules and active/functional monomers through the polymerization of cross-linking agents. Therefore, when the template molecule is removed, pores with multiple active sites appear in the polymer, which match the spatial configuration of the template molecule [248,249]. In recent years, traditional MIPs have been applied in many cross fields, such as chromatography, drug delivery, solid-phase extraction, controlled release, bioremediation, and sensors [200,250–256]. In AFB₁ detection studies, MIP-based biosensors have shown many advantages, such as unique selectivity, sensitivity, user-friendliness, and cost-effectiveness [32,42,200,202]. For instance, Li et al. [173] exploited MIPs by preparing an electrochemiluminescence (ECL) platform for AFB₁ detection with an ultra-low LOD, of 8.5 fg mL⁻¹, and a wide linear range (10⁻⁶ to 10 ng mL⁻¹). While the MIP–ECL platform was used, the recovery rate of corn oil samples was close to that obtained by HPLC, indicating the reliability of the sensor and its potential in food safety evaluation. It is worth mentioning that, as of the publication of this review, this is the lowest LOD of AFB₁ in edible oil.
However, MIP-based biosensors also have some disadvantages, such as generally poorer affinity and specificity than antibodies, slower binding kinetics than biological receptors, incomplete template elimination, and lower utilization of binding sites [133,200,202]. Therefore, there is increasing interest in developing improved MIPs [257–259]. The key to the success of the sensor of an MIP is whether the MIP is effectively attached to the transducer. Three commonly used immobilization methods are in situ polymerization, electropolymerization, and physical coating. Additionally, the number of applications of MIP sensors for detecting AFB\(_1\) in edible vegetable oil is limited [200,202,260].

### Table 2. Techniques used for the detection of AFB\(_1\) in different types of edible oil.

| Matrix            | Analytical Method | Sample Preparation Method | Linear Range | Recovery | LOD      | Ref.       |
|-------------------|-------------------|---------------------------|--------------|----------|----------|------------|
| Peanut oil        | ELISA             | Immunoaffinity column cleanup | -            | 84.40–92.60% | 1.08 µg kg\(^{-1}\) | [20]       |
| Coconut oil       | HPLC-FLD          | Immunoaffinity chromatography | -            | -        | 0.01–0.04 µg kg\(^{-1}\) | [81]       |
| Peanut oil        | HPLC-FLD          | DLLME with in situ derivatization | 0.1–100 ng mL\(^{-1}\) | 106.90–121.50% | 0.03 ng mL\(^{-1}\) | [82]       |
| Corn oil          |                   |                           |              |          |          |            |
| Sunflower oil     |                   |                           |              |          |          |            |
| Olive oil         |                   |                           |              |          |          |            |
| Canola oil        |                   |                           |              |          |          |            |
| Frying oil        |                   |                           |              |          |          |            |
| Blend oil         |                   |                           |              |          |          |            |
| Vegetable oil     | HPLC-FLD          | Immunoaffinity column cleanup | 0.04–0.16 ng g\(^{-1}\) | 95.56–102.13% | 0.16 ng g\(^{-1}\) | [83]       |
| Coconut oil       | HPLC-FLD          | Immunoaffinity chromatography - Solid phase extraction | -          | 95.20–99.00% | 0.25 µg kg\(^{-1}\) | [84]       |
| Almond oil        | HPLC-FLD          | Immunoaffinity chromatography combined with DLLME | 0.005–10.00 ng mL\(^{-1}\) | 96.00–109.90% | 830 ng mL\(^{-1}\) | [85]       |
| Soybean oil       |                   |                           |              |          |          |            |
| Olive oil         |                   |                           |              |          |          |            |
| Sesame oil        |                   |                           |              |          |          |            |
| Sunflower oil     |                   |                           |              |          |          |            |
| Peanut oil        |                   |                           |              |          |          |            |
| Mixed oil         |                   |                           |              |          |          |            |
| Canola oil        |                   |                           |              |          |          |            |
| Corn oil          |                   |                           |              |          |          |            |
| Olive oil         |                   |                           |              |          |          |            |
| Peanut oil        | LC-MS/MS          | Liquid-Partitioning        | -            | 101.00–111.00% | 0.030 µg kg\(^{-1}\) | [87]       |
| Soybean oil       |                   |                           |              |          |          |            |
| Soybean oil       |                   |                           |              |          |          |            |
| Corn oil          |                   |                           |              |          |          |            |
| Rice bran oil     |                   |                           |              |          |          |            |
| Blend oil         |                   |                           |              |          |          |            |
| Peanut oil        | LC-MS/MS          | QuEChERS x DLLME          | -            | 70.70–76.00% | –          | [88]       |
| Maize oil         |                   |                           |              |          |          |            |
| Sunflower oil     | LC-MS/MS          | Hollow fiber liquid phase microextraction | 0.1–500 µg kg\(^{-1}\) | 78.59–80.61% | 0.02 µg kg\(^{-1}\) | [89]       |
| Corn oil          | LC-ESI-MS/MS      | QuEChERS                  | 0.04–2000 ng g\(^{-1}\) | 87.90–106.60% | 0.01 ng kg\(^{-1}\) | [90]       |
| Soybean oil       |                   |                           |              |          |          |            |
| Corn oil          |                   |                           |              |          |          |            |
| Corn oil          | LC-MS/MS          | Immunoaffinity chromatography | 0.16 µg kg\(^{-1}\) | 87.40–97.30% | 0.05 µg kg\(^{-1}\) | [96]       |
| Peanut oil        |                   |                           |              |          |          |            |
| Blended oil       |                   |                           |              |          |          |            |
| Olive oil         |                   |                           |              |          |          |            |
| Peanut oil        | LC-MS/MS          | Immunoaffinity column cleanup | 2–20 mg kg\(^{-1}\) | 87.70–102.20% | 0.1 µg kg\(^{-1}\) | [97]       |
| Sesame oil        |                   |                           |              |          |          |            |
| Olive oil         | LC/ESI-MS/MS      | Matrix Solid Phase Dispersion | 0.2–0.4 (pg inj) | 95.00–98.00% | 0.2 pg inj | [261]      |
| Sunflower oil     |                   |                           |              |          |          |            |
| Soybean oil       |                   |                           |              |          |          |            |
| Corn oil          |                   |                           |              |          |          |            |
| Groundnut oil     |                   |                           |              |          |          |            |
| Cottonseed oil    |                   |                           |              |          |          |            |
| Olive oil         |                   |                           |              |          |          |            |
| Sunflower oil     |                   |                           |              |          |          |            |
| Canola oil        |                   |                           |              |          |          |            |
| Olive oil         |                   |                           |              |          |          |            |
| Groundnut oil     |                   |                           |              |          |          |            |
| Cottonseed oil    |                   |                           |              |          |          |            |
| HPLC              |                   | Liquid-Liquid extraction | 0.2–0.8 µg kg\(^{-1}\) | - | 0.1 µg kg\(^{-1}\) | [102]      |
| Matrix                     | Analytical Method   | Sample Preparation Method       | Linear Range       | Recovery         | LOD              | Ref.  |
|---------------------------|---------------------|---------------------------------|--------------------|------------------|------------------|-------|
| Vegetable oils            | GPC-HPLC-FLD        | Liquid-Liquid Extraction        | 1.0–30.0 μg kg⁻¹   | 82.60–90.60%     | 1.0 μg kg⁻¹      | [104] |
| Peanut oil                | IAC-LC-ESI–MS/MS    | Liquid-Liquid Extraction        | 0.02–10 μg kg⁻¹    | 84.00–99.00%     | 0.02 μg kg⁻¹     | [105] |
| Sunflower oil             |                     |                                 |                    |                  |                  |       |
| Olive oil                 | HPLC-FLD            | Solid Phase Extraction          |                   | 65.50–87.50%     | 0.25 ng g⁻¹      | [110] |
| Virgin olive oil          |                     |                                 |                    |                  |                  |       |
| Canola oil                |                     |                                 |                    |                  |                  |       |
| Soybean oil               |                     |                                 |                    |                  |                  |       |
| Corn oil                  |                     |                                 |                    |                  |                  |       |
| Olive oil                 |                     |                                 |                    |                  |                  |       |
| Pea nut oil               |                     |                                 |                    |                  |                  |       |
| Rapeseed oil              |                     |                                 |                    |                  |                  |       |
| Peanut oil                |                     |                                 |                    |                  |                  |       |
| Blended oil               |                     |                                 |                    |                  |                  |       |
| Blended olive oil         |                     |                                 |                    |                  |                  |       |
| Sunflower oil             |                     |                                 |                    |                  |                  |       |
| Tea oil                   | HPLC-MS/MS          | QuEChERS                        | 0.2–20 ng mL⁻¹     | 87.80–98.60%     | 0.05 ng g⁻¹      | [116] |
| Rice oil                  |                     |                                 |                    |                  |                  |       |
| Corn oil                  |                     |                                 |                    |                  |                  |       |
| Sesame oil                |                     |                                 |                    |                  |                  |       |
| Soya bean oil             |                     |                                 |                    |                  |                  |       |
| Groundnut oil             |                     |                                 |                    |                  |                  |       |
| Palm kernel oil           |                     |                                 |                    |                  |                  |       |
| Melon oil                 |                     |                                 |                    |                  |                  |       |
| Coconut oil               |                     |                                 |                    |                  |                  |       |
| Pea nut oil               |                     |                                 |                    |                  |                  |       |
| Virgin olive oil          |                     |                                 |                    |                  |                  |       |
| Olive oil                 |                     |                                 |                    |                  |                  |       |
| Peanut oil                |                     |                                 |                    |                  |                  |       |
| Olive oil                 |                     |                                 |                    |                  |                  |       |
| Peanut oil                |                     |                                 |                    |                  |                  |       |
| Peanut oil                |                     |                                 |                    |                  |                  |       |
| Corn germ oil             |                     |                                 |                    |                  |                  |       |
| Peanut oil                |                     |                                 |                    |                  |                  |       |

