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Identification of istihadhah blood color using TCS3200 color sensor with Multilayer Perceptron (MLP) method

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ABSTRACT

One of the natures of women, including menstruation, namely the discharge of blood from the vagina periodically and has a certain cycle. However, this cycle can experience disturbances, in Islam it is referred to as istihadloh. Women who are experiencing istihadloh are called mustahadloh. One of the mustahadloh categories is Mu'tadah Ghoiru Mumayyizah, namely women who have recently bled but cannot distinguish between strong and weak blood. This study aims to distinguish between menstrual blood and istihadloh based on its color. The research method was carried out by designing and manufacturing the TCS3200 color sensor tool based on Arduino Uno with RGB value output results. The average RGB value of istihadloh blood is R 71.6, G 83.7 and B 55.2. While the average RGB values for menstrual blood color are R 143.3, G 176.6 and B 79.3. The results of the classification accuracy using the MLP method in differentiating menstrual blood and istihadloh based on color using the TCS3200 color sensor are 96.7%.

Keywords:
Istihadloh, TCS3200 Sensor, RGB.

Introduction

In Islam, particularly within Shafi'i jurisprudence (Fiqh Shafi'iyyah), there are three types of blood that may exit the female reproductive organ: menstrual blood (haidh), postpartum bleeding (nifas), and istihadhah blood (al-Bajuri). According to Bujairimi 'ala al-Khatib by Sulaiman bin Muhammad, menstruation linguistically means "to flow," while terminologically it refers to natural blood that exits a woman's vagina during a healthy state (not due to illness), unrelated to childbirth (nifas), and occurring at specific times. Imam Shafi'i categorized menstrual blood into five colors: black, red, reddish-gold, yellow, and turbid. Meanwhile, Imam Hanafi recognized six types: black, red, yellow, greenish, and soil-like in color (Nuruddin, 2018). There are cases of green menstrual blood, typically found in individuals suffering from malnutrition (Saribanon, 2016).

According to Shahih Fiqh Sunnah by Abu Malik Kamal bin as-Sayyid Salim, istihadhah is defined as blood that flows outside the menstrual or postpartum period, caused by a ruptured vein, and is typically fresh, continuous blood (Nailatus Sa'adah, 2020). A woman experiencing istihadhah is called a mustahadhah. Some women are unable to distinguish between menstrual and istihadhah blood when bleeding occurs, perceiving them as the same. Such women fall under the category of Mu'tadah Ghairu Mumayyizah (Barakah A., 2018).

In medical science, only two types of female reproductive bleeding are recognized: menstrual and postpartum. There is no term equivalent to istihadhah. Medically, menstruation results from the shedding of the uterine lining, composed of blood and tissue, not triggered by egg fertilization, and it occurs regularly in healthy women (Abdullah, 2019). Medically, istihadhah may be classified as pathological menstruation or a menstrual disorder, although this does not address its classification under Islamic law (Asyikin Y, et al., 2015). Clinically, it is known as menorrhagia (Mahadi, 2018), which is influenced by various factors such as stress, fatigue, medication side effects, contraceptive use, or medical conditions like endometriosis, polyps, myomas, and cervical cancer (Fuadah, 2017).

Menorrhagia refers to excessive menstrual bleeding lasting several consecutive cycles, with blood volume reaching or exceeding 80 mL per cycle. As such, it is considered a significant health concern for women (M. K. Oehler, 2003). In Islam, women experiencing istihadhah are still required to perform ibadah mahdhah (ritual worship) such as prayer, reciting the Qur'an, fasting, and pilgrimage, as they are still considered ritually pure (tahir) and not in a state of hadath (impurity) (Syah, 2017).

From a medical perspective, the color of menstrual and istihadhah blood is essentially the same, but variations occur due to external factors. Menstrual blood changes color depending on how long it remains in the vagina, typically darkening from red to brown or black due to exposure to acidity (Auliawati, 2009). However, understanding of istihadhah remains limited since only a subset of women experience it. Therefore, there is a need for a tool that can identify istihadhah blood to support both health monitoring and religious practices.

