Detection Technology of Aflatoxin Content Based on Smart Phone

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Abstract. Grain and agricultural products contaminated by AFTB1 have a strong carcinogenic effect that may damage people’s health. Rapid and effective screening of agricultural products contaminated by AFTB1 is an effective measure to ensure food safety and body health. This paper analyzes the fluorescence characteristics of AFTB1, and designs a smart phone detection system composed of portable optical device and smart phone detection software. The portable optical device uses ultraviolet light LED as an excitation source to excite fluorescence, and uses smart phone’s CMOS image sensor to collect fluorescence. It is convenient to connect with the CMOS image sensor with the help of portable optical device, thereby realizing image storage, processing and transfer of the observed object. The software developed for image acquisition and data processing on the smart phone can analyze and process the fluorescence image of AFTB1, obtain the fluorescence concentration of AFTB1 measured, and display the AFB1 content data, to achieve quantitative detection of AFB1.

1. Introduction
In the process of storage, transportation and processing, grain and agricultural products are prone to have aflatoxin due to the influence of temperature and humidity, and thus producing aflatoxin (AFT) B1. AFTB1 is a highly toxic substance, with a strong carcinogenic effect, and its main target organ is the liver. Agricultural products contaminated by AFTB1 will lose production value, food value and economic value. The food with AFTB1 will cause great damage to people’s internal organs, especially the liver [1]. Therefore, rapid screening of agricultural products contaminated by AFTB1 is an effective measure to ensure food safety and people’s health, thereby promoting international trade exchanges and socio-economic development.

2. Design Principle and Institutions
The traditional aflatoxin detection methods mainly include chemical analysis method, biological analysis method and fluorescence spectrum detection method using a photomultiplier tube as a fluorescence detector. Although the detection accuracy is high, the detection process is complicated, the operation of the instrument is difficult, the equipment is expensive, and the professional requirements are high, which are not conducive to rapid on-site detection of aflatoxin content in grain and agricultural products. This paper analyzes the fluorescence characteristics and fluorescence generation mechanism of aflatoxin, and proposes a scheme of detecting the content of aflatoxin in...
grain and agricultural products by using ultraviolet LED to induce fluorescence spectroscopy. Fluorescence is excited by ultraviolet LED, and CMOS image sensor of smart phone collects the fluorescent image.

2.1. Design Principle
More than 20 kinds of AFT and its derivatives have been separated so far, and the AFTs commonly found in grain and agricultural products include AFTB1, AFTB2, AFTG1, and AFTG2. Studies have shown that these four substances can be distinguished by the color of the fluorescence emitted under the excitation of ultraviolet light. According to the color of the emitted fluorescent light, AFT is divided into two categories, B group (blue fluorescence) and G group (green fluorescence). When the excitation light wavelength is 365nm, the fluorescence emission wavelength of B-type AFT is 425nm, and that of G-type AFT is 450nm [2]. Among the mycotoxins that have been discovered so far, AFTB1 is the most toxic and carcinogenic, and can induce a variety of cancers at the same time, and its pollution to rice is very serious. Since AFTB1 rice emits fluorescence at a wavelength of 425nm under the excitation of ultraviolet light of 365nm, and the greater the toxin content, the stronger the fluorescence emitted, the camera of smart phone can be used to collect the fluorescent image. The color feature is collected in the form of image, and then the collected images are processed by special image processing software or an APP program installed on the smart phone to realize the quantization of signals, thus displaying data results.

2.2. Overall Design
The detection system comprises a fixing frame, a smart phone, a micro-focus lens, a filter, a convex lens, an ultraviolet LED, a sample, a sample cell, a sealed cavity, a circuit board, a battery and a control button, and a sample cell is arranged below the sealed cavity. The middle of the sample cell is where the sample is placed. A fixing frame is arranged above the sample cell, and a micro-focus lens, a convex lens, a filter, and an ultraviolet LED are respectively arranged from bottom to top in the fixing frame; the battery and the control button are connected to the circuit board through a circuit. The human-computer interaction module, the battery and the control button are all disposed outside the sealed cavity. There is a mobile phone positioning slot on the fixing frame, and a 10mm×30mm bayonet hole is arranged in the middle of the mobile phone positioning slot for placing the CMOS image sensor of smart phone to obtain an excited fluorescent image of the reaction zone on the sample cell.