Table 2. Cont.
| Matrix      | Analytical Method                                                                 | Sample Preparation Method                  | Linear Range         | Recovery          | LOD              | Ref.  |
|------------|-----------------------------------------------------------------------------------|---------------------------------------------|----------------------|-------------------|------------------|-------|
| Vegetable oil | Immobilized immunosensor based on the hybrid gold nanoparticles-poly 4-aminobenzoic acid supported graphene | -                                           | 0.01–25 ng mL\(^{-1}\) | -                 | 0.001 ng mL\(^{-1}\) | [207] |
| Peanut oil | UCNP\(_{s}\)-BPN\(_{Ns}\) aptamer Dual-terminal stemmed aptamer beacon, aggregation-induced emission | Liquid-Liquid Extraction                     | 0.2–500 ng mL\(^{-1}\) | 92.89–99.24%      | 0.028 ng mL\(^{-1}\) | [224] |
| Peanut oil | -                                                                                | Liquid-Liquid Extraction                     | 40–300 ng mL\(^{-1}\) | 93.59–109.30%      | 27.3 ng mL\(^{-1}\)  | [225] |
| Corn oil   | -                                                                                | Liquid-Liquid Extraction                     | 5–5120 nM            | 91.50–117.60%      | 1.88 nM          | [226] |
| Corn oil   | electrochemical aptasensor base on an AuNPs/ZIF-8 nanocomposite                  | An electrochemical aptasensor base on an AuNPs/Zn/Ni-ZIF-8-800@graphene nanocomposite | 10.0–1.0 × 10\(^5\) pg mL\(^{-1}\) | 93.49–106.90%      | 1.82 pg mL\(^{-1}\)  | [227] |
| Peanut oil | -                                                                                | Electrochemical aptasensor base on an AuNPs/Zn/Ag@ZIF-8 nanocomposite | 0.18–100 ng mL\(^{-1}\) | 80.26–109.60%      | 0.18 ng mL\(^{-1}\)  | [228] |
| Oil        | Zn\(^{2+}\)-dependent DNAzyme catalyzed cleavage                               | Electrochemical immunosensor base on AFB\(_{2}\)-BSA-QDs | 0.4–16 nmol L\(^{-1}\) | 92.20–107.80%      | 0.22 nmol L\(^{-1}\)  | [237] |
| Oil        | Electrochemical aptasensors                                                      | Electrochemical immunosensor base on AFB\(_{2}\)-BSA-QDs | 0.04–0.10 ng mL\(^{-1}\) | 94.5–103.3%        | 0.002 ng mL\(^{-1}\)  | [184] |
| Peanut oil | SERS aptasensor                                                                  | SERS aptasensor                              | 0.0001–100 ng·mL\(^{-1}\) | 96.60–115.00%      | 0.40 pg·mL\(^{-1}\)  | [174] |
| Peanut oil | SERS aptasensor                                                                  | SERS aptasensor                              | 0.001–10 ng·mL\(^{-1}\) | 94.70–109.00%      | 0.54 pg·mL\(^{-1}\)  | [169] |
| Peanut oil | GO fluorescence quenching system Atomic absorption spectroscopy                   | GO fluorescence quenching system Atomic absorption spectroscopy | 1.6–160 µM | -                          | 1.4 nM          | [242] |
| Peanut oil | SERS aptasensor                                                                  | SERS aptasensor                              | 2.5–240 µg kg\(^{-1}\) | -                 | 0.04 µg kg\(^{-1}\)  | [241] |
| Peanut oil | SERS aptasensor                                                                  | SERS aptasensor                              | 0.01–100 ng mL\(^{-1}\) | 91.09–105.73%      | 0.0036 ng mL\(^{-1}\) | [170] |
| Peanut oil | NH\(_{2}\)-Rh-Au@Ag CSNPs                                                        | Solid Phase Extraction                       | 0.1–5.0 ng mL\(^{-1}\) | -                 | 0.03 ng mL\(^{-1}\)  | [244] |
Table 2. Cont.

| Matrix         | Analytical Method                        | Sample Preparation Method | Linear Range       | Recovery        | LOD             | Ref.  |
|----------------|------------------------------------------|---------------------------|--------------------|----------------|-----------------|-------|
| Olive oil      | Dual DNA tweezers nanomachine             | -                         | 0.08–10 ppb        | 90.00–110.00%  | 0.035 ppb       | [245] |
| Peanut oil     | Electrochemical aptasensor based on smart | -                         | 0.1 × 10⁻⁴–10 ng mL⁻¹ | 94.50–106.70%  | 0.049 pg mL⁻¹   | [246] |
| Peanut oil     | host-guest recognition of β-cyclodextrin polymer | -                         | 1–1000 pg mL⁻¹    | 87.56–105.28%  | 0.492 pg mL⁻¹   | [236] |
| Corn oil       | A dual signal amplified aptasensor based on DNA walker, (DTNs) and network (HCR) | -                         | 0.5–50 ng mL⁻¹    | 90.30–92.40%   | 0.13 ng mL⁻¹    | [262] |
| Peanut oil     | A novel fluorescence aptasensor based on mesoporous silica nanoparticles | -                         | 1.0–200 ng mL⁻¹   | 90.30–102.91%  | 0.9 ng mL⁻¹     | [263] |
| Corn oil       | A simple, proximity aptamer probes        | -                         | 0.05–5.0 ng mL⁻¹   | 95.29–109.19%  | 0.026 ng mL⁻¹   | [264] |
| Peanut oil     | An aptamer-based MCE-LIF                  | -                         | 0.1–0.8 ng mL⁻¹    | 103.80–108.00% | 70 pg mL⁻¹      | [171] |
| Peanut oil     | SERS aptasensor                           | -                         | 0.01–100 ng mL⁻¹   | 90.40–113.10%  | 5.0 ng mL⁻¹     | [172] |
| Edible oil     | Immuoaffinity chromatography fluorometer  | Immunoaffinity column clean-up | 1.0–32.2 µg kg⁻¹ | -              | 1 µg kg⁻¹       | [265] |
| Corn oil       | An MIP-ECP-ECL sensing platform based on small molecule recognition | -                         | 10⁻⁵–10 ng mL⁻¹   | 102.00–110.00% | 8.5 fg mL⁻¹     | [173] |
| Soybean oil    | Ch₃NH₃PbBr₃ quantum dots (MAPB QDs)@SiO₂ | -                         | -                  | -              | 2 µg kg⁻¹       | [162] |
| Peanut oil     | THz spectroscopy                          | -                         | -                  | -              | -               | [266] |
| Corn oil       | ELC based on Escherichia coli             | -                         | 0.01–0.3 µg mL⁻¹   | 90.00–112.00%  | 1 µg mL⁻¹       | [266] |

5. Conclusions and Perspectives

Mycotoxin contamination, especially AFB₁ contamination in edible oil, is usually unavoidable. A more sensitive and rapid sensor-based early warning tool for AFB₁ detection would help to reduce risk. Various traditional, modern, and biosensing technologies have been used to detect toxins in contaminated food. Spectroscopic techniques, chromatographic techniques are general methods for the detection of AFB₁ in edible oils. In recent years, based on the cross-integration of multiple disciplines, the innovation, progress and development of general methods have also been promoted. Although traditional chromatographic techniques can effectively detect mycotoxins, their performance in all
aspects cannot achieve satisfactory results. Combined use with other sensor equipment can effectively improve reliability, sensitivity and accuracy. However, due to the high cost of equipment, on-site inspection cannot be performed, and sample pretreatment is required, which limits the use of chromatography technology in the detection of AFB1 in edible oil. The development of spectroscopic techniques has become increasingly diverse and can effectively detect mycotoxins, especially AFB1 in edible oils. However, these methods are not suitable for on-site detection, because they still have many shortcomings, such as low sensitivity and reliability, and the need for professional personnel to operate.

Unlike conventional detection techniques, novel biosensors show high accuracy, sensitivity, and specificity; better cost controllability and portability; and reliability and simplicity in operation.

This review also discusses the development of important recognition elements in sensors. The recognition element of the sensor should have sensitivity and specificity sufficient enough to detect small amounts of target toxins, even in samples with complex matrix systems. The development and use of nanomaterials further improve the efficiency of biosensor conversion systems, but these require further improvements in their sensitivity, selectivity, and reproducibility. Of course, the stability and cost will also affect the selection of identification elements, which can improve the practicability.

Despite significant progress in biosensors for the detection of AFB1, there are some problems and challenges in the future. (1) The recognition elements of biosensors (such as metal nanoparticles, quantum dots, and graphene) improve the efficiency of sensing systems, but all these require further improvements in terms of sensitivity, selectivity, and reproducibility. (2) Future studies can perform AFB1 toxicity measurements and develop advanced nanomaterial-integrated biosensors to improve the overall detection of harmful substances, such as AFB1, in contaminated food samples. (3) When detecting AFB1 in contaminated food samples, researchers can focus on combining biosensing systems with microarray technology to fabricate more portable devices. (4) Reagent-free, clean-free, calibration-free, or nonbiological contamination biosensors for aflatoxin analysis require more effort and will reduce the possible future hazards.

