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A simple colorimeter based on microcontrollers to detect food dyes

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Abstract. A simple colorimeter has been successfully designed using a microcontroller to detect food dyes. This article describes the performance specifications and design specifications of the colorimeter that was designed as a detector for food dyes using a photodiode sensor and a light emitting diode lamp as a source. System performance specifications consist of mechanical systems that are supported by electronic systems. Data collection techniques were carried out directly and indirectly. Color absorption data were measured directly using an ultraviolet-visible spectrophotometer and indirect absorption data is determined by the voltage that was processed by the microcontroller. The test was carried out by measuring 10 variations in the concentration of food dye liquid, in the range of 0.1% - 1.0%. Measurements were made with 10 repetitions. The data were analyzed in two ways, statistically and graphically. The accuracy of the colorimeter design was done by comparing it with the measurement results from the ultraviolet-visible spectrophotometer. The average percentage of errors are 1.7% and the average relative accuracy of the system is 93.3%. These results indicate that a simple colorimeter can be used to measure the concentration of food dyes quickly and with good accuracy.

1. Introduction

Color is one of the factors used by humans as an indicator in assessing a product. In food, color is an attraction to increase product sales. The colors used in food, usually come from natural dyes and synthetic dyes. Natural dyes usually come from plants, while synthetic dyes come from a mixture of chemicals.

Synthetic food coloring has the advantage of having color stability that is better balanced with natural dyes. The use of synthetic dyes also has a limit of use, because if you exceed the usage limit it will cause cancer. Food coloring substances that are permitted in their use in food are known as permitted color or certified color. The use of these dyes must also undergo tests and use procedures called the certification process. The allowed amount of synthetic dyes should not exceed 100 mg / kg of product, and it is determined that the content of arsenic should not be more than 0.00014% and the lead content must not be more than 0.001%, and there should not be any heavy metals in it.

The development of electronic technology is inseparable from the existence of sensors as an important component in making tools. In general, sensors are better known as devices that can change physical quantities such as radiation, magnetic, thermal, mechanical, and chemical into electrical quantities as output [1]. At present, sensors have been made in very small sizes, namely in the nanometer order. This size saves energy even makes it easy to use [2]. Sensors used in making tools vary and are adapted to the use of the sensor itself. One sensor commonly used is an optical sensor. The optical sensor functions to capture light and turn it into voltage. One of the optical sensors is a photodiode sensor. A photodiode sensor is a sensor that is very sensitive to light.

A study of color measuring devices by Evi Syukriah Bako [3], where he used the LDR (Light Depend Resistor) sensor which is used as a color sensor to measure the brightness of the colors in the paper. The disadvantage in the study is the ineffectiveness of the packaging, so that the measurement results are disrupted by the presence of light from the outside so that the sensor reading becomes less valid. Besides that, the sensor also has a very long response when doing detection. Based on the description above, the researcher was interested in making a color measuring instrument as well, but here the researcher used the colorimetric method as a reference to measure a color intensity in solution.

Colorimetric method is a method that uses a comparison of the color intensity of a solution with the color of the standard solution [4]. Measurements are made to obtain data in order to draw conclusions [5]. In this research, photodiode sensors and a red LED light source are used. The use of red LEDs aims to make reading from the sensor output more sensitive and accurate. The use of photodiode sensors as sensors to detect food coloring because the sensor has a high sensitivity to light and a faster response than the LDR sensor. When an intensity of light falls into the sensor, the sensor immediately detects the intensity of the light.

Colorimetric known as 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 color intensity of the solution [4]. Determination of the color intensity of the solution follows the Lambert-Beer Law, where the Beer Law is used to calculate the concentration of the absorption measurements from experiments [6]. Reduced light intensity indicates the presence of light absorbed by absorbent molecules [7].

With this method, the concentration of a solution can be determined by analyzing the intensity of the light passed by the solution. This method usually uses a single light source, namely white light. The main factor in this method is that the color intensity of the solution used must be balanced with its concentration [4]. The solution that will be detected by the absorption of light seems to be a colored solution in order to get the results of its absorption measurements. The tool used to measure the comparison of the intensity of this color is the colorimeter. While the tool used to measure its absorption is the UV-Vis Spectrophotometer. Some researchers, have been reported with the use of UV-Vis together with colorimetry for detection of plant dyes [8, 9, 10, 11, 12].

