RESEARCH ARTICLE OPEN ACCESS

Manuscript received January 18, 2024; revised March 10, 2024; accepted March 12, 2024; date of publication March 25, 2024

Digital Object Identifier (**DOI**): https://doi.org/10.35882/teknokes.v17i1.666

How to cite: Ahmad Faisal Islamudin, Triana Rahmawati, Triwiyanto and Vugar Abudlayev, "Improvement of Non-invasive Blood Sugar and Cholesterol Meter with IoT Delivery", Jurnal Teknokes, Vol. 17, No. 1, pp. 63-68, March. 2024

Improvement of Non-invasive Blood Sugar and Cholesterol Meter with IoT Technology

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ABSTRACT In checking blood sugar levels, patients often feel uncomfortable because invasive blood sampling must be done and if done to patients who have a history of high glucose, it can cause wounds that are difficult to heal and can be operated on. This study aims to non-invasively monitor cholesterol levels, reducing discomfort and pain for patients by eliminating the need for invasive procedures. The method used in this research is the MAX30102 sensor will detect blood sugar through the patient's finger, the data will be processed in ESP8266 as monitoring will connect to the OLED LCD as a viewer and IoT as data storage with Wi-Fi connected. In this study, the greatest accuracy value was obtained 99.03% with the largest error value of 10.52% and the smallest accuracy value was 89.48% with the smallest error value of 0.97%. From all measurement results, the average accuracy value is 93.974% and the average error is 6.026%. It can be concluded that the development of a non-invasive method for monitoring blood sugar levels by utilizing the MAX30102 sensor with this accuracy value shows that this non-invasive method is reliable for monitoring blood sugar levels. In future studies, researchers are expected to use more accurate sensors and take more data to get a better average value.

INDEX TERMS Blood Sugar, Non-invasive, and IoT

I. INTRODUCTION

It is important to understand that human health is not just about the absence of disease, but also involves active efforts in maintaining a fit and balanced body. Modern technology makes it easy to monitor health, but awareness of a healthy lifestyle remains key in disease prevention. Regular health check-ups are a proactive measure to detect potential risks and ensure optimal quality of life.

Non-communicable diseases (NCDs), often referred to as chronic diseases, are complex outcomes of genetic, physiological, environmental and behavioral factors that intertwine over long periods of time. Statistics illustrate the serious impact of NCDs, with 41 million people dying each year, accounting for about 71% of total global deaths. Particularly alarming, more than 15 million deaths each year involve the 30 to 69 age group, and most occur prematurely in low- and middle-income countries.Data from the World Health Organization (2021) notes that cardiovascular disease dominates as the leading cause of death, resulting in 17.9 million deaths each year. Cancer, respiratory diseases, and diabetes are also serious threats with significant numbers of deaths. For example, diabetes, as explained by the Ministry of Health of the Republic of Indonesia, relates to a deficiency of the hormone insulin produced by the pancreas, resulting in elevated blood sugar levels which, if not controlled, can lead to serious consequences. In this context, health education and prevention efforts are essential to reduce the burden of NCDs. Understanding risk factors and promoting healthy lifestyles are key in facing this global challenge.

Protecting yourself from non-communicable diseases can start with maintaining stable blood sugar, cholesterol and uric acid levels in the body. For diabetics in particular, regular monitoring of blood sugar levels is a critical step. Currently, measurement methods using a glucometer require analyzing a blood sample from a vein or fingertip. While effective, this procedure often causes pain and discomfort, especially for those who need to perform the check multiple times a day. Innovations in health technology that reduce this discomfort can play an important role in improving patients' quality of life and encouraging adherence to regular health monitoring[1].

Cholesterol, as a fat in the bloodstream, is essential for forming cell walls and as a base material for the formation of certain hormones. Cholesterol levels that are considered normal should be below 200 mg/dl. However, when it reaches levels above 240 mg/dl, the risk of serious diseases such as heart attack and stroke increases. Although the body produces cholesterol naturally, some of it also comes from the consumption of animal foods such as meat, chicken, fish, margarine, cheese and milk.The importance of monitoring cholesterol-related health is illustrated by the fact that high levels of cholesterol, or hyperuricemia, can reach 230 mg/dl per individual. In comparison, uric acid levels in men are usually desirable below <7 mg/dl and in women <6 mg/dl. Therefore, understanding and managing cholesterol and uric acid levels is an important element in maintaining heart health and preventing the risk of metabolic diseases.