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Abbreviations

| Acronym | Description |
|---------|-------------|
| AChE    | Acetylcholinesterase |
| Adans   | Aunr@DNTB@Ag Nanorods |
| AFB1    | Aflatoxin B1 |
| AFB2    | Aflatoxin B2 |
| AFBO    | Aflatoxin B1–8,9-Epoxide |
| AFG1    | Aflatoxin G1 |
| AFG2    | Aflatoxin G2 |
| AFM1    | Aflatoxin M1 |
| AFM2    | Aflatoxin M2 |
| Afs     | Aflatoxins |
| AIE     | Induced Emission |
| AOAC    | Association of Analytical Communities |
| AuNPs   | Gold Nanoparticles |
| BPNSs   | Black phosphorus nanosheets |
References

1. Shabeer, S.; Asad, S.; Jamal, A.; Ali, A. Aflatoxin Contamination, Its Impact and Management Strategies: An Updated Review. *Toxins* **2022**, *14*, 307. [CrossRef] [PubMed]

2. Skrzydlewska, P.; TwaruzeK, M.; Grajewski, J. Cytotoxicity of Mycotoxins and Their Combinations on Different Cell Lines: A Review. *Toxins* **2022**, *14*, 244. [CrossRef]

3. Holban, A.M.; Grumesescu, A.M. *Microbial Contamination and Food Degradation*; Academic Press: London, UK, 2018; Volume 10.

4. Pickova, D.; Ostry, V.; Malíř, F. A Recent Overview of Producers and Important Dietary Sources of Aflatoxins. *Toxins* **2021**, *13*, 186. [CrossRef] [PubMed]

5. Anater, A.; Manyes, L.; Meca, G.; Ferrer, E.; Luciano, F.B.; Pimpao, C.T.; Font, G. Mycotoxins and their consequences in aquaculture: A review. *Aquaculture* **2016**, *451*, 1–10. [CrossRef]

6. Wang, Y.; Nie, J.; Yan, Z.; Li, Z.; Cheng, Y.; Chang, W. Occurrence and co-occurrence of mycotoxins in nuts and dried fruits from China. *Food Control* **2018**, *88*, 181–189. [CrossRef]

7. Lee, H.J.; Ryu, D. Worldwide Occurrence of Mycotoxins in Cereals and Cereal-Derived Food Products: Public Health Perspectives of Their Co-occurrence. *J. Agric. Food Chem.* **2017**, *65*, 7034–7051. [CrossRef]

8. Azam, M.S.; Ahmed, S.; Islam, M.N.; Maitra, P.; Islam, M.M.; Yu, D. Critical Assessment of Mycotoxins in Beverages and Their Control Measures. *Toxins* **2021**, *13*, 323. [CrossRef]

9. Mahato, D.K.; Lee, K.E.; Kamle, M.; Devi, S.; Dewangan, K.N.; Kumar, P.; Kang, S.G. Aflatoxins in Food and Feed: An Overview on Prevalence, Detection and Control Strategies. *Front. Microbiol.* **2019**, *10*, 2266. [CrossRef]

10. Ünüşan, N. Systematic review of mycotoxins in food and feeds in Turkey. *Food Control* **2019**, *97*, 1–14. [CrossRef]

11. Ahlberg, S.H.; Joutsjoki, V.; Korhonen, H.J. Potential of lactic acid bacteria in aflatoxin risk mitigation. *Int. J. Food. Microbiol.* **2015**, *207*, 87–102. [CrossRef]

12. Jard, G.; Liboz, T.; Mathieu, F.; Guyonvarc’h, A.; Lebrihi, A. Review of mycotoxin reduction in food and feed: From prevention in the field to detoxification by adsorption or transformation. *Food Addit. Contam. Part A* **2011**, *28*, 1590–1609. [CrossRef] [PubMed]

13. OECD/FAO. *OECD-FAO Agricultural Outlook 2022–2031*; OECD Publishing: Paris, France, 2022. [CrossRef]

14. Mao, X.; Yan, A.; Wen, Y.; Luo, D.; Yang, H. Dispersive Solid-Phase Extraction Using Microporous Sorbent UiO-66 Coupled to Gas Chromatography-Tandem Mass Spectrometry: A QuEChERS-Type Method for the Determination of Organophosphorus Pesticide Residues in Edible Vegetable Oils without Matrix Interference. *J. Agric. Food Chem.* **2019**, *67*, 1760–1770. [CrossRef] [PubMed]

15. Pitt, J.L.; Taniwaki, M.H.; Cole, M.B. Mycotoxin production in major crops as influenced by growing, harvesting, storage and processing, with emphasis on the achievement of Food Safety Objectives. *Food Control* **2013**, *32*, 205–215. [CrossRef]

16. Vassegian, Y.; Moradi, M.; Dragoi, E.-N.; Khanegah, A.M. A review on mycotoxins detection techniques in edible oils. *Int. J. Environ. Anal. Chem.* **2020**, *102*, 2125–2139. [CrossRef]

17. Javanmardi, F.; Khodaei, D.; Sheidaei, Z.; Bashiry, M.; Nayebezadeh, K.; Vassegian, Y.; Mousavi Khanegah, A. Decontamination of Aflatoxins in Edible Oils: A Comprehensive Review. *Food Res. Int.* **2020**, *38*, 1–17. [CrossRef]

18. Shavakkhi, F.; Rahmani, A.; Pirav-Vanak, Z. A global systematic review and meta-analysis on prevalence of the aflatoxin B1 contamination in olive oil. *J. Food. Sci. Technol.* **2022**, *1–10*. [CrossRef]

19. He, X.; Zhang, Y.; Yang, X.; Chen, M.; Pang, Y.; Shen, F.; Fang, Y.; Liu, Q.; Hu, Q. Estimating bulk optical properties of AFB1 contaminated edible oils in 300–900 nm by combining double integrating spheres technique with laser induced fluorescence spectroscopy. *Food Chem.* **2022**, *375*, 131666. [CrossRef]

20. Qi, N.; Yu, H.; Yang, C.; Gong, X.; Liu, Y.; Zhu, Y. Aflatoxin B1 in peanut oil from Western Guangdong, China, during 2016-2017. *Food Addit. Contam. Part B* **2019**, *12*, 45–51. [CrossRef]

21. Li, S.; Li, X.; Zhang, Q. Advances in the development of detection techniques for mycotoxins in vegetable oil. *Chin. J. Chromatogr.* **2019**, *37*, 569–580. [CrossRef]

22. Ji, J.; Jiang, M.; Zhang, Y.; Hou, J.; Sun, S. Co-occurrence of aflatoxins in plant oil products from China. *Food Addit. Contam. Part B* **2022**, *1–8*. [CrossRef]