The Lambert-Beer law states the relationship between the sacrifice and the concentration of a chemical solution which is directly proportional, and will be inversely proportional to the transmittance. According to Rohman [13], there are some limitations in the Lambert-Beer Law, which is that rays used will be considered monochromatic rays or can be called rays with a single wavelength, absorption that occurs in a solution will not affect anything in solution, the concentration used it must be low because if it is high it will affect the linearity of the sacrifice. The Lambert-Beer Law can be stated in the equation (1).

$$A = a \,.l.c \tag{1}$$

where A is absorptive or absorption, is molar absorptivity (constant type of substance) with units (L/mol cm), l is the path length (cm) and c is concentration (mol/L).

2. Methods

This research included laboratory experimentation. Experimental research is research that will observe and examine the influence of dependent variables due to the treatment of independent variables. This research will later produce a colorimeter tool that we can use as a color measuring instrument that can test how the color intensity of a solution of food coloring agents. The independent variable of this study is food coloring and the dependent variable is absorption. While the control variables of this study are concentration and volume.

2.1. Mechanical System Design

The design of the colorimeter is in the form of a black box with the intention that the light to be forwarded to the sensor will not affect the light from outside. This colorimeter design can be shown in figure 1.

In figure 1 is the mechanical design of the colorimeter tool system that will be created, where there are two boxes where the circuit is placed. In the left box is an Arduino placement as programming, while the right is a box where the red LED is a light source, a test tube as a solution sample container, and a photodiode sensor as a detector.

A photodiode sensor is a sensor that is sensitive to light (photo detector), where this sensor will experience changes in current if it receives light intensity. Electric current will experience forward bias if the anode diode is given a positive voltage and the cathode is given a negative voltage. This current change will affect the output voltage. The photodiode can detect wavelengths from ±100 to ±1100 nm in Ta = 25°C.

At the top there is an LCD as a viewer and pushbutton as a start button and a reset button. In the box filled with LEDs and photodiode sensors laying sensors and LEDs will be placed parallel, this is required so that the sensor reading to the emission released by the LED does not spread to all sides. When the led push button is pressed, the device is turned on. The LED beam will pass through the test tube which will contain a solution sample that varies in color and concentration. The color intensity of the solution can be detected by a photodiode sensor. The output of the photodiode will be programmed in an Arduino microcontroller and the results can be displayed on the LCD.

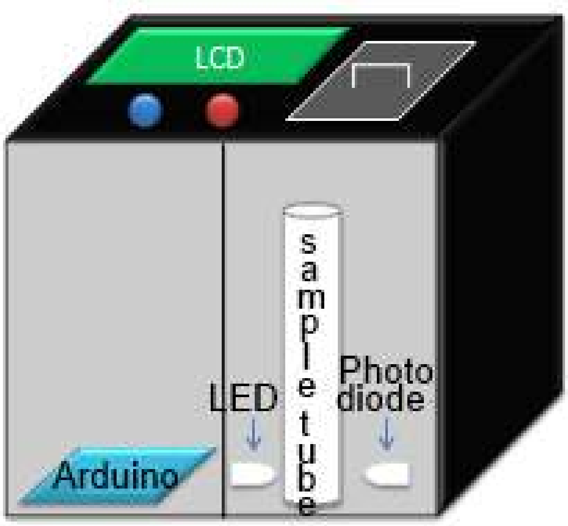

Figure 1. Mechanical design of colorimeter

2.2. Software Design

Software is closely related to hardware performance. Software on the microcontroller is also called firmware. The software functions as an instructor and runs the microcontroller. The design of the software for a colorimeter tool is needed so that the performance produced is in line with expectations. The software flow chart that will be made on the colorimeter tool as a detector of food coloring using photodiode sensors are shown in figure 2.

The figure 2 describes the software design flowchart, when the program starts, the Arduino will declare the variable and initialize the photodiode sensor. The sensor will read the output value in the form of voltage, then it will record the output value for the sample data. The value of the photodiode sensor voltage will be calibrated so that the output will be as expected. The output from the photodiode sensor that has been calibrated will be displayed on the 16x2 LCD by displaying sample data used and absorption. The absorption value is the value of the sensor output that has been calibrated.

