Design of OTA Contaminated Feed Screener Based on Light Intensity Sensor

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Abstract. OTA is one of the major pollutants in grain and agricultural products. The key to preventing ochratoxin poisoning in livestock and poultry is to prevent feed containing OTA from being eaten by them. The availability of OTA contamination in feed is helpful to the development of the aquaculture. This paper is based on the fluorescence characteristics and mechanism of OTA, and ultraviolet LED is used as the excitation light source. It uses light intensity sensor to collect fluorescence signal and convert photoelectric signal, and uses single-chip microcomputer to control and designs OTA contaminated feed screener. The screener is made into a rod, which is quite easy to insert into the feed pile for detection, and can make qualitative screening of AFT in the feed quickly on the spot.

1. Introduction

Ochratoxin is a toxic secondary metabolite produced by eurotium and aspergillus. Among them, ochratoxin A (OTA) is the most toxic and widely distributed[1]. OTA has not only liver/kidney toxicity and immunotoxicity, but also carcinogenicity, teratogenicity and mutagenicity[2]. Because of the uneven distribution of OTA in the feed, ochratoxin can only be produced in large quantities when the temperature and humidity come to the optimum conditions for toxin generation. OTA is a substance that is rather difficult to accurately measure. Every step of the measurement is accompanied by errors, the largest of which comes from the sampling process. If we want to get representative samples, we need a large number of samples, but it will increase the time and cost of detection[3]. This paper analyzes the fluorescence characteristics and mechanism of OTA, and puts forward a scheme of screening OTA in feed with ultraviolet LED emitting yellow-green fluorescence. It designs an OTA contaminated feed screener , which consists of fluorescence excitation, fluorescence collection, photoelectric conversion system, data fitting processing and display system. The screener uses a digital control circuit, and the whole circuit consists of a control system with a single-chip microcomputer as the core.

2. Design Principle and Mechanism

2.1 Design Principle

OTA can produce fluorescence with a wavelength greater than that of the irradiated light when excited by ultraviolet light. The stronger the fluorescence, the higher the content and the more serious the contamination of the material. Because the corn contaminated by ochratoxin will produce fluorescence with wavelength of 450nm ~ 580nm when excited by ultraviolet of 330nm, the higher the toxin content is, the stronger the fluorescence intensity will be. Therefore, fluorescence analysis can be used to screen for corn contaminated with ochratoxin. Ultraviolet LED with wavelength of 330±5nm is selected as the excitation light source, so that the fluorescence spectrum range emitted by ochratoxin conversion is reasonable, with long peak wavelength and high fluorescence brightness. The fluorescent signal is selectively collected through the filter, and the fluorescent signal is collected and photoelectric converted by the color sensor to obtain the converted fluorescent electric signal. Besides, an amplification and digital-to-analog conversion circuit are designed according to the characteristics of the ochratoxin fluorescent electric signal. After amplifying circuit and digital-to-analog conversion, the photoelectric converted electric signal is processed by data fitting by single-chip microcomputer to get the content information of OTA[4].

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2.2 Overall Design

OTA contaminated feed screener includes photoelectric detection head, stainless steel tube, circuit board, human-computer interaction circuit, battery, etc. The stainless steel tube is evenly drilled with 8 detection holes. The photoelectric detection head is fixed in the stainless steel tube and the bolt frame is fixed on the detection hole. The screen is made into a rod, which is easy to insert into the feed pile for detection. The photoelectric detection head consists of shell, ultraviolet LED, filter and visible light intensity sensor. The ultraviolet LED and visible light intensity sensor of 8 photoelectric detection heads are connected to the control circuit board after connecting with the amplifier circuit through wires; Human-computer interaction and batteries are connected with the circuit board through the circuit[5].