23. Eirnglhoffazi, M.; Talebi-Ghane, E.; Ranjarb, A.; Mehr, F. Concentration of aflatoxins in edible vegetable oils: A systematic meta-analysis review. *Eur. Food Res. Technol.* **2021**, *247*, 2887–2897. [CrossRef]
24. Bordin, K.; Sawada, M.M.; Rodrigues, C.E.d.C.; da Fonseca, C.R.; Oliveira, C.A.F. Incidence of Aflatoxins in Oil Seeds and Possible Transfer to Oil: A Review. Food Eng. Rev. 2014, 6, 20–28. [CrossRef]
25. Shephard, G.S. Aflatoxins in peanut oil: Food safety concerns. World Mycotoxin J. 2018, 11, 149–158. [CrossRef]
26. Wu, L-X.; Ding, X.X.; Li, P.W.; Du, X.H.; Zhou, H.Y.; Bai, Y.Z.; Zhang, L.X. Aflatoxin contamination of peanuts at harvest in China from 2010 to 2013 and its relationship with climatic conditions. Food Control 2016, 60, 117–123. [CrossRef]
27. Wu, L.; Li, G.; Xu, Z.; Zhu, L.; Huang, R.; Chen, X. Application of nano-ELISA in food analysis: Recent advances and challenges. TrAC, Trends Anal. Chem. 2019, 113, 140–156. [CrossRef]
28. Hayashi, Y.; Matsuda, R.; Maitani, T.; Imai, K.; Nishimura, W.; Ito, K.; Maeda, M. Precision, limit of detection and range of quantitation in competitive ELISA. Anal. Chem. 2004, 76, 1295–1301. [CrossRef]
29. Bhardwaj, H.; Sumana, G.; Marquette, C.A. A label-free ultrasensitive microfluidic surface Plasmon resonance biosensor for aflatoxin B1 detection based on nanotechnology and nanomaterials-A review. Anal. Chim. Acta. 2019, 1069, 1–27. [CrossRef]
30. Goud, K.Y.; Reddy, K.K.; Satyanarayana, M.; Kummini, S.; Gobi, K.V. A review on recent developments in optical and electrochemical aptamer-based assays for mycotoxins using advanced nanomaterials. Mikrochim. Acta. 2019, 187, 29. [CrossRef]
31. Bhardwaj, H.; Sumana, G.; Marquette, C.A. Gold nanobipyramids integrated ultrasensitive optical and electrochemical biosensor for Aflatoxin B1 detection. Talanta 2021, 222, 121578. [CrossRef] [PubMed]
32. Danesh, N.M.; Bostan, H.B.; Abnous, K.; Ramezani, M.; Youssefi, K.; Taghdisi, S.M.; Karimi, G. Ultrasensitive detection of aflatoxin B1 and its major metabolite aflatoxin M1 using aptasensors: A review. TrAC Trends Anal. Chem. 2018, 99, 117–128. [CrossRef]
33. Castillo, G.; Poturnayová, M.; Šnejdařková, M.; Hianik, T.; Spinella, K.; Mosiello, L. Development of electrochemical aptasensor using dendrimers as an immobilization platform for detection of Aflatoxin B1 in food samples. In Proceedings of the 2015 XVIII AISEM Annual Conference, Trento, Italy, 3–5 February 2015; pp. 1–4.
34. Zheng, M.Z.; Richard, J.L.; Binder, J. A review of rapid methods for the analysis of mycotoxins. Mycopathologia 2006, 161, 261–273. [CrossRef]
35. Bennett, J.W.; Klisch, M. Mycotoxins. Clin. Microbiol. Rev. 2003, 16, 497–516. [CrossRef] [PubMed]
36. Robbins, C.A.; Swenson, L.J.; Nealley, M.L.; Gots, R.E.; Kelman, B.J. Health effects of mycotoxins in indoor air: A critical review. Appl. Occup. Environ. Hyg. 2000, 15, 773–784. [CrossRef] [PubMed]
37. Catanante, G.; Rhouati, A.; Hayat, A.; Marty, J.L. An Overview of Recent Electrochemical Immunosensing Strategies for Mycotoxins Detection. Electroanalysis 2016, 28, 1750–1763. [CrossRef]
38. Yao, H.; Hruska, Z.; Di Mavungu, J.D. Developments in detection and determination of aflatoxins. World Mycotoxin J. 2015, 8, 181–191. [CrossRef]
39. Liu, D.; Li, W.; Zhu, C.; Li, Y.; Shen, X.; Li, L.; Yan, X.; You, T. Recent progress on electrochemical biosensing of aflatoxins: A review. TrAC Trends Anal. Chem. 2020, 133, 115966. [CrossRef]
40. Hui, Y.; Wang, B.; Ren, R.; Zhao, A.; Zhang, F.; Song, S.; He, Y. An electrochemical aptasensor based on DNA-AuNPs-HPR nanoprobes and exonuclease-assisted signal amplification for detection of aflatoxin B1. Food Control 2020, 109, 106902. [CrossRef]
41. Luo, Y.; Chen, Z.; Xie, G.; Chen, J.; Lu, A.; Li, C.; Hu, F.; Ma, Z.; Wang, J. Rapid Visual Detection of Aflatoxin B1 by Label-Free Aptasensor Using Unmodified Gold Nanoparticles. J. Nanosci. Nanotechnol. 2015, 15, 1357–1361. [CrossRef]
42. Nguyen, B.H.; Tran, L.D.; Do, Q.P.; Nguyen, H.L.; Tran, N.H.; Nguyen, P.X. Label-free detection of aflatoxin M1 with electrochemical Fe3O4/polyaniline-based aptasensor. Mater. Sci. Eng. C Mater. Biol. Appl. 2013, 33, 2229–2234. [CrossRef]
43. Taghdisi, S.M.; Danesh, N.M.; Ramezani, M.; Abnous, K. A new amplified fluorescent aptasensor based on hairpin structure of G-quadruplex oligonucleotide-Aptamer chimera and silica nanoparticles for sensitive detection of aflatoxin B1 in the grape juice. Food Chem. 2018, 268, 342–346. [CrossRef]
44. Henry, S.H.; Bosch, F.X.; Troxell, T.C.; Bolger, P.M. Reducing liver cancer–global control of aflatoxin. Science 1999, 286, 2453–2454. [PubMed]
45. Mao, J.; He, B.; Zhang, L.; Li, P.; Zhang, Q.; Ding, X.; Zhang, W. A Structure Identification and Toxicity Assessment of the Degradation Products of Aflatoxin B(1) in Peanut Oil under UV Irradiation. Toxins 2016, 8, 332. [CrossRef]
46. Mousavi Khanehghah, A.; Es, I.; Raeisi, S.; Fakhri, Y. Aflatoxins in cereals: State of the art. J. Food Saf. 2018, 38, 12532. [CrossRef]
47. Qureshi, H. Is Aflatoxin B1 A Biomarker for Pathogenic Potential of Aspergillus flavus? J. Cell Sci. 2014, 5, 1000188. [CrossRef]
48. Ali, N. Aflatoxins in rice: Worldwide occurrence and public health perspectives. Toxicon. Rep. 2019, 6, 1188–1197. [CrossRef]
49. Sun, C.; Liao, X.; Jia, B.; Shi, L.; Zhang, D.; Wang, R.; Zhou, L.; Kong, W. Development of a ZnCdS@ZnS quantum dots-based label-free electrochemiluminescence immunosensor for sensitive determination of aflatoxin B1 in lotus seed. Mikrochim. Acta 2020, 187, 236. [CrossRef]
50. Bhardwaj, H.; Sumana, G.; Marquette, C.A. A label-free ultrasensitive microfluidic surface Plasmon resonance biosensor for Aflatoxin B1 detection using nanoparticles integrated gold chip. Food Chem. 2020, 307, 125530. [CrossRef]
51. Ramalho, L.N.Z.; Porta, L.D.; Rosim, R.E.; Petta, T.; Augusto, M.J.; Silva, D.M.; Ramalho, F.S.; Oliveira, C.A.F. Aflatoxin B1 residues in human livers and their relationship with markers of hepatic carcinogenesis in Sao Paulo, Brazil. Toxicon. Rep. 2018, 5, 777–784. [CrossRef]
54. Kensler, T.W.; Roebuck, B.D.; Wogan, G.N.; Groopman, J.D. Aflatoxin: A 50-year odyssey of mechanistic and translational toxicology. *Toxicol. Sci*. 2011, 120 (Suppl. 1), S28–S48. [CrossRef] [PubMed]

55. Rushing, B.R.; Selim, M.I. Aflatoxin B1: A review on metabolism, toxicity, occurrence in food, occupational exposure, and detoxification methods. *Food Chem. Toxicol*. 2019, 124, 81–100. [CrossRef] [PubMed]

56. Chu, Y.J.; Yang, H.I.; Wu, H.C.; Liu, J.; Wang, L.Y.; Lu, S.N.; Lee, M.H.; Jen, C.L.; You, S.L.; Santella, R.M.; et al. Aflatoxin B1 exposure increases the risk of cirrhosis and hepatocellular carcinoma in chronic hepatitis B virus carriers. *Int. J. Cancer* 2017, 141, 711–720. [CrossRef] [PubMed]

57. Marin, S.; Ramos, A.J.; Cano-Sancho, G.; Sanchis, V. Mycotoxins: Occurrence, toxicology, and exposure assessment. *Food Chem. Toxicol*. 2013, 60, 218–237. [CrossRef]

58. Wild, C.P.; Turner, P.C. The toxicity of aflatoxins as a basis for public health decisions. *Mutagenesis* 2002, 17, 471–481. [CrossRef]

59. Zhou, Q.; Tang, D. Recent advances in photoelectrochemical biosensors for analysis of mycotoxins in food. *TrAC Trends Anal. Chem.* 2020, 124, 115814. [CrossRef]

60. Eivazzadeh-Keihan, R.; Pashazadeh, P.; Hejazi, M.; de la Guardia, M.; Mokhtarzadeh, A. Recent advances in Nanomaterial-mediated Bio and immune sensors for detection of aflatoxin in food products. *TrAC Trends Anal. Chem.* 2017, 87, 112–128. [CrossRef]

61. Keenan, J.; Jolly, P.; Preko, P.; Baidoo, J.; Wang, J.S.; Phillips, T.D.; Williams, J.H.; McGwin, G., Jr. Association Between Aflatoxin Exposure and Linear Growth in Children in Sub-Saharan Africa. *Environ. Health Persp.* 2004, 112, 1334–1338. [CrossRef]

62. Abdolmaleki, K.; Khedri, S.; Alizadeh, L.; Javanmardi, F.; Oliveira, C.A.F.; Mousavi Khaneghah, A. The mycotoxins in edible oils: An overview of prevalence, concentration, toxicity, detection and decontamination techniques. *Trends Food Sci. Technol.* 2021, 115, 500–511. [CrossRef]

63. Claeyts, L.; Romano, C.; De Ruyck, K.; Wilson, H.; Fervers, B.; Korenjak, M.; Zavadil, J.; Gunter, M.J.; De Saeger, S.; De Boevre, M.; et al. Mycotoxin exposure and human cancer risk: A systematic review of epidemiological studies. *Comp. Rev. Food Sci. Food Saf.* 2020, 19, 1449–1464. [CrossRef] [PubMed]

64. Adyeeye, S.A.O.; Yildiz, F. Fungal mycotoxins in foods: A review. *Cogent Food Agric.* 2016, 2, 1213127. [CrossRef]

65. Selamat, J.; Iqbal, S.Z. *Food Safety: Basic Concepts, Recent Issues, and Future Challenges*; Springer: Berlin/Heidelberg, Germany, 2016. [CrossRef]

66. Selamat, J.; Iqbal, S.Z. Mycotoxin exposure and human cancer risk: A systematic review of epidemiological studies. *Comp. Rev. Food Sci. Food Saf.* 2020, 218–237. [CrossRef]

67. Aiko, V.; Mehta, A. Occurrence, detection and detoxification of mycotoxins. *Arch. Clin. Microbiol.* 2011, 18, 1–14. [CrossRef]

68. Mazumder, P.M.; Sasmal, D. Mycotoxins–limits and regulations. *Anz. Sci. Life 2001*, 20, 1.

69. Zinedine, A.; Mañes, J. Occurrence and legislation of mycotoxins in food and feed from Morocco. *Food Control* 2015, 48, 227–241. [CrossRef]

70. Le, V.T.; Vasseghian, Y.; Dragoi, E.N.; Mousavi Khaneghah, A. A review on graphene-based electrochemical sensors for detection of aflatoxins in food products. *TrAC Trends Anal. Chem.* 2020, 124, 115814. [CrossRef] [PubMed]

71. Turner, N.W.; Bramhmbhatt, H.; Szabo-Vezse, M.; Coker, R.; Piletsky, S.A. Analytical methods for determination of mycotoxins: An update (2009–2014). *Anal. Chim. Acta.* 2015, 901, 12–33. [CrossRef]