Based on its characteristics, istihadhah blood can be identified through indicators such as odor, viscosity, and color. Thus, potential detection tools include odor sensors, viscosity sensors, and color sensors. In this study, the distinguishing indicator used is color. The most suitable tool for identifying color differences between menstrual and istihadhah blood is the TCS3200 color sensor. This sensor is commonly used for color detection applications, such as in Simamora's study (2017), which successfully identified meat freshness levels based on color using the TCS3200 sensor. This sensor can respond to differences in red levels that indicate freshness in meat. The TCS3200 uses microcontroller technology, with one of the most widely developed platforms being Arduino Uno, a versatile and accessible tool for educational and practical applications (Mintoro, 2018).

The visible spectrum refers to the full range of colors perceivable by the human eye and represents a depiction of visible light. Visible light is a form of electromagnetic radiation and is part of the electromagnetic spectrum. Electromagnetic radiation travels in waves with varying wavelengths and frequencies. The wavelength of the visible spectrum is measured in nanometers (10^{-9} m), and frequency in terahertz (10^{12} Hz). The visible colors, from shortest to longest wavelength, are violet, indigo, blue, green, yellow, orange, and red. Each color occupies a specific wavelength range within the 400–700 nm spectrum (Ryan Johnson, 2021). Rainbows visually represent the continuous frequency range of visible light (Gaikwad, 2019).

The TCS3200 color sensor is a chip that converts light from a specific color into a frequency output. It consists of two main components: an array of photodiodes arranged in parallel and an inverter section. The TCS3200 uses photodiodes with filters for red, green, and blue (RGB) as well as photodiodes without filters. Each section of the sensor operates at an 8-bit scale (Artha, 2012). Arduino Uno is an open-source electronics prototyping platform based on a microcontroller chip. It is designed to simplify the application of electronics across various fields (Setiadi, 2019). "Uno" means "one" in Italian. This microcontroller board is based on the Atmega328 chip, featuring 14 digital I/O pins (6 of which support PWM output), 6 analog inputs, a 16 MHz quartz crystal oscillator, USB connection, power jack, ICSP header, and a reset button. To use the microcontroller, the Arduino Uno board can be connected to a DC adapter or battery using a USB or AC power cable (Zulkarnain, Ramadhan, & Anwar, 2019).

Multilayer Perceptron (MLP) is a classification algorithm in Artificial Neural Networks (ANN) used to analyze datasets. MLP is a powerful class of nonlinear statistical models composed of multiple layers of nodes in a directed graph, where each layer is fully connected to the next (Castro et al., 2017). This study addresses the issue that many women remain unable to differentiate between menstrual and istihadhah blood based on color, which is crucial for religious obligations. The research aims to determine the average RGB values of menstrual and istihadhah blood, and to evaluate the classification accuracy of the TCS3200 color sensor using the MLP method. The study's significance lies in its potential contribution to researchers, healthcare professionals, and institutions by offering a non-invasive method to aid in distinguishing these two types of blood.

Methods

This research employed the Research and Development (R&D) method, resulting in the creation of a functional product. The research stages included tool design, device assembly, data grouping, and data identification. The tools and materials used in this study are Arduino Uno, LCD 6x12, Jumper Cables, TCS3200 Color Sensor, IC 7805, Resistors, Battery, Hole-type PCB, ON/OFF Switch, WEKA Software and Arduino IDE Software.

Research Procedure

The experimental procedure involved the following stages: tool design, calibration, data collection, and data classification (Figure 1). Tool testing included both calibration and accuracy testing. Calibration was performed by comparing the RGB values of a red-colored object to similar RGB values obtained in previous studies. The calibrated RGB values were then used for accuracy evaluation.