3. Key Component Design

3.1. Fluorescence Excitation
The selection of the excitation source is the key to the whole system. It is not simply to illuminate the object, and the cooperation of the light source and the driving scheme should highlight the characteristics of the object to be tested. There are several factors to consider: the stability of the light source affects the accuracy of the measurement; the efficiency of the fluorescence conversion, when aflatoxin is illuminated by monochromatic excitation light sources with different wavelengths, is different; the intensity of the light source affects the sensitivity of the measurement, for only the light source with sufficient intensity can make the converted fluorescence intense enough, to ensure high sensitivity. However, if the light source is too strong, the aflatoxin will be easily decomposed under the long-time irradiation of the strong excitation light source, and the fluorescence emission intensity will be decreased. In order to avoid errors caused by photodecomposition, the excitation source can only be turned on during the fluorescence time [2]. The detection system uses ultraviolet LED (wavelength 365nm ~ 370nm, diameter 5mm, emission angle 100 ~ 1200, current 20mA, forward working voltage 3.2V ~ 3.8V) as the excitation light source, and its center wavelength is in good agreement with the fluorescence excitation. A plurality of ultraviolet LEDs are arranged to form an
ultraviolet LED array, which is distributed in a circular light-emitting space and emits ultraviolet rays to irradiate samples containing aflatoxin at a certain radiation power to excite fluorescence.

3.2. Fluorescence Signal Detection

In order to achieve a reasonable or even the best match between the fluorescence emitted by aflatoxin and the CMOS image sensor, it is necessary to process fluorescent signal [3]. Since the efficiency of the conversion of ultraviolet light to aflatoxin to fluorescence is only 18%, the fluorescence intensity is weak. A convex lens (diameter 77.5mm, height 29.5mm, side thickness 5mm, focal length 50mm, angle 50 ~ 90°, light transmittance 98% and aspheric design) is used to gather the fluorescence, allowing the fluorescence to reach the photodiode as much as possible. There are also scattered light and stray light in the fluorescent light path. A projection-type quartz glass filter (diameter 63mm, ultraviolet cutoff wavelength 400nm, ultraviolet cutoff rate ≥99.5%) is installed outside the receiving end of the photodiode, the filter is transparent only for the fluorescence with wavelength >400nm in the continuous spectrum and prevents the entry of ultraviolet light with wavelength ≤400nm and other lights.

The holes in the phone’s positioning slot are designed to match the buttons on the phone to prevent mechanical touches from affecting phone operation. Since the focal length imaging distance of the camera on the smart phone is not long enough to meet the needs of the experiment, a micro-focus lens is added to the detector to make the mobile phone obtain the largest and clearest image when the imaging distance is 15mm~25mm. Use the card slot to clamp the phone, adjust the lens bayonet, make the phone lens placed in the middle of the bayonet hole, turn on the phone camera function, adjust the optical axis position of the phone lens and micro-focus lens, filter and convex lens; turn on the phone camera again. The observation image is located in the center, which is clearly visible. Obtaining high-quality images is to ensure the objectivity, accuracy and repeatability of mobile phone’s imaging quality detection results.

Aflatoxin content detection system requires the cooperation between software and hardware. Android mobile phone is a very popular image acquisition device that has been widely used in many occasions. This paper uses Android mobile phone as the development platform of detection software to compose APP software. The software is divided into five basic modules, reading image, calibrating wavelength, drawing spectral curve, calculating optical parameters, and drawing chromaticity diagram. The acquired fluorescent image signal is introduced into the software, RGB value of the spectrum is extracted from the spectrum image, the gradation value of each pixel point is obtained from the RGB value of each pixel point, and according to the proportional relationship between the gray value of the calibration light source and the energy value, the gray value of the light source to be tested is converted into energy value [4].

4. Test Results

When using the aflatoxin content detection system to detect the aflatoxin content of grain and agricultural products, the error of the detection system should be taken into account, and calibration methods are needed to improve the accuracy. As B1 in aflatoxin has the strongest toxicity, standard aflatoxin is purchased from the Institute, and according to The Limits of Mycotoxins in Foods (GB2761-2011), the National Food Safety Standard of the Ministry of Health of the People’s Republic of China, the limit indicator of B1 in aflatoxins is used to calibrate the aflatoxin spectral detector. Evenly put 1ug of standard aflatoxin into 50g of rice and rice products from which aflatoxin is removed, just reaching the highest limit of standard (GB2761-2011), which is applied as a test sample. The sample is placed in the sample cell of the detector to prevent light leakage, and the test results are compared with the results measured according to the method specified in GB/T18979 to verify the feasibility and practicability of the detection system designed by the project. Then increase and decrease the content of standard aflatoxin in rice products, put it into the sample cell in the detection system for airtight detection, compare the test results with the results measured according to the
method specified in GB/T18979, verify the accuracy and error of the detection system, extract the
function data of detection system, and input the data into the software as a relevant basis.

5. Conclusion
The sample detection is realized by the aflatoxin content detection system of the smart phone, and the
content of AFB1 in the sample is directly displayed, thereby realizing rapid, simple and low-cost
quantitative detection of AFB1. Compared with traditional instrumental analysis methods, the
aflatoxin content detection system is more lightweight, portable, and the operator can skillfully master
without special training. It can reliably detect the content of aflatoxin in grain and agricultural
products, help know the changes in the quality of grain and agricultural products in time, and reduce
the harm caused by food mildew to people's health. It can be widely used in rapid on-site batch
detection and quality control in fields including food processing, breeding, customs, storage, shopping
malls, family farming and the like.

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