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Abstract

Advanced Analysis of Solutions with a Low-Cost Electronic Device Containing Color Sensor and Programmable Red, Green, and Blue (RGB) LED †

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Abstract: Although methods for point-of-care testing gains are growing in importance, it is still essential to develop alternatives for tests performed centrally on commercial analyzers, thus making photometry cheaper and more accessible to the public. We introduce a low-cost photometer based on the Arduino with APDS9960 sensor and RBG LED in this work. A photometric platform based on a color sensor can gain a four-signal response. Acetylcholinesterase was chosen as the model element for the biosensor. The device can also easily be upgraded for fluorometric assays.

Keywords: photometry; enzyme biosensor; color analysis; instrumentation

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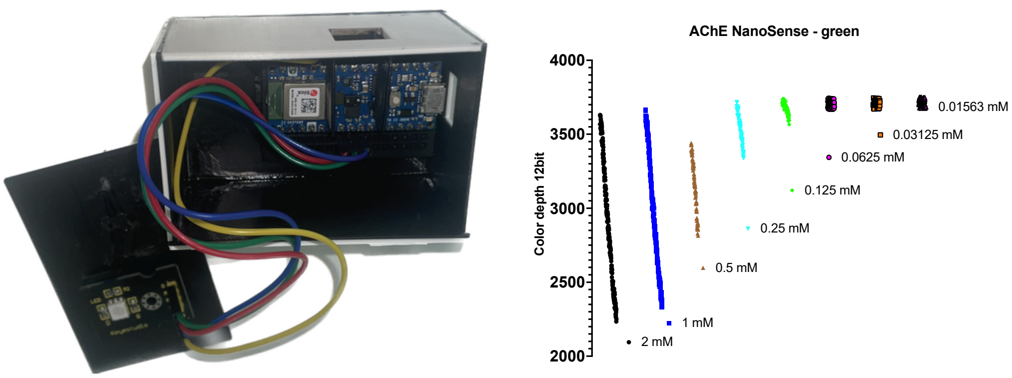
1. Introduction

In the field analysis of cholinesterase inhibitors, one can encounter miniaturized spectrophotometric systems, but reflectance measurements on colored strips are also sometimes encountered [1]. Based on the principle of attaching a sensor to a color surface, color sensors work by having a white LED light in the vicinity and reflected light that passes through filters on the sensor, determining the resulting color. According to the ratio of light incidents on sensors with different color filters (red, green, or blue), acetylcholinesterase was used as a biorecognition element for the determination of pesticides, medicine, and other toxicologically relevant substances, which inhibits the cholinesterase active site [2]. The Ellman method was used for the determination of cholinesterase activity [3]. An enzyme kinetic assay was used to prove the capabilities of the proposed system (Figure 1).



(**a**) (**b**)

Figure 1. (**a**) Overview of proposed system. (**b**) Distribution of signal response to various concentrations of acetylthiocholine. Y-axis shows the color depth of G-channel in 12-bit resolution.

2. Materials and Methods

This work showed the use of color sensor APDS9960 integrated on the Arduino Nano BLE Sense (Arduino, Italy) microcontroller board with a color-programmable RGB LED (Keyestudio, China). ASA signal white and jet black (Prusa research, Czech Republic) and FFF 3D printer i3 MK3S+ with MMU2S upgrade (Prusa Research, Czech Republic) were used to print the box. Acetylcholinesterase from electric eel was used as a biorecognition element, acetylthiocholine chloride was used as a substrate, and phosphate-buffered saline (pH = 7.4) was established for use in the optimal reaction conditions (All chemicals were obtained from Merck (Germany). The programmed color of the LED was equivalent for the wavelength 412 nm. 5′-dithiobis (2-nitrobenzoic acid, DTNB) was used as the chromogenic reagent for an assay lasting 5 min. Data acquisition was carried out through the Visual Studio code interface.

3. Discussion

The use of a color sensor for photometry has been demonstrate recently [4]. Also, the diode array color sensor has already been used as a wireless RFID-like color analyzer on surfaces [5]. To the best of our knowledge, there is not yet a printed paper that maps the coupling of APDS9960 sensor and a RGB LED for photometry. It is the addition of RGB LED that may allow for the response to be monitored in multiple color modes and to switch continuously and verify trends during analysis.

Colorimetric analysis confirmed that the highest difference in signal directly related to cholinesterase activity is in the green channel. It is probably caused by the complementarity of color with the created nitro- 5-thiobenzoic acid, because green color was not used for emission. Decreases in color depth were assessed to be inversely proportional to cholinesterase activity. Validation with inhibitors of cholinesterase is the next step, and changes in RGB LED to LED with emission maximum at approx. 410 nm will be tested for dual-readout photo-/fluorimetry. Tests which use acetylcholinesterase point to the fact that the colorimetric sensor is suitable for the analysis of enzymes, allowing it to serve for diagnosis in clinical biochemistry and toxicology, and it could also be adopted for use in other assays.

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References

1. Matejovsky, L.; Pitschmann, V. A Strip Biosensor with Guinea Green B and Fuchsin Basic Color Indicators on a Glass Nanofiber Carrier for the Cholinesterase Detection of Nerve Agents. *ACS Omega* **2019**, *4*, 20978–20986. [CrossRef] [PubMed]
2. Keresteš, O.; Pohanka, M. Enzymatic Biosensors for the Environmental Analysis of Pesticides. *Chem. Listy* **2022**, *116*, 358–364. [CrossRef]
3. Ellman, G.L.; Courtney, K.D.; Andres, V., Jr.; Feather-Stone, R.M. A new and rapid colorimetric determination of acetylcholinesterase activity. *Biochem. Pharmacol.* **1961**, *7*, 88–95. [CrossRef] [PubMed]

4. de Carvalho Oliveira, G.; Machado, C.C.S.; Inácio, D.K.; Silveira Petruci, J.F.d.; Silva, S.G. RGB color sensor for colorimetric determinations: Evaluation and quantitative analysis of colored liquid samples. *Talanta* **2022**, *241*, 123244. [CrossRef] [PubMed]
5. Lazaro, A.; Boada, M.; Villarino, R.; Girbau, D. Color Measurement and Analysis of Fruit with a Battery-Less NFC Sensor. *Sensors* **2019**, *19*, 1741. [CrossRef] [PubMed]