Development of color detector using colorimetry system with photodiode sensor for food dye determination application

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Abstract. Colorimeter is a detector that is used to determine the concentration by analyzing the intensity of light transmitted by the solution. The samples used in this study are harmful and harmless dyes. The light emitted will pass through the sample, so that the beam of light in the sample will be captured by the photodiode sensor. The photodiode sensor functions to convert light into an output voltage. The output voltage will be amplified by a voltage amplifier circuit. The results of the output voltage are confirmed on the arduino which is then displayed on the LCD. In this paper, we will explain the performance of color detector devices that have been developed and their implications for the field of medicine and food.

1. Introduction

Plants are one of the living things in the world. Plants have varied colors, because they have pigments. So that plants can become one of the natural dyes that have extracts that can be used by humans.

The development of science and technology in humans makes him think to be able to produce a natural thing into something useful and can be developed with a variety of new innovations. Experts also continue to conduct research to produce technology products to meet human needs. The science and technology results have proven to provide many facilities and benefits for humans.

One of the disciplines that contributed significantly to the development of science and technology was Physics. In physics has provided a strong foundation for technological progress. Technological progress that is closely related to the advancement of physics. One of the fields of physics study that is no less rapidly developing today is Electronics and Instrumentation. The advancement of Electronics and Instrumentation is enough to help humans meet their needs. Therefore, the field of Electronics and Instrumentation is a serious and interesting concern among the generation of new technology designers.

The development of science and technology can also be observed in the transition of mechanical or manual systems into digital systems. The transition from a manual system to a digital system requires a sensor. The sensor is a device that can change physical quantities to electrical quantities. A sensor is a device that receives a stimulus and responds with an electrical signal [1]. Through sensors can be
designed various systems that can work automatically and the sensors used in building a measurement and control system vary according to the usefulness of the sensor itself.

1.1. Colorimetric and Colorimeter
Colorimetric or colorimetry is a method used in chemical analysis using a comparison of the color intensity of a solution with the color of the standard solution by measuring the instrument used to measure the comparison of the intensity of this color is the calorimeter [2].

The colorimeter itself is a detector used to determine concentration by analyzing the intensity of light transmitted by the solution [3]. The colorimeter detector works according to the Beer-Lambert Law. Daang rays with a wave length of wave \( \lambda \) have an intensity of \( I_0 \), after passing through the absorbent molecule the intensity becomes \( I \). The intensity of the light decreases indicating the light absorbed by the absorbent molecule.

1.2. Spectrophotometer UV-Vis
Uv-Vis Spectrophotometer (Ultra Violet-Visible) is a tool to measure the transmittance and absorbance of a sample as a function of wavelength. UV-Vis spectrophotometer can be used for qualitative and quantitative analysis of a chemical. Ultraviolet (UV) light has a wavelength between 180-380 nm, and visible light has a wavelength of 380-780 nm shown in Figure 1.

![Figure 1. UV and visible spectrum region](image)

Measurements using a spectrophotometer involved considerable electronic energy in the analyzed molecule, so UV-Vis spectrophotometer was more widely used for quantitative analysis than qualitative. The concentration of the analyte in the sample solution can be determined by measuring the absorbance of the light by the sample at certain wavelengths using the Lambert-Beer law [4].

1.3. Beer-Lambert Law
Beer and Lambert's law states that the absorbance of a sample is directly proportional to the concentration of the sample turned out to be linear. The amount of transmittance is:

\[
T = \frac{I}{I_0}
\]

(1)

A beam of light with an initial intensity (I0) has a wavelength \( \lambda \). Light files are fired towards the sample. Some light will be transmitted or transmitted (I), partially reflected (Ir), and partially absorbed. Transmittance (T) is defined as the ratio between the intensity of light coming out of a solution with the intensity of light coming. Lambert-Beer's law can also be stated in the equation:

\[
A = a.b.c
\]

(2)
A is absorbance or absorption that we will look for systematically, \( a \) is molar absorption (constant type of substance), \( b \) is the thickness of cuvette and \( c \) is the sample concentration.