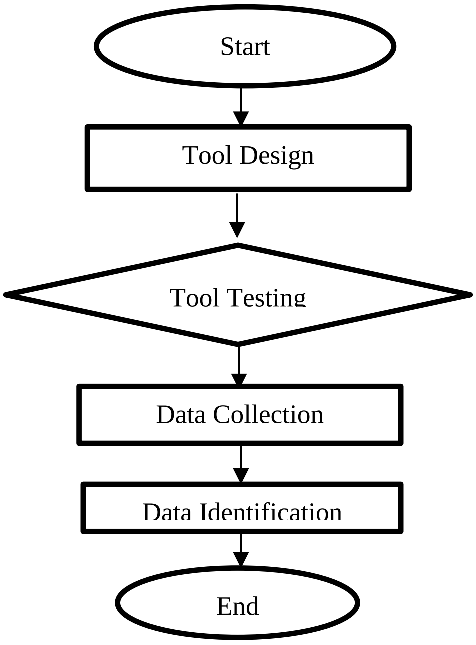

Figure 1. Research Procedure Diagram

To calculate measurement error and accuracy, the following formulas were used:

$$Error = \frac{\text{Measured Value} - \text{Standard Value}}{\text{Standard Value}} \, x \, 100\% \quad (1)$$

$$Accuracy = 100\% - error \quad (2)$$

Tool Design

Figure 2 show design of the Istihadhah Blood Identification Tool Using TCS3200 Color Sensor

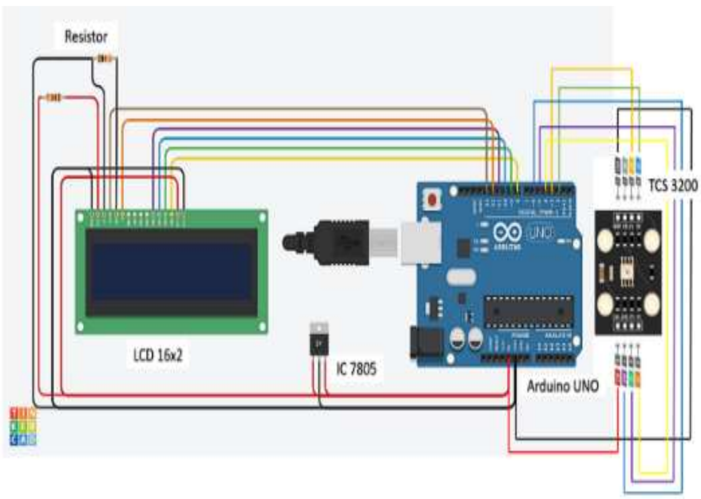

Figure 2. Design of the Istihadhah Blood Identification Tool Using TCS3200 Color Sensor

Sample Data Collection Method

Blood samples were collected from the surface of sanitary pads (Figure 3). The surface area of the blood stain on the pad had to match the detection area of the color sensor. If the stained area was smaller than the sensor's detection area, the sample was considered invalid. Valid samples were scanned using the TCS3200 color sensor, and the resulting RGB values were displayed on the LCD screen. The sensor irradiated a 4×4 cm area, corresponding to its detection range, to ensure consistency during data collection.

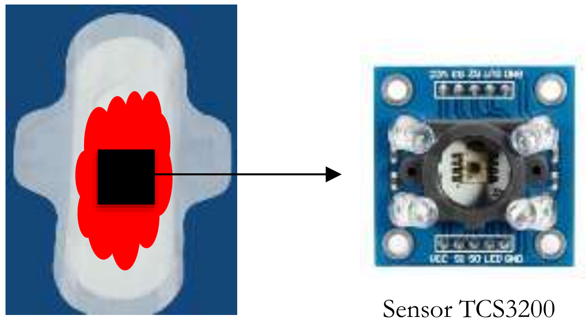

Figure 3. Blood Sample Collection Method

Data Analysis Technique

The collected RGB data series from each sample were compiled in Microsoft Excel and converted into CSV format before classification using the WEKA software. The classification matrix in WEKA includes: TP (True Positive), FP (False Positive), TN (True Negative), and FN (False Negative). Performance metrics such as accuracy, sensitivity, and specificity were calculated using the following formulas:

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} x\ 100\% \tag{3}$$

$$Sensitivity = \frac{TP}{TP + FN} x\ 100\% \tag{4}$$

$$Specificity = \frac{TN}{TN + FP} x\ 100\% \tag{5}$$

Result and Discussions

TCS3200 Color Sensor Prototype for Istihadloh Blood Identification

Results obtained in this research include a color identification tool prototype for differentiating menstruation and istihadloh using the TCS3200 color sensor (figure 4). This prototype is designed as electronic hardware including the TCS3200 color sensor connected to Arduino Uno, then connected through Arduino IDE software for sensor program settings to obtain data. Color detection with the TCS3200 sensor works when photodiodes receive input signals, then current continues from photodiodes and is converted to square signals.