72. Ingenbleek, L.; Sulyok, M.; Adegboye, Y.; Oyede, A.D.; Kisito, C.; Dembele, Y.K.; Eyangoh, S.; Verger, P.; et al. Regional Sub-Saharan Africa Total Diet Study in Benin, Cameroon, Mali and Nigeria Reveals the Presence of 164 Mycotoxins and Other Secondary Metabolites in Foods. *Toxins* 2019, 11, 54. [CrossRef] [PubMed]

73. Zhu, C.; Liu, D.; Li, Y.; Shen, X.; Ma, S.; Liu, Y.; You, T. Ratiometric electrochemical aptasensor for ultrasensitive detection of Ochratoxin A based on a dual signal amplification strategy: Engineering the binding of methylene blue to DNA. *Biosens. Bioelectron.* 2020, 150, 118184. [CrossRef] [PubMed]

74. Karunarathna, N.B.; Fernando, C.J.; Munasinghe, D.M.S.; Fernando, R. Occurrence of aflatoxins in edible vegetable oils in Sri Lanka. *Food Control* 2019, 101, 97–103. [CrossRef]
82. Wang, N.; Duan, C.; Geng, X.; Li, S.; Ding, K.; Guan, Y. One step rapid dispersive liquid-liquid micro-extraction with in-situ derivatization for determination of aflatoxins in edible oils based on high performance liquid chromatography fluorescence detection. Food Chem. 2019, 287, 333–337. [CrossRef]

83. Nabizadeh, S.; Shariatifar, N.; Shokooohi, E.; Shoebi, S.; Gavahian, M.; Fakhri, Y.; Azari, A.; Mousavi Khaneghah, A. Prevalence and probabilistic health risk assessment of aflatoxins B1, B2, G1, and G2 in Iranian edible oils. Environ. Sci. Pollut. Res. Int. 2018, 25, 35562–35570. [CrossRef]

84. Ma, F.; Chen, R.; Li, P.; Zhang, Q.; Zhang, W.; Hu, X. Preparation of an immunoaffinity column with amino-silica gel microparticles and its application in sample cleanup for aflatoxin detection in agri-products. Molecules 2013, 18, 2222–2235. [CrossRef]

85. Afzali, D.; Ghanbarian, M.; Mostafavi, A.; Shamspur, T.; Ghaseminezhad, S. A novel method for high preconcentration of ultra trace amounts of B(1), B(2), G(1) and G(2) aflatoxins in edible oils by dispersive liquid-liquid microextraction after immunoaffinity column clean-up. J. Chromatogr. A 2012, 1247, 35–41. [CrossRef]

86. Elzupir, A.O.; Suliman, M.A.; Ibrahim, I.A.; Fadul, M.H.; Elhussein, A.M. Aflatoxins levels in vegetable oils in Khartoum State, Sudan. Mycotoxin Res. 2010, 26, 69–73. [CrossRef] [PubMed]

87. Zhang, K.; Xu, D. Application of Stable Isotope Dilution and Liquid Chromatography Tandem Mass Spectrometry for Multi-Mycotoxin Analysis in Edible Oils. J. AOAC Int. 2019, 102, 1651–1656. [CrossRef] [PubMed]

88. Eom, T.; Cho, H.D.; Kim, J.; Park, M.; An, J.; Kim, M.; Kim, S.H.; Han, S.B. Multiclass mycotoxin analysis in edible oils using a simple solvent extraction method and liquid chromatography-tandem mass spectrometry. Food Addit. Contam. Part A 2017, 34, 2011–2022. [CrossRef] [PubMed]

89. Huang, S.; Chen, X.; Wang, Y.; Zhu, F.; Jiang, R.; Ouyang, G. High enrichment and ultra-trace analysis of aflatoxins in edible oils by a modified hollow-fiber liquid-phase microextraction technique. Chem. Commun. 2017, 53, 8988–8991. [CrossRef] [PubMed]

90. Sharmili, K.; Jinap, S.; Sukor, R. Development, optimization and validation of QuEChERS based liquid chromatography tandem mass spectrometry method for determination of multimycotoxin in vegetable oil. Food Control 2016, 70, 152–160. [CrossRef]

91. Pereira, V.L.; Fernandes, J.O.; Cunha, S.C. Comparative assessment of three cleanup procedures after QuEChERS extraction for determination of trichothecenes (type A and type B) in processed cereal-based baby foods by GC-MS. Food Chem. 2015, 182, 143–149. [CrossRef] [PubMed]

92. Nathanial, A.V.; Syvahuoko, J.; Malachova, A.; Jestoi, M.; Varga, E.; Michlmayr, H.; Adam, G.; Sievilainen, E.; Berthiller, F.; Peltonen, K. Simultaneous determination of major type A and B trichothecenes, zearalenone and certain modified metabolites in Finnish cereal grains with a novel liquid chromatography-tandem mass spectrometric method. Anal. Bioanal. Chem. 2015, 407, 4745–4755. [CrossRef]

93. Capriotti, A.L.; Cavaliere, C.; Foglia, P.; Samperi, R.; Stampachiacchiere, S.; Ventura, S.; Lagana, A. Multiclass analysis of mycotoxins in biscuits by high performance liquid chromatography-tandem mass spectrometry. Comparison of different extraction procedures. J. Chromatogr. A 2014, 1343, 69–78. [CrossRef]

94. Malachova, A.; Sulyok, M.; Beltran, E.; Berthiller, F.; Kraska, R. Optimization and validation of a quantitative liquid chromatography-tandem mass spectrometry method covering 295 bacterial and fungal metabolites including all regulated mycotoxins in four model food matrices. J. Chromatogr. A 2014, 1362, 145–156. [CrossRef]

95. Tsiplakou, E.; Anagnostopoulou, C.; Liapis, K.; Haroutounian, S.A.; Zervas, G. Determination of mycotoxins in feedstuffs and ruminant’s milk using an easy and simple LC-MS/MS multiresidue method. Talanta 2014, 130, 8–19. [CrossRef]

96. Yang, L.; Xu, D.; Zhang, Z.; Wei, J.; Chang, F.; Sun, J.B. Determination of aflatoxins levels in vegetable oils in Khartoum State, Sudan. Mycotoxin Res. 2010, 26, 69–73. [CrossRef] [PubMed]

97. Junsai, T.; Poapolathep, S.; Sutjarit, S.; Giorgi, M.; Zhang, Z.; Logrieco, A.F.; Li, P.; Poapolathep, A. Determination of Multiple Mycotoxins and Their Natural Occurrence in Edible Vegetable Oils Using Liquid Chromatography-Tandem Mass Spectrometry. J. AOAC Int. 2010, 93, 936–942. [CrossRef] [PubMed]

98. Bao, L.; Truckses, M.W.; White, K.D. Determination of aflatoxins B1, B2, G1, and G2 in olive oil, peanut oil, and sesame oil. J. AOAC Int. 2010, 93, 936–942. [CrossRef] [PubMed]

99. Junsai, T.; Poapolathep, S.; Sutjarit, S.; Giorgi, M.; Zhang, Z.; Logrieco, A.F.; Li, P.; Poapolathep, A. Determination of Multiple Mycotoxins and Their Natural Occurrence in Edible Vegetable Oils Using Liquid Chromatography-Tandem Mass Spectrometry. Foods 2021, 10, 2795. [CrossRef]

100. Deng, H.; Su, X.; Wang, H. Simultaneous Determination of Aflatoxin B1, Bisphenol A, and 4-Nonylphenol in Peanut Oils by Liquid-Liquid Extraction Combined with Solid-Phase Extraction and Ultra-High Performance Liquid Chromatography-Tandem Mass Spectrometry. Food Anal. Methods 2017, 11, 1303–1311. [CrossRef]

101. Hidalgo-Ruiz, J.L.; Romero-Gonzalez, R.; Martinez Vidal, J.L.; Garrido Frenich, A. A rapid method for the determination of mycotoxins in edible vegetable oils by ultra-high performance liquid chromatography-tandem mass spectrometry. Food Chem. 2019, 288, 22–28. [CrossRef]

102. Zhu, Z.; Feng, M.; Zuo, L.; Zhu, Z.; Wang, F.; Chen, L.; Li, J.; Shan, G.; Luo, S.Z. An aptamer based surface plasmon resonance biosensor for the detection of ochratoxin A in wine and peanut oil. Biosens. Bioelectron. 2015, 65, 320–326. [CrossRef]

103. Idris, Y.M.; Mariod, A.A.; Elnour, I.A.; Mohamed, A.A. Determination of aflatoxin levels in Sudanese edible oils. Food Chem. Toxicol. 2010, 48, 2539–2541. [CrossRef]

104. Majerus, P.; Graf, N.; Kramer, M. Rapid determination of zearalenone in edible oils by HPLC with fluorescence detection. Mycotoxin Res. 2009, 25, 117–121. [CrossRef]

105. Wang, H.; Zhao, L.; Yang, H.; Guo, Q.; Shi, H.; Pan, H.; Zhao, L.; Qian, C. Determination of benzo(apyrene and aflatoxins (B1, B2, G1, G2) in vegetable oil by GPC-HPLC-FLD. Anal. Methods 2014, 6, 1545–1549. [CrossRef]
105. Xie, J.; Peng, T.; He, J.L.; Shao, Y.; Fan, C.L.; Chen, Y.; Jiang, W.X.; Chen, M.; Wang, Q.; Pei, X.Y.; et al. Preparation and characterization of an immunoaffinity column for the selective extraction of aflatoxin B1 in 13 kinds of foodstuffs. J. Chromatogr. B 2015, 988–989, 50–56. [CrossRef]

106. Han, X.; Xu, W.; Zhang, J.; Xu, J.; Li, F. Co-Occurrence of Beauvericin and Enniatins in Edible Vegetable Oil Samples, China. Toxins 2019, 11, 100. [CrossRef]