However, this kind of invasive testing method makes patients who need regular testing feel sick and a kind of non-invasive blood glucose meter is needed. The traditional method of drawing blood with a needle to assess blood sugar, cholesterol, and uric acid levels, often involves the use of paper in recording medical records of the results. However, this approach has several disadvantages that need to be recognized. With such a busy schedule, the author found it difficult to make time for medical check-ups at the hospital, especially since she has a phobia of needles. This condition provides an extra challenge, and the author tries to find alternatives to maintain health despite these limitations. For example, there are constrained individuals who can be a serious obstacle in undergoing this procedure. Overcoming such obstacles, innovations in health technology that allow for more practical blood sampling and minimize the use of needles can improve the accessibility of health check-ups. Updates to medical record systems that utilize digital solutions can also benefit patients in terms of efficiency and convenience [3].

Asmat Nawaz conducted a study [5], entitled Non-Invasive Continuous Blood Glucose Measurement Techniques, saying that this is to describe brief and organized information about the differences in non-invasive continuous blood glucose monitoring techniques. Many research groups have been working to develop wearable sensors for continuous blood glucose monitoring, but currently, there is to our knowledge no commercially successful non-invasive glucose monitor on the market. In further development, continuous glucose sensor systems are predictable, selective, reliable and acceptable for patient use.

In his research Redho Yurizal [3], in his research titled "Design and Analysis Photoplethysmograph Signal for Blood Glucose Measurements" highlighted that the information contained in the blood volume change signal during the cardiac cycle can be the key to calculating blood sugar levels. He emphasized that each wave peak in the signal has a significant correlation with blood sugar concentration, opening up new potential for innovative measurement methods.

Indras Marhaendrajaya [4], in his research entitled "Design and Realization of a Non-Invasive Blood Cholesterol Content Meter" suggests that the measurement of cholesterol content in the blood can be done non-invasively through the use of NIR laser absorption from an oximeter sensor.

Based on this, we conducted a research entitled "Improvement of Non-Invasive Blood Sugar and Cholesterol Level Measuring Device with Iot Delivery (Cholesterol, and MAX30102 pulse sensor)". Measurements on this tool are implemented through a non-invasive method, with a compact design and connected to a smart phone application for Internet of Things (IoT) based medical records. The main advantages of this tool are its small size, minimizing discomfort, and its connection with smartphone technology allows efficient and accurate medical records. This innovation makes it easy for individuals to conduct health monitoring from the comfort of their own homes. This is an invaluable solution, especially for those who experience needle phobia or have busy schedules that make it difficult to attend regular check-ups at health facilities. With this tool, users can independently and proactively monitor their health conditions, enabling early detection and more effective preventive measures.

The aim and contribution of glucose monitoring devices, especially in the context of managing diabetes, are significant. These devices play a crucial role in helping individuals with diabetes monitor their blood glucose levels and make informed decisions about their treatment and lifestyle. The contribution of this study is as follows:

1. Glucose monitoring devices provide real-time information about blood glucose levels, allowing individuals with diabetes to track their levels throughout the day. This helps in understanding how different factors such as food, exercise, and medication impact blood sugar.
2. With regular monitoring, individuals can make timely adjustments to their treatment plans. For example, they can adjust insulin doses, modify their diet, or engage in physical activity to maintain optimal blood glucose levels.
3. By closely monitoring glucose levels, individuals can take prompt action to prevent hypoglycemia (low blood sugar) or hyperglycemia (high blood sugar), both of which can have serious health consequences.
4. Continuous glucose monitoring (CGM) devices offer continuous readings throughout the day and night, providing a more comprehensive understanding of blood sugar trends. This can lead to better glycemic control, reducing the risk of diabetes-related complications and improving overall quality of life.
5. Glucose monitoring devices generate data that can be analyzed over time, helping healthcare professionals and individuals identify patterns and trends. This data-driven approach allows for more personalized and effective diabetes management.
6. Access to real-time glucose data empowers individuals to take an active role in managing their diabetes. It encourages a proactive approach to health, fostering a sense of control and self-efficacy.
7. Timely interventions based on glucose monitoring data can potentially reduce the frequency of hospital visits and complications associated with uncontrolled diabetes. This, in turn, may contribute to lower healthcare costs over time.