Calibration

Calibration was performed on red-colored paper samples. This was done to adjust red color range values on the istihadloh blood color identification tool prototype with color range values performed on plain red-colored paper. Testing in this research was performed at a 4.0 cm distance from objects, where at this distance, TCS3200 sensor illumination corresponds to object cross-sectional areas with dimensions between 3.5×3.5 cm to 5×5.5 cm^2 (Table 1).

Figure 4. Menstrual and Istihadloh Blood Color Identification Tool Prototype

Table 1. Average Red Color Values

RGB	Value 1	Value 2	Value 3	Value 4	Value 5	Average
R	138	131	130	136	137	134.4
G	183	184	182	187	182	183.6
B	137	140	144	143	143	141.4

Accuracy Testing

Accuracy testing was performed to determine error levels occurring in data classification (Sampurno & Thoriq, 2016). Accuracy testing includes error percentages is shown in Table 2.

Table 2. Accuracy and Error Percentages

RGB	Standard Value	Measured Value	Error	Accuracy
R	133.0	134.4	1.1%	98.9%
G	178.0	183.6	3.1%	96.9%
B	146.0	141.4	3.2%	96.8%
Average	**152.3**	**153.1**	**2.5%**	**97.5%**

Sample Data Collection

Sample data was obtained from 10 women experiencing menstruation and 10 women experiencing istihadloh, with each sample data collected three times over three consecutive days when discharged blood was red. Thus, 60 data points were obtained with 30 menstruation data and 30 istihadloh data respectively. Average color values for menstrual blood and istihadloh have been presented in graphs 5, 6, and 7. These graphs show comparisons and classifications of menstrual blood and istihadloh color values across red, green, and blue periods.

Graphs 5, 6, and 7 show that average istihadloh blood color is lower than average menstrual blood color, making istihadloh blood color lighter or more faded than menstrual blood with clearer red color. These three graphs demonstrate that menstrual blood and istihadloh blood have different RGB range values and can be classified based on color. Based on graphs, istihadloh blood color appears pinkish-red, while menstrual blood color appears red.

Data Classification

TP (True Positive) indicates correct data for istihadloh, FP (False Positive) indicates error data for istihadloh. Meanwhile, TN (True Negative) indicates correct data for menstruation and FN (False Negative) indicates error data for menstruation. Therefore, data accuracy percentage, data sensitivity, and data specificity of 96.7% were obtained (Table 3).

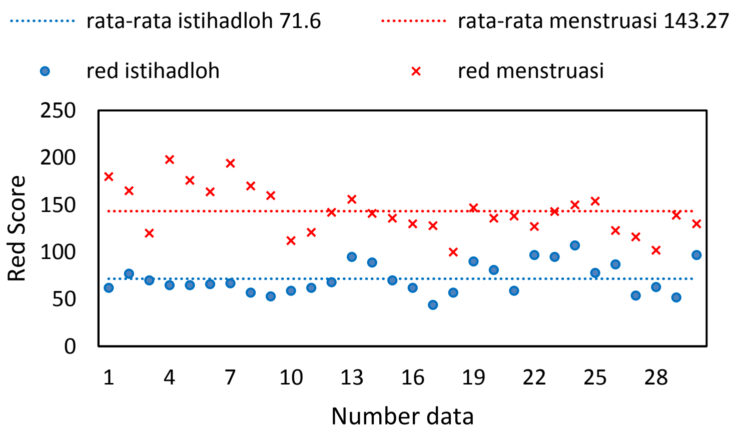

Figure 5. Comparison of Average Menstrual and Istihadloh Blood Color Values for Red Period