107. Drzymala, S.S.; Weiz, S.; Heinze, J.; Marten, S.; Prinz, C.; Zimathies, A.; Garbe, L.A.; Koch, M. Automated solid-phase extraction coupled online with HPLC-FLD for the quantification of zearalenone in edible oil. Anal. Bioanal. Chem. 2015, 407, 3489–3497. [CrossRef] [PubMed]

108. Yu, X.; Yang, H. Pyrethroid residue determination in organic and conventional vegetables using liquid-solid extraction coupled with magnetic solid phase extraction based on polystyrene-coated magnetic nanoparticles. Food Chem. 2017, 217, 303–310. [CrossRef] [PubMed]

109. Sheng, J.; Zuo, J.; Ma, L.; Li, C.; Li, Y.; Kong, D. Highly selective enrichment of aflatoxin B1 from edible oil using polydopamine-modified magnetic nanomaterials. Food Sci. Technol. 2021, 41, 321–327. [CrossRef]

110. Ferracane, R.; Tafuri, A.; Logieco, A.; Galvano, F.; Balzano, D.; Ritiieni, A. Simultaneous determination of aflatoxin B1 and ochratoxin A and their natural occurrence in Mediterranean virgin olive oil. Food Addit. Contam. 2007, 24, 173–180. [CrossRef]

111. Giménez, I.; Herrera, M.; Escobar, J.; Ferruz, E.; Lorán, S.; Herrera, A.; Ariño, A. Distribution of deoxynivalenol and zearalenone in milled germ when milling and analysis of toxin levels in wheat germ and wheat germ oil. Food Control 2013, 34, 268–273. [CrossRef]

112. Jiang, Y.; Li, Y.; Jiang, Y.; Li, J.; Pan, C. Determination of multiresidues in rapeseed, rapeseed oil, and rapeseed meal by acetonitrile extraction, low-temperature cleanup, and detection by liquid chromatography with tandem mass spectrometry. J. Agric. Food Chem. 2012, 60, 5089–5098. [CrossRef]

113. Payanan, T.; Leepipattipiboon, N.; Varanusupakul, P. Low-temperature cleanup with solid-phase extraction for the determination of polycyclic aromatic hydrocarbons in edible oils by reversed phase liquid chromatography with fluorescence detection. Food Chem. 2013, 141, 2720–2726. [CrossRef]

114. Urusov, A.E.; Petakova, A.V.; Vozniak, M.V.; Zherdev, A.V.; Dzantiev, B.B. Rapid immunoenzyme assay of aflatoxin B1 using magnetic nanoparticles. Sensors 2014, 14, 21843–21857. [CrossRef]

115. Yu, X.; Li, Z.; Zhao, M.; Lau, S.C.S.; Ru Tan, H.; Teh, W.J.; Yang, H.; Zheng, C.; Zhang, Y. Quantification of aflatoxin B1 in vegetable oils using low temperature clean-up followed by immuno-magnetic solid phase extraction. Food Chem. 2019, 275, 390–396. [CrossRef]

116. Zhao, H.; Chen, X.; Shen, C.; Qu, B. Determination of 16 mycotoxins in vegetable oils using a QuEChERS method combined with high-performance liquid chromatography-tandem mass spectrometry. Food Addit. Contam. Part A 2017, 34, 255–264. [CrossRef] [PubMed]

117. Qian, M.; Zhang, H.; Wu, L.; Jin, N.; Wang, J.; Jiang, K. Simultaneous determination of zearalenone and its derivatives in edible vegetable oil by gel permeation chromatography and gas chromatography-triple quadrupole mass spectrometry. Food Chem. 2015, 166, 23–28. [CrossRef] [PubMed]

118. Alshannaq, A.; Yu, J.H. Occurrence, Toxicity, and Analysis of Major Mycotoxins in Food. Int. J. Environ. Res. Public. Health 2017, 14, 632. [CrossRef] [PubMed]

119. Santos, A.; Vaz, A.; Rodrigues, P.; Veloso, A.; Venâncio, A.; Peres, A. Thin Films Sensor Devices for Mycotoxins Detection in Foods: Applications and Challenges. Chemosensors 2019, 7, 3. [CrossRef]

120. Shepard, G.S. Current Status of Mycotoxin Analysis: A Critical Review. J. AOAC Int. 2016, 99, 842–848. [CrossRef] [PubMed]

121. Schwack, W.; Pellissier, E.; Morlock, G. Analysis of unauthorized Sudan dyes in food by high-performance thin-layer chromatography. Anal. Bioanal. Chem. 2018, 410, 5641–5651. [CrossRef]

122. Gauthier, M.S.; O’Brien, E.L.; Bigornia, S.; Mott, M.; Cacicedo, J.M.; Xu, X.J.; Gokce, N.; Apovian, C.; Ruderman, N. Decreased insulin resistance in morbidly obese humans. Biochem. Biophys. Res. Commun. 2011, 404, 382–387. [CrossRef]

123. Sun, Y.; Wang, H.; Wang, W.; Hu, B.; Zhou, L.; Ye, H.; Zeng, X. Changes in molecular structure of chickpea starch during processing treatments. A thin layer chromatography study. Food Chem. 2018, 243, 186–191. [CrossRef]

124. Villani, T.S.; Reichert, W.; Ferruzzi, M.G.; Pasinetti, G.M.; Simon, J.E.; Wu, Q. Chemical investigation of commercial grape seed extractives. Food Chem. 2015, 170, 271–280. [CrossRef]

125. Wacoo, A.P.; Wendiro, D.; Vuzi, P.C.; Hawumba, J.F. Methods for Detection of Aflatoxins in Agricultural Food Crops. J. Appl. Chem. 2014, 2014, 706291. [CrossRef]

126. Cabezudo, I.; Salazar, M.O.; Ramallo, I.A.; Furlan, R.L.E. Effect-directed analysis in food by thin-layer chromatography assays. Food Chem. 2022, 390, 132937. [CrossRef] [PubMed]

127. Lin, L.; Zhang, J.; Wang, P.; Wang, Y.; Chen, J. Thin-layer chromatography of mycotoxins and comparison with other chromato- graphic methods. J. Chromatogr. A 1998, 815, 3–20. [CrossRef]

128. Sereshti, H.; Poursorkh, Z.; Aliakbarzadeh, G.; Zarre, S. Quality control of saffron and evaluation of potential adulteration by means of thin layer chromatography-image analysis and chemometrics methods. Food Control 2018, 90, 48–57. [CrossRef]
154. Rawson, A.; Sunil, C.K. Recent Advances in Terahertz Time-Domain Spectroscopy and Imaging Techniques for Automation in Agriculture and Food Sector. Food Anal. Methods 2020, 15, 498–526. [CrossRef]

155. Jan, A.; Fandiselvam, R.; Kothakota, A.; Sruthi, N.; Ramesh, S. Terahertz Spectroscopy Imaging Technique: Non-Destructive Tool For Evaluation Of Quality And Safety Of Food Products. In Handbook of Research on Food Processing and Preservation Technologies; Apple Academic Press: New York, NY, USA, 2021; pp. 141–157.

156. Feng, C.H.; Otani, C. Terahertz spectroscopy technology as an innovative technique for food: Current state-of-the-Art research advances. Crit. Rev. Food Sci. Nutr. 2021, 61, 2523–2543. [CrossRef]

157. Asfah-Hejri, L.; Hajeb, P.; Ara, P.; Elsani, R.J. A Comprehensive Review on Food Applications of Terahertz Spectroscopy and Imaging. Compr. Rev. Food Sci. Food Saf. 2019, 18, 1563–1621. [CrossRef]

158. Kawano, Y.; Ishibashi, K. An on-chip near-field terahertz probe and detector. Nat. Photonics 2008, 2, 618–621. [CrossRef]

159. McIntosh, A.I.; Yang, B.; Goldup, S.M.; Watkinson, M.; Donnan, R.S. Terahertz spectroscopy: A powerful new tool for the chemical sciences? Chem. Soc. Rev. 2012, 41, 2072–2082. [CrossRef] [PubMed]

160. Wang, K.; Sun, D.-W.; Pu, H. Emerging non-destructive terahertz spectroscopic imaging technique: Principle and applications in the agri-food industry. Trends Food Sci. Technol. 2017, 67, 93–105. [CrossRef]

161. Chen, M.; Lijuan, X. A Preliminary Study of Aflatoxin B1 Detection in Peanut Oil by Terahertz Time-Domain Spectroscopy. Trans. ASABE 2014, 57, 1793–1799. [CrossRef]

162. Liu, W.; Zhao, P.; Wu, C.; Liu, C.; Yang, J.; Zheng, L. Rapid determination of aflatoxin B1 concentration in soybean oil using terahertz spectroscopy with chemometric methods. Food Chem. 2019, 293, 213–219. [CrossRef]

163. Wang, Q.; Xie, L.; Ying, Y. Overview of imaging methods based on terahertz time-domain spectroscopy. Appl. Spectrosc. Rev. 2021, 57, 249–264. [CrossRef]

164. Zhang, W.; Ma, J.; Sun, D.W. Raman spectroscopic techniques for detecting structure and quality of frozen foods: Principles and applications. Crit. Rev. Food Sci. Nutr. 2021, 61, 2623–2639. [CrossRef]

165. He, H.; Sun, D.W.; Pu, H.; Chen, L.; Lin, L. Applications of Raman spectroscopic techniques for quality and safety evaluation of milk: A review of recent developments. Crit. Rev. Food Sci. Nutr. 2019, 59, 770–793. [CrossRef]

166. Deng, J.; Zhang, X.; Li, M.; Jiang, H.; Chen, Q. Feasibility study on Raman spectra-based deep learning models for monitoring the contamination degree and level of aflatoxin B1 in edible oil. Microchem. J. 2022, 180, 107613. [CrossRef]