1.4. Dissolved Substance and Molarity
Substances that have solid and gas phases are commonly referred to as solutes while the liquid ones are said to be solvents. A substance is said to be a solvent if it has more amount than the amount of solute. Under certain conditions, for example a mixture of alcohol and water with a ratio of 50:50. From such a mixture water and alcohol can be said to be solvents and can also be said to be solutes.

Molarity or beauty can be reduced through a dilution process with the consequence of changing the volume of solution. The dilution process is carried out by adding pure water (aquades) to the solution so that the desired beauty is obtained. The dilution process can be done by following the formulation as follows:

\[
V_1M_1 = V_2M_2
\]

Where \( V_1 \) is the initial volume in liters or milliliter (l or ml). \( M_1 \) is the initial molarity in molL\(^{-1}\) or mmolmL\(^{-1}\). \( V_2 \) is the volume after dilution in l or ml. \( M_2 \) is molarity after dilution in molL\(^{-1}\) or mmolmL\(^{-1}\).

1.5. Coloring
Food coloring is an additive added to increase the color of food or drink. Food coloring is mixed to color the food, increase the visual appeal of food, stimulate the senses of sight, and stabilize colors, and overcome color changes. This substance is available in various forms, such as liquids, powders, gels, or pastes. There are 2 kinds of food coloring, which are harmful and harmless food coloring.

![Figure 2. Synthetic dyes](image)

1.6. Dangerous Food Dyes
Food coloring is divided into two, namely natural and synthetic (chemical). Natural dyes are made from plants, animals, minerals, or other natural sources. According to the Republic of Indonesia Health Minister Regulation No.033 of 2012 concerning Food Additives, a list of natural dyes that are permitted are curcumin, riboflavin, carmin and cochineal extract, chlorophyll, caramel, plant carbon, beta-carotene, anato extract, carotenoids, red beets, anthocyanin, and titanium dioxide. Some dyes are also used as a mixture in making food including:

- **Alizarin S**
  Alizarin S is an example of synthetic organic dyes that have the potential to pollute the environment. This is due to the wide use of alizarin S compounds in various industries of textiles, paper, plastics, paints and inks as well as food.

- **Bromphenol Blue**
  Bromphenol Blue is a type of dye from a class of reactive dyes. Bromophenol Blue solution will exchange colors from yellow at PH 3.0 and blue at PH 4.6. at a low pH, this dye will absorb ultraviolet and blue light, and the color seems to be yellow in the solution.
• **Indigo Carmin**
Indigotin (Indugo Carmine) is blue, brown, reddish flour, easy to dissolve in water and the solution is blue. Soluble in glycerol and glycol, slightly soluble in 95% alcohol. This dye is very resistant to light, so the color disappears quickly. Even so the resistance to acid is good, while the concentrated NaOH is less resistant. Not resistant to oxidizing, but rather resistant to reducing agents. Indigotine is not affected by Cu or Al both neutral and acidic solutions.

**1.7. Harmless Food Dyes**
The government has provided a list of dyes that can be used in food. But the fact is that there are still dyes not for foods mixed in snacks, two of which are often found in Indonesia are rhodamine B and methanil yellow.

• **Soursop Leaf Extract**
Soursop (Annona muricata L) is one of the easiest plants to grow. Soursop plants that have been extracted can be used as food coloring ingredients that contain very high anti-oxidants because of their use in food to maintain quality and from changes in food chemical properties due to the oxidation process that occurs especially during storage.

• **Breadfruit Leaf Extract**
Breadfruit leaves are breadfruit plants that have leaves that are easy to grow in both urban and rural areas. Breadfruit leaf extract can be used as food coloring because it contains saponins, flavonoids and tannins so that it is good for health.

• **Dayak Onions**
Dayak onion is a typical plant of Central Kalimantan that is used by Dayak tribal traders as medicine. This plant has a height of about 30-40 cm

**1.8. RGB**
The spectrum of light produced by LED is not just visible light, but can also produce light with an infrared or ultraviolet spectrum. The light produced by low-power LEDs is caused by the transfer of electron and hole charges to a higher energy level or otherwise will produce photons. These photons will be seen in the eye as light. While for LED RGB spectrum can be seen in Figure 4.