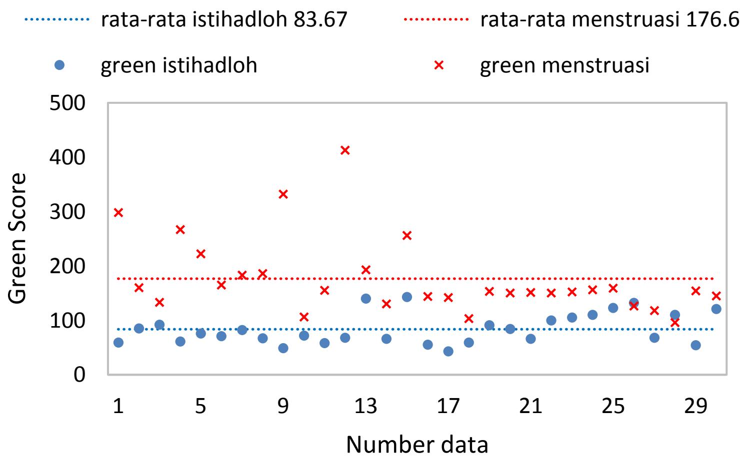

Figure 6. Comparison of Average Menstrual and Istihadloh Blood Color Values for Green Period

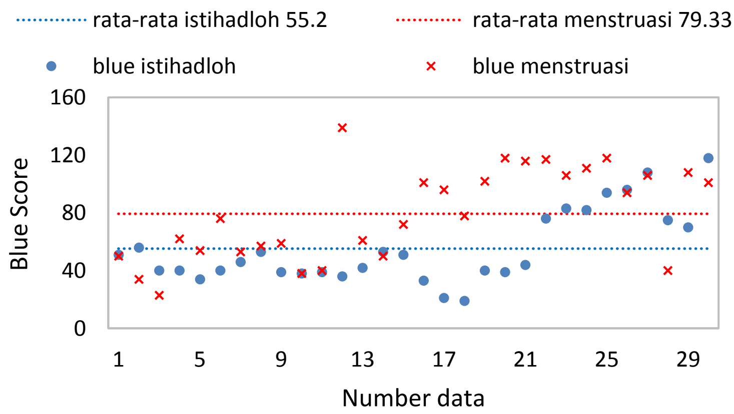

Figure 7. Comparison of Average Menstrual and Istihadloh Blood Color Values for Blue Period

Table 3. Results of TP, FP, TN, FN, Accuracy Percentage, Sensitivity and Specificity

TP	FP	TN	FN	Accuracy	Sensitivity	Specificity
29	1	29	1	96.7%	96.7%	96.7%

Discussion

Medical condition diagnoses experienced during menstrual disorders include urinary tract infections, ectopic pregnancy, and irritable bowel syndrome. Additionally, endometriosis and uterine fibroids can cause heavy bleeding and chronic pain. To confirm these diagnoses, examinations can be performed through Ultrasonography and Sonohisteriography, which are imaging techniques often used to detect specific conditions possibly caused by menstrual disorders (Resources, 2022). According to fiqh scholars, differences between menstruation and istihadloh, besides temporal aspects, can be seen from emergence location. Menstrual blood emerges from the uterine tip, while istihadloh blood emerges from the cervical opening or lowest uterine part (Nuroniyah, 2019). Non-invasive istihadloh blood identification tool development has not been discussed, as istihadloh blood identification is only based on menstrual period calculations. Innovation in creating istihadloh blood identification tools is expected to become a media development facilitating Muslim women when encountering abnormal menstrual cycles.

This prototype uses the TCS3200 color sensor based on Arduino Uno displaying output in Red, Green, and Blue (RGB) values. Testing was performed on sample data then averaged. Average values for menstrual blood and istihadloh show differences between these two blood colors. Based on Table 4, average RGB values for menstrual blood color are higher compared to average RGB values for istihadloh blood color. There is a comparison between TCS3200 color sensor Red Green Blue (RGB) output values for dark-colored objects versus light-colored objects. Darker object colors result in higher RGB values on the TCS3200 color sensor, conversely, lighter object colors result in lower RGB values on the sensor (Ratnawati & Vivianti, 2018). Based on research results, istihadloh blood has lighter red color compared to menstrual blood.