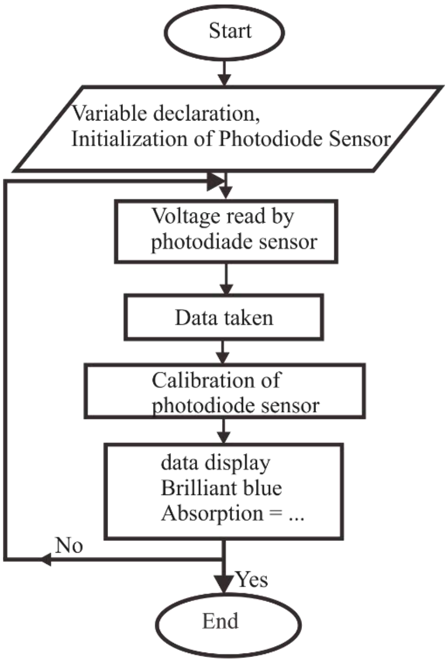

Figure 2. Flowchart of software design

3. Results and Discussion

3.1. Results
In this study, a colorimeter device will be used to detect food coloring using photodiode sensors. In this chapter, we will discuss the results of the design of the colorimeter system as a food coloring detector using photodiode sensors in detail and the measurement data obtained. Through processing the data obtained, it can be seen the relationship between the variables measured. Data analysis carried out both measurement and calculation illustrates the compatibility between the accuracy and accuracy of this tool. Presentation of data is displayed in the form of tables and graphs. The results of data processing are analyzed with the intended research objectives.

3.1.1. System Performance Specifications. Performance specifications commonly referred to as functional specifications are a detailed description of each material and component forming the system. Performance specifications also identify the function of each system constituent component. Performance specifications are generally measured in terms of the quality and quantity of the system builder, so that a system can work well and provide ease of use.

Quality is the most important thing to consider in producing a product. The performance specification of the colorimeter tool system as a food coloring detector using a photodiode sensor is the identification of each part forming The system. The colorimeter tool system using photodiode sensors can be seen in figure 3.

Figure 3 is the design result of a colorimeter tool using a photodiode sensor. Overall the colorimeter tool consists of one large black box measuring 25 cm x 15 cm x 15 cm. In the big box there are 2 boxes in it, the first box is 15 cm in size, which serves as an Arduino laying place, LCD circuit, pushbutton circuit, and sensor circuit. In the second box the place to place the sample and the LED circuit. The color of the colorimeter tool box is used in black so that the light from outside does not enter the box. Material from the colorimeter toolbox uses 3 mm acrylic.

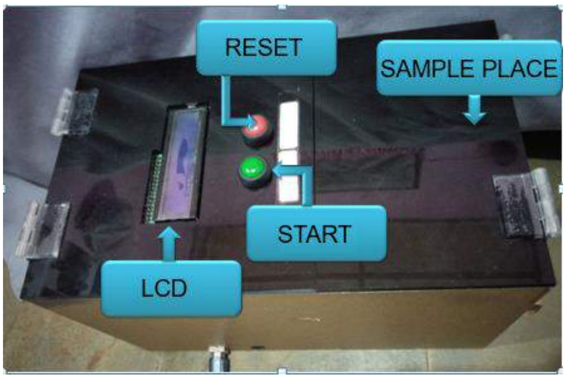

Figure 3. The colorimeter system

3.1.2. System Performance Specification. Design specifications commonly referred to as product specifications explain the characteristics of the product, system-forming materials, system size, system dimensions and tolerance. Design specifications refer to the accuracy of the system. Accuracy is defined as the difference or proximity between the values read from the measuring instrument and the actual value.

A good measuring instrument has an accuracy of close to 1 or 100%, while accuracy compares the results of system measurements with theoretical calculations, then repeated measurements are made. The accuracy of this colorimeter can be seen in Table 1.

Table 1. The accuracy of colorimeter measurement

Concentration (%)	Spectro-photo meter UV-Vis (Å)	Colorimeter (Å)	Percentage Error (%)	Percent Accuracy (%)
0.1	9.48	11.085	16.9304	83.07
0.2	13.20	11.085	0.1602	83.98
0.3	17.18	18.385	0.0701	92.99
0.4	21.27	22.03	0.0357	96.43
0.5	25.2	25.675	0.0188	98.12
0.6	29.23	29.325	0.0033	99.67
0.7	32.97	32.975	0.0002	99.98
0.8	36.94	36.62	0.0087	99.13
0.9	41.00	43.915	0.0711	92.89
1	45.08	51.21	0.1360	86.40
	Mean =		1.7434	93.2661

Based on Table 1, it can be explained that there are errors in measurement, where the errors that occur are very small, which is only 1.7%. The average relative accuracy of the tool is 0.93 and the percentage of accuracy of the tool is very good, 93.3%.

Comparison of measurements of UV-Vis spectrophotometers with colorimeters was carried out by comparing measurements of absorption of UV-Vis spectrophotometers with colorimeters. This comparison can be seen in the graph form shown in figure 4.