![Light Spectrum](image)

**Figure 3. Light Spectrum**
Figure 4. RGB LED Light Spectrum [5]

It can be seen that in the RGB LED the blue wavelength range is 400-500 nm, the green wavelength is 450-600 nm, and the red wavelength is 600-700 nm. Blue has the longest intensity compared to red and green. The RGB LED circuit to Arduino can be seen in Figure 5:

Figure 5. RGB LED to Arduino [6]

RGB LED has 4 legs, where the legs function to turn on the red, green and blue LEDs and the other one is the cathode feet.

1.9. Photodiode

When Photodiode is exposed to light, photons which are the smallest particles of light will penetrate the N-type semiconductor layer and enter the P-type semiconductor layer. The photons will then collide with the electrons that are bound so that the electron is separated from the core and causes a hole. Separate electrons due to collisions and near the PN junction (PN junction) will cross the intersection into the N-type semiconductor region. As a result, the electrons will increase on the side of the semiconductor N while the semiconductor side P will be excess Hole. This separation of positive and negative charges causes a potential difference at the PN junction. When we connect a load or cable to the cathode (the side of the semiconductor N) and the anode (the side of the semiconductor P), the electrons will flow through the load or cable from the cathode to the anode or we usually call it an electric current.

Figure 6. Form and Photodiode Symbol.
1.10. **Arduino**
Arduino is a single-board microcontroller that is open-source, derived from the wiring platform, designed to facilitate electronic use in various fields. The hardware has an Atmel AVR processor and the software has its own programming language. Currently Arduino is very popular throughout the world so many beginners who learn to know robotics and electronics use Arduino because it is easy to learn. But not only beginners, professional users are also happy to develop electronic applications using Arduino.

1.11. **Voltage amplifier**
Operational amplifiers or abbreviated as op-amps are one of the popular analog components used in various electronic circuit applications. Popular op-amp applications that are most often made include inverter, non-inverter circuits, integrators and differentiators. The most basic op-amp application, which is as a voltage comparator (comparator).

1.12. **LCD**
The LCD functions to display a sensor value, displays text, or displays a menu in the microcontroller application. The LCD used is a type of LCD M1632. M1632 LCD is an LCD module with 16x2 line display with low power consumption. The module is equipped with a microcontroller specifically designed to control LCDs.

![Figure 7. LCD circuit](image)

Based on this background the authors are interested in making a light intensity measuring instrument using warana plant extract as a sample for how much light intensity in plants with different colors. here the author uses OPT101 sensor to capture the intensity of the light given by the plant extract so that it can be read by the sensor and connected to the microcontroller as a tool to display how much light intensity generated on the PC.

The purpose of this study is to develop color detector using colorimetry system with photodiode sensor for food dye determination.

2. **Method**
In system design, it is planned from a simple block diagram shown in Figure 8.

2.1. **Block Diagram**

![Figure 8. Circuit Block Diagram](image)
In accordance with the block diagram above, this system consists of:

1. RGB LEDs are a blue wavelength range of 400-500 nm, a green wavelength of 450-600 nm, and a red wavelength of 600-700 nm. Blue has the longest intensity compared to red and green.

2. The samples used in this study are dyes, the following categories are dangerous and harmless dyes:
   a. Dangerous Dyes
      1) Alizarin S
      2) Bromophenol Blue
      3) Indigo Carmin
   b. Harmless Dyes
      1) Soursop Leaf Extract
      2) Breadfruit Leaf Extract
      3) Dayak Onion Extract

3. Photodiode sensor, as an optical sensor that is used to capture RGB light emitted on color samples that are replaced to see the voltage difference of each sample.

4. Voltage amplifier is a circuit used as a reinforcement of the output voltage released by the photodiode, because the photodiode produces a very small voltage.

5. The Arduino microcontroller used is the hardware that has the Atmel AVR processor and the software has its own programming language.