Table 4. Average RGB Value Ranges for Menstrual Blood and Istihadloh

RGB	Menstruation	Istihadloh
R	143.3	71.6
G	176.6	83.7
B	79.3	55.2

Previous theory explained that menstrual blood experiences considerable settling time in the uterus, making its color darker, while istihadloh blood emerges outside the menstrual cycle, so blood does not experience settling time and has lighter color (Dan Brennan, 2021). Additionally, fiqh scholars provide calculation methods for determining menstrual blood and istihadloh status: 'adah method and tamyiz method. The 'adah method calculates habits or customs from menstrual periods, while the tamyiz method calculates blood status by observing strength and weakness of emerging blood. If emerging blood is strong, it is considered menstruation; if emerging blood is categorically weak, it is considered istihadloh (Nuroniyah, 2019). According to scholars, blood strength and weakness are observed from color aspects, having very concentrated colors. If emerging blood has concentrated red color, it is considered strong blood. Meanwhile, if emerging blood has light red color, it is considered weak blood (Barakah A., 2018).

Based on the above theory, this corresponds to TCS3200 color sensor RGB values for object brightness and darkness. Thus, it can be stated that lighter blood will be read as weak blood and categorized as istihadloh blood. Istihadloh blood color is pink, as istihadloh blood RGB ranges fall between pink and red colors (Appendix 1). However, it should be noted that during measurement using the TCS3200 color sensor, small possibilities exist for light distraction, affecting resulting RGB values. This research uses average RGB values obtained based on menstrual blood and istihadloh RGB color range results. This was done to focus on one number for easier data analysis reading.

Based on graphs 5, 6, and 7, menstrual blood and istihadloh RGB values are stable only for R values; for G and B values in menstruation and istihadloh data, they intersect. This occurs because each RGB value has optimum distances. Research by Athifa and Rachmat (2019) shows that TCS3200 color sensor RGB values have optimum distances during object illumination, resulting in fluctuative distances during object illumination. Based on this research, resulting data shows R values can detect colors well up to 6.5 cm distance. G and B values can detect colors well up to 3.5 cm distance. G and B values become fluctuative after 3.5 cm distance. Meanwhile, in this research, object illumination was performed at 4 cm distance, causing G and B values to experience fluctuation resulting in G and B values in menstrual blood intersecting with istihadloh blood.

Menstrual blood color and istihadloh blood color classification was determined through WEKA software using the Multilayer Perceptron (MLP) method with 96.7% accuracy results. One menstruation data was categorized as istihadloh data (data sequence 49) and one istihadloh data was categorized as menstruation data (data sequence 40). This shows that occasionally menstrual blood range values can be low and istihadloh blood range values can be high.

However, in this research, blood RGB value measurements were not pure because blood absorbed into pads made blood redness fade. Additionally, wet or dry blood conditions already attached to pads caused by pad absorption of blood were considered, as this would affect RGB values. Therefore, blood illumination was standardized, performed when pads were not too wet or had already absorbed. In this research, RGB value readings for pads were ignored.

WEKA detection or identification errors were caused by similar color ranges. Menstruation RGB values (data sequence 49) of 100, 103, 78 tended more toward istihadloh RGB value range categories. Conversely, istihadloh RGB values (data sequence 40) of 107, 110, 82 tended more toward menstruation RGB value range categories. Additionally, surrounding light can affect RGB value readings on objects.

Conclusion

Average RGB values for istihadloh blood color were **R** 71.6; **G** 83.7 and **B** 55.2. Meanwhile, menstrual blood color ranges were **R** 143.3; **G** 176.6 and **B** 79.3. Istihadloh blood RGB values show lighter red color compared to menstrual blood with darker red color. This occurs because istihadloh blood does not experience prolonged settling like menstrual blood. Classification accuracy using the MLP method in differentiating menstrual blood and istihadloh based on color using the TCS3200 color sensor achieved 96.7%. The istihadloh blood identification tool should be developed by adding aroma sensors and humidity sensors to become a more adequate health tool innovation. This research should be used as a reference for future research.

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Conflicts of interest

The authors affirm that they have no conflicts of interest.

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