II. MATERIALS AND METHOD

Investigations are being conducted experimentally. The author suggests a non-invasive blood sugar measurement test kit. The next section will discuss the supplies and procedures.

A. *DATA COLLECTION*

This Non-invasive Blood Sugar Level Meter uses one sensor called the MAX30102 sensor used to detect hemoglobin levels in the patient's blood. Where, MAX30102 has 2 important components in the form of an LED component as a light emitter that will be passed to the patient's finger and a photodiode component as a light intensity capture.

The light captured by the photodiode will affect the amount of voltage output in the form of an analog signal that will be forwarded to the ESP8266 microcontroller. The data that has been processed by the microcontroller will be displayed on the OLED LCD and sent to the Google Sheet Web.

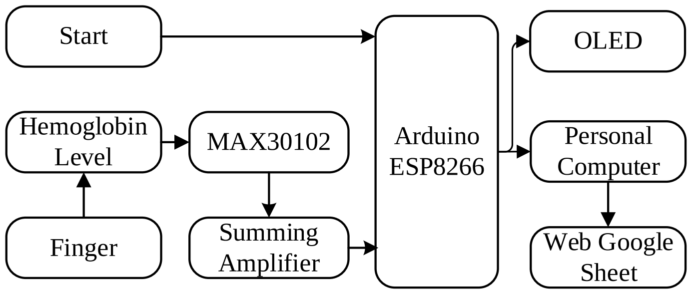

FIGURE 1. System Block Diagram.

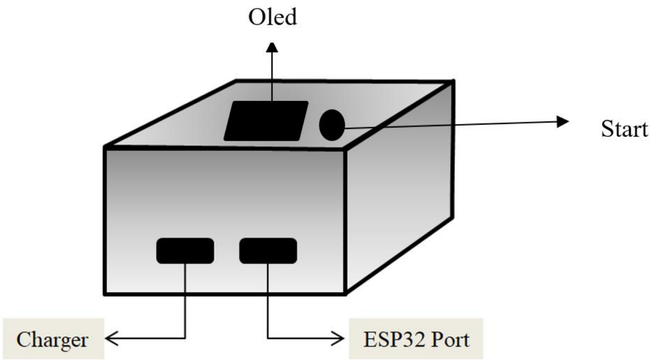

FIGURE 2. System Mechanical Diagram

This study was designed using experiments with quantitative methods. By obtaining data from non-invasive measurement of blood sugar. The data captured will be processed by ESP8266 which will be accommodated and sent the results which will be displayed in the form of numbers on the Google Sheet Web. As an independent variable in the research of making this tool is blood sugar levels because it is not dependent and controlled by other circuits. Then as a dependent variable in the research of making this tool is the MAX30102 sensor which produces data output. And the controlled variable here is ESP8266 as access to the Google Sheet Web. In FIGURE 4 the module server and PC are connected to the hospital's local Wi-Fi at the nurse station for central monitoring. The MAX 30102 sensor reads the patient's blood sugar level, which is processed by the ESP8266. The data is then sent to the OLED LCD and IoT storage via Wi-Fi. The results are accessible on the PC at the nurse station.

B. *DATA ANALYSIS*

The research that was conducted by measuring blood sugar levels in the patient's body without invasive was carried out on ten respondents with each of them taking five times of non-invasive data collection with the research module made. To get the accuracy value between the invasive tool and the non-invasive module, it is necessary to perform several stages and calculations to get an accurate value. One of the first steps is to know the regression value. Similar to calibration, regression is a method of predicting the influence between two variables to get the ADC value.