3. Hardware Component

3.1 Photoelectric Detection Head

The selection of excitation light source is the key of the whole system, which is not simply illuminating the object. The cooperation of the light source and the driving scheme should highlight the characteristics of the object to be measured as much as possible. It considers factors as follows. The stability of light source affects the accuracy and veracity of measurement; The efficiency of conversion from OTA to fluorescence is different with monochromatic excitation light sources of different wavelengths; The intensity of the light source affects the sensitivity of the measurement. Only when the light source has enough intensity can the converted fluorescence have enough intensity to ensure high sensitivity. However, if the light source is too strong, OTA will easily decompose under the long-term irradiation of a strong excitation light source, and on the contrary, the fluorescence emission intensity will decline. In order to avoid errors caused by photolysis, the excitation light source can only be turned on during the fluorescence. The photoelectric detection head uses ultraviolet LED (spectral distribution range: 315nm ~ 345nm, central wavelength: 330nm, size: 6mm×6mm, emission angle: 110-1200, current: 20mA, forward working voltage: 3.3v) as the excitation light source. Its central wavelength matches well with fluorescence excitation. 8 ultraviolet LED are used to form an ultraviolet LED array, which is distributed in a circular luminous space. Under the control of single-chip microcomputer, the feed containing OTA may be irradiated by ultraviolet light at a certain radiation power, a certain illumination intensity and a certain illumination frequency to stimulate fluorescence.

The photoelectric conversion part is the main one to realize photoelectric detection. Its main function is to convert fluorescent signal into fluorescent electric signal. In order to achieve reasonable or even best matching between the fluorescence emitted by OTA and the fluorescence detector, it is necessary to process the fluorescence signal. As scattered light and stray light still exist in the fluorescence path, a filter is installed outside the receiving end of the visible light intensity sensor. In the continuous spectrum, the filter can only pass through the fluorescence with wavelength of 460nm ~ 590nm, which prevents the entry of ultraviolet light and other light.

This design uses the visible light intensity sensor (ON9658) developed by Shenzhen on Institute of Optical & Electronic Technology, whose typical incident wavelength is 520 nm. This is an integrated photoelectric sensor, which is composed of double silicon photodiode and other devices. It is mainly made up of voltage regulator circuit, photodiode, operational amplifier and linear correction circuit. It has a high sensitivity in the range of visible light, and the output current changes linearly with the illumination, as shown in Fig. 1. Electric characteristics: Working voltage range is 2.4 ~ 12V; The output is current signal, which changes linearly with the change of light intensity, with small dark current, low illumination response and high sensitivity; Built-in dual sensitive elements, high sensitivity, automatic attenuation near infrared, spectral response close to human eye function; Built-in micro-signal CMOS amplifier, high precision voltage source and correction circuit, large output current, wide operating range, good temperature stability. Optical nano-epoxy resin packaging, visible light transmission, ultraviolet cut-off, near infrared relative attenuation, which enhances the optical filtering effect[6].

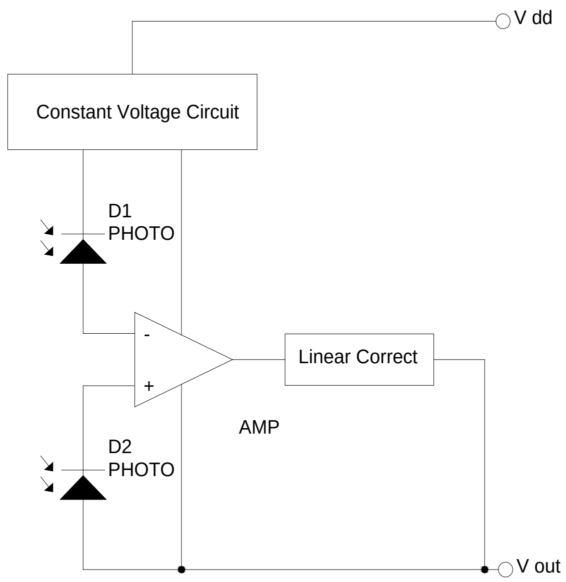

Fig. 1 Structure Diagram of Light Intensity Sensor ON9658

3.2 Signal Conversion Circuit

Since the sensor ON9658 outputs current, which is an analog signal, the external analog quantity is received and processed by the computer, which must be converted from analog to digital signal. The converter used is called analog-to-digital converter, which can be referred to as AD converter by symbol. The double integral high precision bit half-weighted AD converter ICL7135 is selected, which is quite easy to connect with the single-chip microcomputer. The data collected by the single-chip microcomputer is in serial mode. ICL7135 has the advantages of high resolution, strong anti-interference ability and low cost. It also has 14-bit resolution and highly adaptive interface design; The maximum output range of digital signal is 0 ~ 19999, and the minimum conversion error can be accurate to ±1 bit; The input of analog signal has the characteristics of high stability. The chip pins are shown in Fig. 2.

