Food-Care: An Optoelectronic Device for Detection of Fertilizer Contamination in Fruits and Vegetables in Smart Agriculture Framework

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***Abstract*—In this work, a portable device for real-time detection of nitrate concentration for fruits and vegetables is developed. First, the identification of the target wavelength was carried out by measurement of standard nitrate solutions on a UV-Visible 730 spectrometer of spectrum range between $200nm$ and $800nm$. The experimental results reveal a peak absorbance spectrum of $265nm$ at different nitrate concentrations. Then a novel device is developed consisting of UVC-LED, quartz, photodiode, trans-impedance amplifier, micro-controller, A to D converter, display unit, and a power supply. The quartz cuvettes of length $10mm$ are placed between LED and photodiode for measurement of standard nitrate solutions. When LED is turned on the attenuation of the light beam is measured in terms of photodiode current and further amplified through a trans-impedance amplifier for readout circuitry. The developed prototype shows good linearity over amplifier response for nitrate concentration of $10-100\mu g/mL$ with a correlation coefficient $R^2 = 0.998$. As the device operates at a very low voltage (of the order 5 V), it can be easily powered by a rechargeable battery or a smartphone.**

***Index Terms*—Smart Agriculture, Smart Sensing, Food Quality, Fertilizer Contamination**

I. Introduction

Smart agriculture framework collects and analyzes various sensor data to monitor parameters of agriculture/farming including crop health, environmental conditions, and soil moisture [1]. The major challenges of smart agriculture include contamination of food products due to the excess of fertilizers in crops during farming. The nitrate contents in fruits and vegetables are mainly from artificial fertilizers such as calcium nitrate, ammonium nitrate, sodium nitrate, potassium nitrate, and urea nitrogen in fertilizer by soil transfer [2]. Essentially, nitrate is a non-toxic compound for the human body if it is above 3.7 mg/kg body weight as prescribed by World Health Organization [3]. High levels of nitrates have also been found in the blood, urine, and cancer tissue that cause bladder cancer, non-Hodgkin's lymphoma, and stomach cancer [4]. In addition, nitrates may cause called methemoglobinemia (also known as "blue baby syndrome"), which occurs mainly in babies under three months of age [5]. Hence, the monitoring of nitrate concentration in food substances is very crucial before consummation to maintain healthy habits. In literature, various methods have been developed for nitrate detection including UV-Vis-NIR spectrophotometry, high-performance liquid chromatography (HPLC), ion chromatography (IC), gas chromatography (GC), polarography and capillary electrophoresis (CE) [6]. The above methods of nitrate measurement require centralized facilities with specialized instruments, tools, and equipment, as well as trained human resources, and the testing results usually take one to two days to be issued [7].

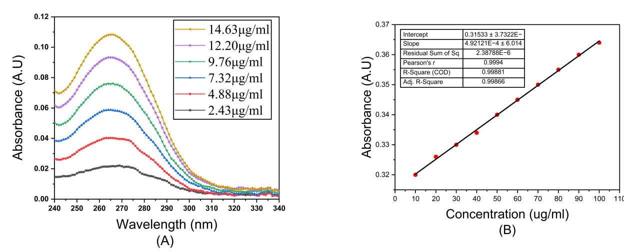

Fig. 1: Absorbance measurement at (A) different wavelength (B) different nitrate stock solution using UV-Visible 730 spectrometer.

In this work, we developed a prototype for a low-cost optoelectronic-based sensing system for onsite monitoring of nitrate content in fruits and vegetables. The proposed device is portable, inexpensive, and less time-consuming for measuring the concentration of nitrates. Hence, It can be a good product for such kind people who care about the quality of fruits and vegetables.

II. Identification of target wavelength

The standard laboratory UV spectrophotometer is used to identify the target wavelength of nitrate ions in the test solution by the principle of absorbance. All measurements were performed using the JASCO UV-Visible 730 spectrometer of the spectrum range between $200nm$ and $800nm$. The test nitrate sample is prepared using standard sodium nitrate that is dried for 1 hour at $110°C$ in a laboratory environment. After cooling it in the desiccator $13.8mg$ of sodium nitrate (equivalent to $10.0mg$ of nitrate) is transferred to a $100.0ml$ volumetric flask. Then $60.0ml$ of distilled water is mixed into it until dissolved.