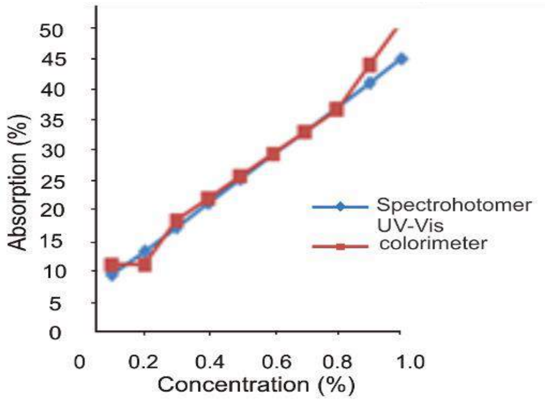

Figure 4. Measurement comparison between UV-Vis spectrophotometer and colorimeter

Based on figure 4, there are differences in the results of measurements of a colorimeter instrument with a UV-Vis spectrophotometer. This is influenced by several factors where the sensor output voltage value is not stable, because the sensor has a high sensitivity to light.

Before being used to measure food coloring samples, the tools made were validated by experts who had the field of instrumentation. The validation process is carried out at the Faculty of Mathematics and Natural Sciences, Physics Laboratory by providing validation sheets to experts. Validation results obtained from experts or lecturers for Colorimeters are generally very valid. The Data validity graph can be seen in figure 5.

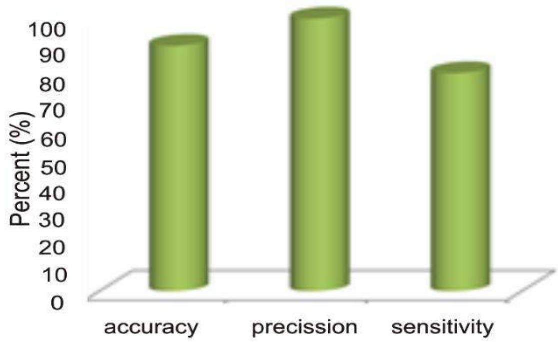

Figure 5. Measurement comparison between UV-Vis spectrophotometer and colorimeter

Figure 5 explains the colorimeter in the aspect of accuracy and precision in the categorical category is very valid, while the sensitivity aspect is in the valid category. This shows that the colorimeter made is in a very valid criterion.

3.2. Discussion

Based on the analysis that has been done graphically and statistically, it has provided research results that are in accordance with the research objectives. The results of the research obtained are the performance specifications of the colorimeter system and the colorimeter tool system design specifications.

Performance specifications of the colorimeter tool from two parts, the first part is the mechanical part and the second part is the electronic circuit part. The mechanical part consists of a sample holder, Arduino, photodiode sensor, LCD, LED, and pushbutton. The electronic circuit section includes a system of colorimeter devices such as photodiode sensor circuits, LCD circuits, pushbutton circuits, LED circuits, and Arduino boards.

The working principle of the colorimeter tool is almost the same as the UV-Vis spectrophotometer that was in the chemistry laboratory of Universitas Negeri Padang. When the sample to be measured absorption is inserted into the test tube and placed into the sample box, the LED will emit light towards the sample so that the light forwarded by the sample will be received by the photodiode sensor. The sample to be entered will vary in concentration. The LEDs used in this colorimeter tool will emit red light, the use of red LEDs on the device adjusts to the sensitivity of the photodiode sensor.

Data retrieval is done by pressing the green pushbutton. After that, sample changes can be made to be measured. The output value of the photodioda sensor will be higher. according to the high concentration. Before retrieving the actual data, it is necessary to calibrate the sensor so that the output value is as expected.

Accuracy of measurements get very good results where the errors that occur are very small, namely 1.7434%. The average relative accuracy of the tool is 0.9327 and the percentage of accuracy of the tool is very good, 93.2661%. The average accuracy of the colorimeter is 1 with a standard deviation of 0 and a relative error of 0%. In the test the colorimeter validity that has been made is in very valid criteria.

4. Conclusion

Based on the results of testing and analysis of the colorimeter tool with a UV-Vis spectrophotometer, several conclusions can be raised from the research, namely; (1). Performance specification of a colorimeter tool from two parts, the first part is the mechanical part and the second part is the electronic circuit part. The mechanical part consists of a sample holder, Arduino, photodiode sensor, LCD, LED, and pushbutton. The electronic circuit section includes a system of colorimeter devices such as photodiode sensor circuits, LCD circuits, pushbutton circuits, LED circuits, and Arduino boards. (2). The accuracy of the colorimeter tool is quite good, where the percentage error is 1.7434% with a percentage accuracy of 93.266%.

Acknowledgment

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