6. LCD is a type of media that uses liquid crystals as the main viewer. Lcd here is used to display the results of the output that has been processed by the Arduino microcontroller to take the form of different output voltage values for each different sample.

The mechanical circuit scheme is the original form made according to the block circuit diagram.
3. Results and Discussion

3.1. Research result

In this research, photodiode sensors are used, the input of which is light from the RGB LED lights emitted on samples that have different colors. The output will be displayed on the monitor in the form of voltage. The monitor used is a monitor on a laptop. Installation of RGB LEDs and photodiode sensors on the appliance must be parallel to each other because the RGB LED is used by the sensor as its input. So that the voltage displayed on the monitor depends on the intensity of the light captured by the photodiode sensor.

In the software written the code “float” which is written in the void loop, this code serves to display the voltage value in the form of a decimal number. Whereas in the next code it says “Serial.println” the code “ln” serves to automatically enter so that the display on the monitor runs vertically. When not given the code “ln”, the display will run horizontally. So the voltage changes on the sensor will appear on the monitor as shown in Figure 12. Testing about the output voltage using hazardous and non-hazardous dye samples harmless by using an Arduino Uno-based colorimeter and UV-Vis are shown in Figure 13.

Samples of harmful dyes measured using an Arduino Uno-based colorimeter are shown in Figure 13 (a). For testing carried out with a wavelength between 400 nm to 700 nm where the measurement results produce a graph of the comparison between wavelength and voltage. Where at a wavelength of 400 nm, 440 nm, 480 nm, 520 nm, 560 nm, 600 nm, 640 nm, 680 nm, 720 nm and 760 nm. The resulting voltage is between 0.2 Volts and 5 Volts.

Figure 11. Hardware circuit scheme
Figure 12. (a). Program series, (b). Voltage value of green samples (c). Voltage value of an Orange sample, (d). Voltage value of a red sample.

Figure 13. Measurement results of various sample using an Arduino Uno-based colorimeter and UV-Vis. (a). harmful dyes measured using an Arduino Uno-based colorimeter, (b). harmful dyes measured using UV-Vis, (c). Non-hazardous dye samples using an arduino Uno-based colorimeter, (d). non-hazardous dyes measured using UV-Vis.
Samples of harmful dyes measured using UV-Vis are shown in Figure 13 (b). For testing carried out with a wavelength between 400 nm to 700 nm where the measurement results produce a comparison graph between the wavelength and absorption. Where at a wavelength of 400 nm, 440 nm, 480 nm, 520 nm, 560 nm, 600 nm, 640 nm, 680 nm, 720 nm and 760 nm. Absorbs produced between 0.1 A to 4.5 A.

Non-hazardous dye samples measured using an arduino Uno-based colorimeter are shown in Figure 13 (c). For testing carried out with a wavelength between 400 nm to 700 nm where the measurement results produce a graph of the comparison between wavelength and voltage. Where at a wavelength of 400 nm, 440 nm, 480 nm, 520 nm, 560 nm, 600 nm, 640 nm, 680 nm, 720 nm and 740 nm. Absorbs produced between 0.5 V to 5 V.

Samples of non-hazardous dyes measured using UV-Vis are shown in Figure 13 (d). For testing carried out with a wavelength between 400 nm to 700 nm where the measurement results produce a comparison graph between the wavelength and absorption. Where at a wavelength of 400 nm, 440 nm, 480 nm, 520 nm, 560 nm, 600 nm, 640 nm, 680 nm, 720 nm and 740 nm. Absorption produced between 0.1 A to 3 A.

4. Conclusion
From the results of the discussion and the series can specify the performance and design specifications of the tool and find out how the colormeter works in natural plant extracts and harmful dyes. Where from RGB light has different wavelengths that produce bright light emitted on plant extracts which are then absorbed by photodiode sensors which produce voltage and absorption which are different from each color of the plant extract and food coloring which is sampled for the colorimeter. From the measurement results we can make a conclusion from the tool that is in a comparison table between the extract color of plants and dangerous ones which is very different where harmful food coloring has a high absorption and very small voltage because the wavelength is inversely proportional to the intensity while the intensity is directly proportional with voltage.

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