Further, it is again diluted with the distilled water to obtain a nitrate concentration of $100.00\mu g/mL$).

The testing was performed at a different wavelengths from 200 nm to 340 nm and the absorbance of the spectrometer is recorded. Fig. 1(a) shows measurement results of the different nitrate concentrations mainly $2.44\mu g/mL, 4.88\mu g/mL, 7.32\mu g/mL, 9.75\mu g/mL,$ $12.19\mu g/mL$, and $14.63\mu g/mL$ from Nitrate stock solutions of $100\mu g/mL$. One can see from Fig. 1(a) that the peak absorbance of nitrate ions in the stock solution was achieved at $265nm$ for all the samples. The measured absorbance is proportional to the change in the concentration of the substance in the solution with a linear trend, as shown in Fig. 1(b).

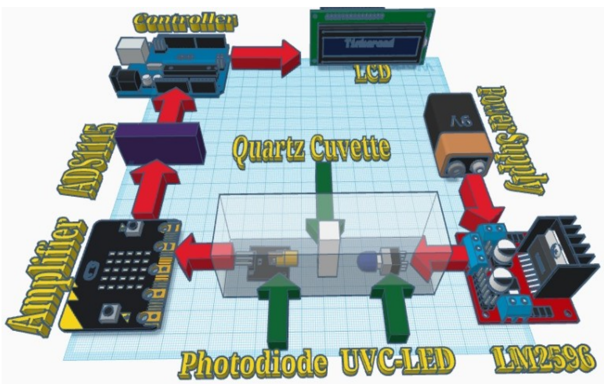

Fig. 2: Experimental setup of the proposed nitrate concentration detector

III. Implementation of Proposed portable device

The Experimental setup of the proposed system is shown in Fig. 2 consists of LED, Quartz, photodiode, trans-impedance amplifier, micro-controller, display unit, A to D converter, and a power supply. The experimental setup was designed in such a way that, each time, the cuvette can easily be taken out and filled with new samples without affecting the position of the other devices. The UVC-LED emits a light spectrum of wavelength 265 nm that will pass through the sample and its rate of absorbance was measured by the photodiode. The input voltage to LED (5 V - 6.7 V) was varied to change the intensity of light emitted and the corresponding output is observed at the photo-detector end. The device includes a trans-impedance amplifier circuit that converts the photo-diode current into equivalent voltage and also amplifies. The output voltage from the trans-impedance amplifier circuit was measured with respect to the LED input voltage. The maximum output voltage across the amplifier is observed at higher LED input corresponding to more intensity of light. The output from the amplifier circuit displayed good linearity with the input voltage to the LED with the correlation coefficient R^2= 0.997 as shown in Fig. 3(a). Further, the developed device is tested for different nitrate concentrations from $10-100\mu g/mL$ and shows very good linearity with amplifier output voltage for the entire range in Fig. 3(b) with correlation coefficient R^2= 0.998. This signifies excellent repeatability and good precision of the proposed device at different sample measurements. The microcontroller will show the predicted nitrate concentration in the display unit, the user can take compare it with the standard value provided by the food safety organization.

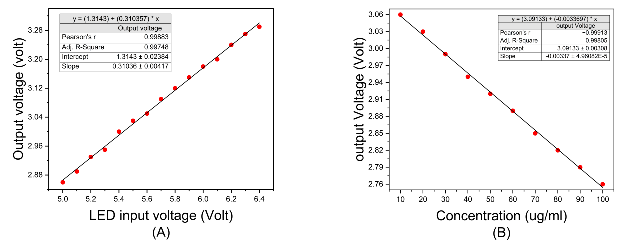

Fig. 3: Amplifier output voltage measurement at (A) different LED input voltage (B) different concentrations of nitrate solutions.

IV. Conclusion

The presented work focuses on developing a miniaturized portable nitrate detection in different fruits and vegetable samples. The proposed device LED can operate between 5V - 6.5 V to detect different nitrate samples with a combination of suitable photo-diode. The measured photodiode current shows good linearity of the device for the entire range of LED input voltage. In order to validate the device, it was tested under a standard sample of nitrate concentration in the range $10-100\mu g/mL$ and shows good linearity with respect to the measured output voltage. The proposed device is portable and low-cost and can be used at any stage of the smart agriculture supply chain for the detection of nitrate contents in fruits/vegetables from farm to table.

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