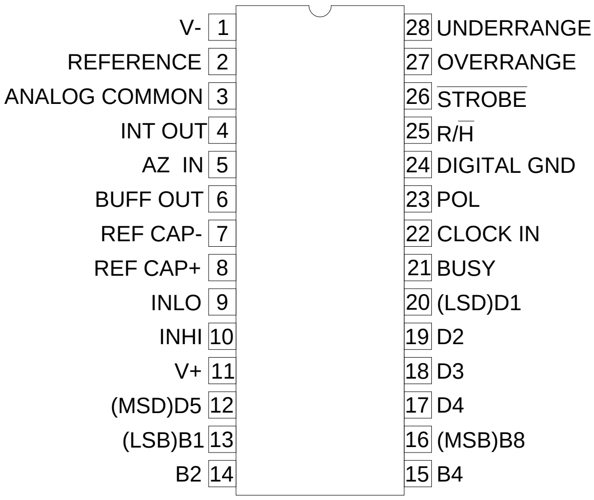

Fig. 2 Chip Pin Diagram of ICL7135

Through a low-pass filter composed of resistance and capacitance, the output analog electric signal of sensor ON9658 is filtered to remove input interference. It inputs from the "2" pin (input REF) of the analog-to-digital converter ICL7135. The "21" pin (output BUSY) signal of AD converter ICL7135 is connected with the P3.2 (INTO) of single-chip microcomputer AT89C52. In addition, BUSY signal is used as the external start signal of AT89C52 timer T0. When the integration phase starts, the BUSY signal jumps from low to high, and the BUSY signal starts the timer to start counting. When ICL7135 is changed from the forward integration stage to the reverse integration stage, the BUSY signal is still at a high level, and T0 retains the counting state. When the back integration phase ends, the BUSY signal becomes low, and the timer stops counting. In this way, the timer T0 counting is synchronized with the integration phase of the analog-to-digital converter. The result of timer counting is proportional to the number of pulse cycles measured by ICL7135.

3.3 Single-chip Microcomputer

OTA contaminated feed screeners need the cooperation of software and hardware to complete the detection. Considering that the system needs high reliability, low power consumption and multiple I/O interfaces, the system chooses single-chip microcomputer (model AT89C52) as the control core. It mainly completes the interface with other circuits, so as to process the data obtained from the outside, and express the processing results in a certain way, like display or alarm. The screener has the function of real-time sampling and timely analysis. In the process of detection, it needs to input many commands, design human-computer interaction module, install buzzer to alarm, and give out the over-standard instructions. As the screener detects the feed contaminated by OTA, the buzzer will give out an alarm and light up the LED (red LED indicates abnormal alarm of FTB1 and green LED indicates normal), and display the relevant data through the LCD screen.

The AT89C52 is a CMOS 8-bit single-chip microcomputer with low voltage and high performance. Its chips contain 8k bytes of repeatable Flash read-only program memory and 256 bytes of random access data memory (RAM), which is an efficient micro-controller. It provides a highly flexible and cheap scheme for many embedded control systems, and provides many control applications for more complex systems.

4. Software

According to the control task of the system, the software design of this system is mainly made up of main program, initialization program, display subroutine, data collection subroutine and delay program. In order to facilitate the development of the program and the subsequent use and maintenance, all the programs use a modular structure, that is, a main program and several subroutine modules. The main program must first complete the initialization. This includes system clock initialization, interrupt initialization, timer initialization, LCD module initialization, initialization of other parameters, and so on. The timer is then started for timing, and the interrupt is turned on to allow the single-chip microcomputer to respond to requests for internal and external interrupts. The function modules of each program include OTA detection, keyboard control, LCD display, alarm prompt and so on. All programs are written in C assembly language. The idea of software design is described as follows: The function of the main program is to initialize the program, calculate the OTA content (obtained in the timing interrupt program and the INT0 external interrupt program), as well as display the decimal content. T0 is set as counting mode and T1 as timing mode. R0 is the flag register, and when it is OOH, it is the normal display mode. When it is 01H, it is in the cumulative display mode, in T1 timing interrupt program. Sample material content in 2 seconds (converted to pulse frequency), and assign values to calculate RAM area and display RAM area.

Conclusion

The application shows that the screener has the advantages of high detection accuracy, simple detection process, simple instrument operation, low professional requirements, easy to insert into the feed pile for detection, reliable and durable, low cost and so on. In this way, OTA in feed can be reliably detected, changes in feed quality can be timely understood, and the harm of feed mildew to livestock and poultry health can be reduced.

Acknowledgments

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