167. Zhu, C.; Jiang, H.; Chen, Q. High Precise Prediction of Aflatoxin B1 in Pressing Peanut Oil Using Raman Spectra Combined with Multivariate Data Analysis. Foods 2022, 11, 1565. [CrossRef] [PubMed]

168. Yang, M.; Liu, G.; Mehedi, H.M.; Ouyang, Q.; Chen, Q. A universal SERS aptasensor based on DTNB labeled GNTs/Ag core-shell nanotriangle and CS-Fe3O4 magnetic-bead trace detection of Aflatoxin B1. Anal. Chim. Acta. 2017, 986, 122–130. [CrossRef] [PubMed]

169. Chen, Q.; Yang, M.; Yang, X.; Li, H.; Guo, Z.; Rahama, M. A large Raman scattering cross-section molecular embedded SERS aptasensor for ultrasensitive Aflatoxin B1 detection using CS-Fe3O4 for signal enrichment. Spectrochim. Acta Part A 2018, 189, 147–153. [CrossRef] [PubMed]

170. Guo, M.; Hou, Q.; Waterhouse, G.I.N.; Hou, J.; Ai, S.; Li, X. A simple aptamer-based fluorescent aflatoxin B1 sensor using humic acid as quencher. Talanta 2019, 205, 120131. [CrossRef]

171. Chen, Q.; Jiao, T.; Yang, M.; Li, H.; Ahmad, W.; Hassan, M.M.; Guo, Z.; Ali, S. Pre etched Ag nanocluster as SERS substrate for the rapid quantification of AFB1 in peanut oil via DFT coupled multivariate calibration. Spectrochim. Acta Part A 2020, 239, 118411. [CrossRef]

172. Li, J.; Wang, Q.; Xiong, C.; Deng, Q.; Zhang, X.; Wang, S.; Chen, M.M. An ultrasensitive CH3NH3PbBr3 quantum dots@SiO2-based electrochemiluminescence sensing platform using an organic electrolyte for aflatoxin B1 detection in corn oil. Food Chem. 2022, 390, 133200. [CrossRef]

173. He, H.; Sun, D.W.; Pu, H.; Huang, L. Bridging Fe3O4@Au nanoflowers and Au@Ag nanospheres with aptamer for ultrasensitive SERS detection of aflatoxin B1. Food Chem. 2020, 324, 126832. [CrossRef]

174. Jiang, Y.; Sun, D.-W.; Pu, H.; Wei, Q. A simple and sensitive aptasensor based on SERS for trace analysis of kanamycin in milk. J. Food Meas. Charact. 2020, 14, 3184–3193. [CrossRef]

175. Toh, S.Y.; Citartan, M.; Gopinath, S.C.; Tang, T.H. Aptamers as a replacement for antibodies in enzyme-linked immunosorbent assay. Biosens. Bioelectron. 2015, 64, 392–403. [CrossRef]

176. Jiang, Y.; Sun, D.W.; Pu, H.; Wei, Q. Ultrasensitive analysis of kanamycin residue in milk by SERS-based aptasensor. Talanta 2019, 197, 151–158. [CrossRef]

177. Azadnia, E.; Goldoni, L.; Bandiera, T.; Morlock, G.E. Same analytical method for both (bio)assay and zone isolation to identify/quantify bioactive compounds by quantitative nuclear magnetic resonance spectroscopy. J. Chromatogr. A 2020, 1628, 461434. [CrossRef] [PubMed]

178. Malu, S.P.; Donatus, R.B.; Ugye, J.T.; Imarenezor, E.P.K.; Leubem, A. Determination of Aflatoxin in Some Edible Oils Obtained from Makurdi Metropolis, North Central Nigeria. Am. J. Chem. Appl. 2017, 4, 36–40. [CrossRef] [PubMed]

179. Zhang, Y.; Li, M.; Cui, Y.; Hong, X.; Du, D. Using of Tyramine Signal Amplification to Improve the Sensitivity of ELISA for Aflatoxin B1 in Edible Oil Samples. Food Anal. Methods 2018, 11, 2553–2560. [CrossRef]
181. Pundir, C.S.; Yadav, N.; Chhillar, A.K. Occurrence, synthesis, toxicity and detection methods for acrylamide determination in processed foods with special reference to biosensors: A review. *Trends Food Sci. Technol.* 2019, 85, 211–225. [CrossRef]

182. Wang, X.; Shan, Y.; Gong, M.; Jin, X.; Lv, L.; Jiang, M.; Xu, J. A novel electrochemical sensor for ochratoxin A based on the hairpin aptamer and double report DNA via multiple signal amplification strategy. *Sens. Actuators B* 2019, 281, 595–601. [CrossRef]

183. Wang, Z.; Ma, B.; Shen, C.; Cheong, L.Z. Direct, selective and ultrasensitive electrochemical biosensing of methyl parathion in vegetables using Burkholderia cepacia lipase/MOF nanofibers-based biosensor. *Talanta* 2019, 197, 356–362. [CrossRef]

184. Lin, T.; Shen, Y. Fabricating electrochemical aptasensors for detecting aflatoxin B1 via layer-by-layer self-assembly. *J. Electroanal. Chem.* 2020, 870, 114247. [CrossRef]

185. Xuan, Z.; Liu, H.; Ye, J.; Li, L.; Tian, W.; Wang, S. Reliable and disposable quantum dot-based electrochemical immunosensor for aflatoxin B1 simplified analysis with automated magneto-controlled pretreatment system. *Anal. Bioanal. Chem.* 2020, 412, 7615–7625. [CrossRef]

186. Ben Rejeb, I.; Arduini, F.; Arvinte, A.; Amine, A.; Gargouri, M.; Micheli, L.; Bala, C.; Moscone, D.; Palleschi, G. Development of a bio-electrochemical assay for AFBI detection in olive oil. *Biosens. Bioelectron.* 2009, 24, 1962–1968. [CrossRef]

187. Kim, M.; Iezzi, R., Jr.; Shim, B.S.; Martin, D.C. Impedimetric Biosensors for Detecting Vascular Endothelial Growth Factor (VEGF) Based on Poly(3,4-ethylene dioxythiophene) (PEDOT)/Gold Nanoparticle (Au NP) Composites. *Front. Chem.* 2019, 7, 234. [CrossRef]

188. Lu, Y.; Zhang, B.; Tian, Y.; Guo, Q.; Yang, X.; Nie, G. An enhanced photoelectrochemical sensor for aflatoxin B1 detection based on organic-inorganic heterojunction nanomaterial: Poly(5-formylindole)/NiO. *Mikrochim. Acta.* 2020, 187, 467. [CrossRef] [PubMed]

189. Farka, Z.; Jurik, T.; Koval, D.; Trnıkova, L.; Skladal, P. Nanoparticle-Based Immunochemical Biosensors and Assays: Recent Advances and Challenges. *Chem. Rev.* 2017, 117, 9973–10042. [CrossRef]

190. Wang, X.; Wu, X.; Lu, Z.; Tao, X. Comparative Study of Time-Resolved Fluorescent Nanobeads, Quantum Dot Nanobeads and Quantum Dots as Labels in Fluorescence Immunochromatography for Detection of Aflatoxin B1 in Grains. *Biomolecules* 2020, 10, 575. [CrossRef]

191. Perez-Fernandez, B.; de la Escosura-Muniz, A. Electrochemical biosensors based on nanomaterials for aflatoxins detection: A review (2015–2021). *Anal. Chim. Acta.* 2022, 1212, 339658. [CrossRef]

192. Xie, G.; Zhu, M.; Liu, Z.; Zhang, B.; Shi, M.; Wang, S. Development and evaluation of the magnetic particle-based chemiluminescence immunoassay for rapid and quantitative detection of Aflatoxin B1 in foodstuff. *Food Agric. Immunol.* 2015, 27, 22–26. [CrossRef] [PubMed]

193. Neelam; Chhillar, A.K.; Rana, J.S. Enzyme nanoparticles and their biosensing applications: A review. *Anal. Biochem.* 2019, 581, 113345. [CrossRef] [PubMed]

194. Ding, L.; Bond, A.M.; Zhai, J.; Zhang, J. Utilization of nanoparticle labels for signal amplification in ultrasensitive electrochemical affinity biosensors: A review. *Anal. Chem.* 2013, 85, 797–12. [CrossRef] [PubMed]

195. Peltomaa, R.; Benito-Pena, E.; Moreno-Bondi, M.C. Bioinspired recognition elements for mycotoxin sensors. *Anal. Bioanal. Chem.* 2018, 410, 747–771. [CrossRef] [PubMed]

196. Miklos, G.; Angeli, C.; Ambrus, A.; Nagy, A.; Kardos, V.; Jurik, T.; Kovar, D.; Trnkova, L.; Skladal, P. Nanoparticle-Based Immunochemical Biosensors and Assays: Recent Advances and Challenges. *Chem. Rev.* 2017, 117, 9973–10042. [CrossRef]

197. Ma, H.; Sun, J.; Zhang, Y.; Bian, C.; Xia, S.; Zhen, T. Label-free immunosensor based on one-step electrodeposition of chitosan-gold nanoparticles biocompatible film on Au microelectrode for determination of aflatoxin B1 in maize. *Biosens. Bioelectron.* 2020, 11, 1916. [CrossRef]

198. Wang, Q.; Yang, Q.; Wu, W. Progress on Structured Biosensors for Monitoring Aflatoxin B1 From Biofilms: A Review. *Front. Microbiol.* 2020, 11, 408. [CrossRef]

199. Langone, J.J.; Van Vunakis, H. Aflatoxin B1: Specific antibodies and their use in radioimmunoassay. *J. Natl. Cancer Inst.* 1976, 56, 591–595. [CrossRef] [PubMed]

