A paper based colorimeter using smartphone light sensor

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Abstract. A paper-based colorimeter for absorbance and concentration measurement of the food colouring dye is proposed. The paper-based colorimeter system consists of a white LED as light source, paper-based cuvette holder, and smartphone light sensor. The paper-based colorimeter with smartphone light sensor is low-cost, mobile and real-time for the detection of colouring dye concentration. The detection response of the paper-based colorimeter system was found to be linear with the colouring dye concentration in the range from 0 to 0.025 g/mL with a correlation coefficient (R2) 0.89±0.04. The experimental results show that this paper-based colorimeter system is highly sensitive and have a potential application, from student labs to small industries.

1. Introduction
A low-cost, mobile and real-time a colorimeter for the detection of solution concentration it’s important and has a potential prospect to developed. A colorimeter has been used in many applications, such as determining the concentration and a kinetically chemical reaction of solutions in student labs, research, and industries laboratories purpose [1,2]. Many colorimeters scientific and technical approach using different detecting and schematic principle such as a simple colorimeter or UV-Visible spectrometer [1,3]. Currently, Anzalone at al build 3D printable and Arduino-based open-source colorimeter yielded a greater performance compared to the commercial colorimeter [4]. Kehoe et al employ the RGB analysis to the digital image of the liquid solution for an activity on chemical laboratory [5]. Meanwhile, Kuntzleman et al. using a smartphone camera to the RGB analysis on the digital image of coloring solution [6]. However, this experiment needs a sophisticated RGB analysis of digital images. So, it needs a looking for a simplified and potential approach using a common sensor, such as smartphone light sensor [7,8]

In this paper, we report a paper-based colorimeter using smartphone light sensor for the absorbance vs. concentration measurement. The transmittance and absorbance ratios of light source were measured for different concentration of the food coloring dye. This experiment shows a simple relation of the absorbance value to the concentration data is linear by smartphone light sensor. Then, we present a measurement procedure that can be used in student labs to small industries.
2. Methods

The colorimeter system consists of a white LED as light source, paper-based cuvette holder, and smartphone light sensor, shown in Figure 1(a). The paper-based cuvette holder preparation shows at Figure 1(b). The prepared paper-based cuvette holder was constructed in order to Smartphone and cuvette (1x1 cm) can stand upright during the measurement process. The white LED lamp is used as the light source with commonly spectral from 400 nm to 750 nm, with spectral peak at 450 nm (blue), and 550 nm (yellow) \[3,9\]. The light from a white LED entering to the sample solution on cuvette, where the sample molecules and the incident light interaction occurs. After that, the transmitted light enters the smartphone light sensor and converted into lux meter value. The value of transmittance \((T)\) and absorbance \((A)\) can be calculated by the Beer-Lambert Law,

\[
T = \exp(-Ad) = \frac{I_s}{I_R}
\]  
(1)

Figure 1. Schematic diagram of (a) a paper-based colorimeter system, and (b) paper-based cuvette holder.

Figure 2. The digital images of a several solutions of the primary food coloring dye (red, green and blue coloring dye).
\[ A = ac = -\ln(T) = -\ln\left(\frac{I_s}{I_B}\right) \]  

(2)

where where \( I_s, I_R, \alpha, \) and \( c \) are the sample intensity, the reference intensity (or water intensity), molar absorptivity and sample concentration, respectively.

Red, green, and blue commercial food coloring dye was purchased from Cap Kupu Co., Ltd. (Bandung, Indonesia). Deionized water was purchased from the local chemical store. All food coloring dye and water were of analytical grade and were used without further purification. Seven solutions of concentration (0 to 0.025 g/mL) for each type of food coloring dye were prepared using simple dilution method. The cuvette holder was placed in front of smartphone light sensor, with centered at a sensor. The white LED source was arranged in the direct illumination and same distance throughout the experiment.

3. Hazard
High light intensity is harmful to vision if exposed directly. To avoid the high light intensity during an experiment, do not use metal jewelry, watches or other.

4. Results and discussion
The transmittance and absorbance measurements for all food coloring dye using a prepared colorimeter system are shown in Figure 3. The data result shows that a prepared colorimeter system is suitably quantitative for a student labs exercise using Beer’s law to calculate concentration from colorimetric data (Eq. 2). The absorbance vs. concentration plots for primary food coloring dye yielded a straight line relationship and R2 values of 0.89±0.03 using linear interpolation fitting (Figure 3 b). The highest and the lowest absorbance value are reaching by red and green coloring dye, respectively. The high absorbance value of the red coloring dye it caused by the red dye was absorbing almost all visible light and scattered specific (red) wavelength [10]. Therefore, it is also interesting to build a colorimeter system using different of spectral light source such as using spectral filter film.

![Figure 3. (a) Transmittance and (b) absorbance measurement of coloring dye using prepared colorimeter system.](image)

5. Conclusion
A paper-based colorimeter for the absorbance and concentration measurement of the liquid coloring dye has been developing. The paper-based colorimeter system consists of a white LED as light source, paper-based cuvette holder, and smartphone light sensor. The transmittance and absorbance ratios of light source were measured for different concentration of the food coloring dye. This experiment shows a
relation of the absorbance value to the concentration data is linear. Then, we present a measurement procedure that can be used in student labs to small industries.

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