200. Baxin, I.; Tria, S.A.; Hayat, A.; Marty, J.L. New biorecognition molecules in biosensors for the detection of toxins. *Biosens. Bioelectron.* 2017, 87, 285–298. [CrossRef]

201. Ma, H.; Sun, J.; Zhang, Y.; Bian, C.; Xia, S.; Zhen, T. Label-free immunosensor based on one-step electrodeposition of chitosan-gold nanoparticles biocompatible film on Au microelectrode for determination of aflatoxin B1 in maize. *Biosens. Bioelectron.* 2016, 80, 222–229. [CrossRef] [PubMed]

202. Zhao, F.; Tian, Y.; Shen, Q.; Liu, R.; Shi, R.; Wang, H.; Yang, Z. A novel nanobody and mimotope based immunoassay for rapid analysis of aflatoxin B1. *Talanta* 2019, 195, 55–61. [CrossRef]

203. Shi, L.; Wang, Z.; Yang, G.; Yang, H.; Zhao, F. A novel electrochemical immunosensor for aflatoxin B1 based on Au nanoparticles-poly 4-aminobenzoic acid supported graphene. *Appl. Surf. Sci.* 2020, 527, 146934. [CrossRef]
235. Zhou, R.; Zeng, Z.; Sun, R.; Liu, W.; Zhu, Q.; Zhang, X.; Chen, C. Traditional and new applications of the HCR in biosensing and biomedicine. Analyst 2021, 146, 7087–7103. [CrossRef]

236. Wang, Q.; Zhao, F.; Yang, Q.; Wu, W. Graphene oxide quantum dots based nanotree illuminates AFB1: Dual signal amplified aptasensor detection AFB1. Sens. Actuators B 2021, 345, 130387. [CrossRef]

237. Zou, L.; Zhang, M.; Li, M.; Xiao, Z.; Ling, L. Hybridization chain reaction and DNAzyme-based dual signal amplification strategy for sensitive fluorescent sensing of aflatoxin B1 by using the pivot of triplex DNA. Food Res. Int. 2022, 158, 115385. [CrossRef]

238. Molaei, M. Principles, mechanisms, and application of carbon quantum dots in sensors: A review. Anal. Methods 2020, 12, 1266–1287. [CrossRef]

239. Lim, S.Y.; Shen, W.; Gao, Z. Carbon quantum dots and their applications. Chem. Soc. Rev. 2015, 44, 362–381. [CrossRef]

240. Tajik, S.; Dourandish, Z.; Zhang, K.; Beitollahi, H.; Le, Q.V.; Jiang, H.W.; Shokouhimehr, M. Carbon and graphene quantum dots: A review on syntheses, characterization, biological and sensing applications for neurotransmitter determination. RSC Adv. 2020, 10, 15406–15429. [CrossRef] [PubMed]

241. Ye, J.; Zheng, M.; Ma, H.; Xuan, Z.; Tian, W.; Liu, H.; Wang, S.; Zhang, Y. Development and Validation of an Automated Magneto-Controlled Pretreatment for Chromatography-Free Detection of Aflatoxin B1 in Cereals and Oils through Atomic Absorption Spectroscopy. Toxins 2022, 14, 454. [CrossRef]

242. Lu, Z.; Chen, X.; Wang, Y.; Zheng, X.; Li, C.M. Aptamer based fluorescence recovery assay for aflatoxin B1 using a quencher system composed of quantum dots and graphene oxide. Microchem. Acta 2014, 182, 571–578. [CrossRef]

243. Hussain, A.; Sun, D.W.; Pu, H. Bimetallic core shell nanoparticles (Au@AgNPs) for rapid detection of thiram and dicyandiamide contaminants in liquid milk using SERS. Food Chem. 2020, 317, 126429. [CrossRef]

244. Jiao, T.; Ahmad, W.; Zhu, J.; Hassan, M.M.; Wang, J.; Yong, Y.; Guo, Z.; Li, H.; Ding, Z.; Lv, C.; et al. Aggregation triggered aflatoxin B1 determination in foodstuffs employing 5-amino-4tetramethylrhodamine decorated gold–silver core–shell nanoparticles in surface enhanced Raman scattering. Sens. Actuators B 2021, 331, 129424. [CrossRef]

245. Xiong, Z.; Wang, Q.; Xie, Y.; Li, N.; Yun, W.; Yang, L. Simultaneous detection of aflatoxin B1 and ochratoxin A in food samples by dual DNA tweezers nanomachine. Food Chem. 2021, 338, 128122. [CrossRef] [PubMed]

246. Wu, S.S.; Wei, M.; Wei, W.; Liu, Y.; Liu, S. Electrochemical aptasensor for aflatoxin B1 based on smart host-guest recognition of β-cyclodextrin polymer. Biosens. Bioelectron. 2019, 129, 58–63. [CrossRef] [PubMed]

247. Ahmad, O.S.; Bedwell, T.S.; Esen, C.; Garcia-Cruz, A.; Piletsky, S.A. Molecularly Imprinted Polymers in Electrochemical and Optical Sensors. Trends Biotechnol. 2019, 37, 294–309. [CrossRef]

248. Uzun, L.; Turner, A.P. Molecularly-imprinted polymer sensors: Realising their potential. Biosens. Bioelectron. 2016, 76, 131–144. [CrossRef] [PubMed]

249. BellBruno, J. Moleculary Imprinted Polymers. Chem. Rev. 2019, 119, 94–119. [CrossRef] [PubMed]

250. Li, S.; Ge, Y.; Piletsky, S.A.; Lunec, J. Moleculally Imprinted Sensors: Overview and Applications; Elsevier: Amsterdam, The Netherlands, 2012.

251. Haupt, K. Molecular Imprinting; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2012; Volume 325.

252. Mirsky, V.M.; Yatsimirsky, A. Artificial Receptors for Chemical Sensors; John Wiley & Sons: Hoboken, NJ, USA, 2010.

253. Sergey, A.; Piletsky, M.J.W. Designing Receptors for the Next Generation of Biosensors, 1st ed.; Springer: Berlin/Heidelberg, Germany, 2013; Volume 12, p. 264.

254. Lee, S.-W.; Kunitake, T. Handbook of Molecular Imprinting: Advanced Sensor Applications; CRC Press: Boca Raton, FL, USA, 2012.

255. Wang, S.; Zhu, X.; Zhao, M.; Li, S.; Le, Y.; Li, H. Optical sensors based on molecularly imprinted nanomaterials. In Smart Nanomaterials for Sensor Application; Bentham: Oak Park, IL, USA, 2012; pp. 60–75.

256. Alvarez-Lorenzo, C. Handbook of Moleculatory Imprinted Polymers; Smithers Rapra: Shawbury, UK, 2013.

257. Chen, L.; Wang, X.; Lu, W.; Wu, X.; Li, J. Molecular imprinting: Perspectives and applications. Chem. Soc. Rev. 2016, 45, 2137–2211. [CrossRef]

258. Sergyeyeva, T.; Yarynka, D.; Piletska, E.; Linnik, R.; Zaporozhets, O.; Brovko, O.; Piletsky, S.; El’skaya, A. Development of a smartphone-based biomimetic sensor for aflatoxin B1 detection using molecularly imprinted polymer membranes. Talanta 2019, 201, 204–210. [CrossRef]

259. Gu, Y.; Wang, Y.; Wu, X.; Pan, M.; Hu, N.; Wang, J.; Wang, S. Quartz crystal microbalance sensor based on covalent organic framework composite and molecularly imprinted polymer of poly(o-aminophenol) with gold nanoparticles for the determination of aflatoxin B1. Sens. Actuators B 2019, 291, 293–297. [CrossRef]

260. Gui, R.; Jin, H.; Guo, H.; Wang, Z. Recent advances and future prospects in molecularly imprinted polymers-based electrochemical biosensors. Biosens. Bioelectron. 2018, 100, 56–70. [CrossRef] [PubMed]

261. Cavaliere, C.; Foglia, P.; Guarino, C.; Nazzari, M.; Samperi, R.; Lagana, A. Determination of aflatoxins in olive oil by liquid chromatography–tandem mass spectrometry. Anal. Chim. Acta 2007, 596, 141–148. [CrossRef]

262. Tan, H.; Ma, L.; Guo, T.; Zhou, H.; Chen, L.; Zhang, Y.; Dai, H.; Yu, Y. A novel fluorescence aptasensor based on mesoporous silica nanoparticles for selective and sensitive detection of aflatoxin B1. Anal. Chim. Acta 2019, 1068, 87–95. [CrossRef]

263. Xia, X.; Wang, Y.; Yang, H.; Yong, Y.; Zhang, K.; Lu, Y.; Deng, R.; He, Q. Enzyme-free amplified and ultrasensitive detection of aflatoxin B1 using dual-terminal proximity aptamer probes. Food Chem. 2019, 283, 32–38. [CrossRef]

264. Xiao, M.W.; Bai, X.L.; Liu, Y.M.; Yang, L.; Liao, X. Simultaneous determination of trace Aflatoxin B1 and Ochratoxin A by aptamer-based microchip capillary electrophoresis in food samples. J. Chromatogr. A 2018, 1569, 222–228. [CrossRef]
265. Li, R.; Wang, X.; Zhou, T.; Yang, D.; Wang, Q.; Zhou, Y. Occurrence of four mycotoxins in cereal and oil products in Yangtze Delta region of China and their food safety risks. Food Control 2014, 35, 117–122. [CrossRef]

266. Chen, Y.; Yang, Y.; Wang, Y.; Peng, Y.; Nie, J.; Gao, G.; Zhi, J. Development of an Escherichia coli-based electrochemical biosensor for mycotoxin toxicity detection. Bioelectrochemistry 2020, 133, 107453. [CrossRef] [PubMed]