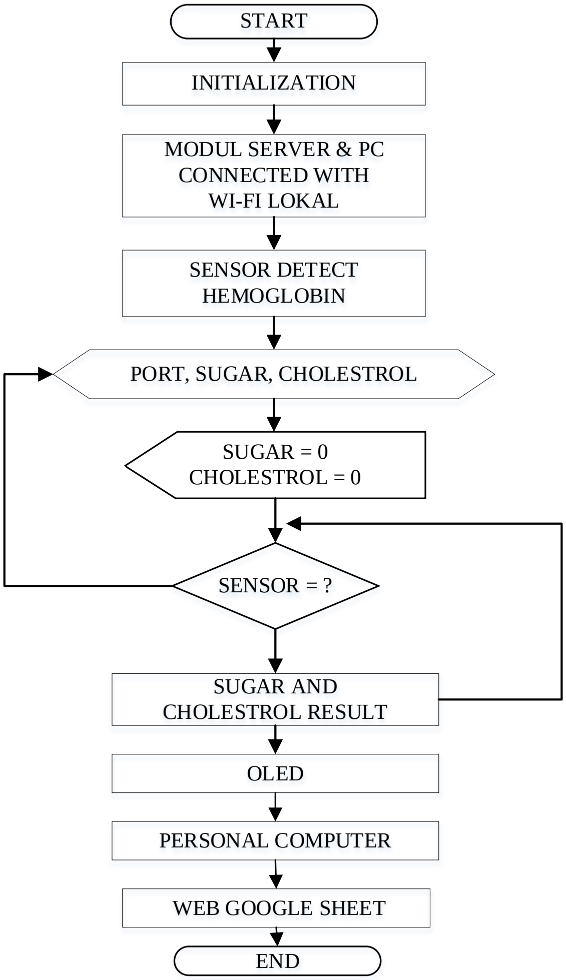

FIGURE 3. Flowchart

This correspondence is produced with the actual blood sugar level value of the Easy Touch GCU Glucometer and with the non-invasive module carried out in this study. The researcher used an invasive blood glucose meter to obtain the blood glucose value of the subject. To get the ADC value that will present the value of blood sugar levels, it is necessary to take measurements using a non-invasive module in this study by positioning the respondent on the sensor which then the ADC value will be read by the researcher. The following are the regression results of the suitability between the Easy Touch GCU Glucometer tool and the non-invasive module made. From the graph, the relationship between ADC value and blood sugar level is obtained as follows:

$$Y = -(1{,}2799x + 187{,}97)1{,}6 \quad (1)$$

where the Y value represents the blood sugar level and X represents the ADC value in Bit units. The coefficient or R value shows that the X value greatly affects the Y value, which is 0.9736.

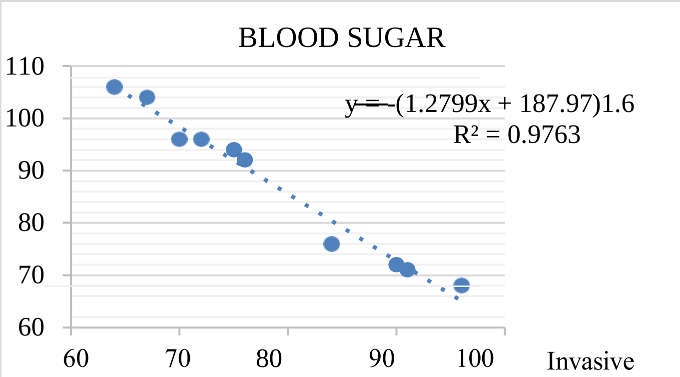

FIGURE 4. Relation Graph of ADC Values with Invasive Blood Sugar Levels

Furthermore, to obtain the accuracy value of the non-invasive module with the actual invasive tool, data has been collected ten times with each respondent five times. From fifty results, it is necessary to calculate the average. By applying equation (2), the average is used to determine the mean value of the measurement:

$$\bar{x} = \frac{\sum \mathbf{Xi}}{\mathbf{n}} \quad (2)$$

with arithmetic mean. And the real meaning is the number obtained from dividing the number of data values by the number of data in the collection. Average is the value or result of dividing the amount of data taken or measured by the amount of data taken or the number of measurements. Where x̄ represents the average value for Xi is all the data available with n being the number of data available.

$$Error = \bar{x} - p \quad (3)$$

The p value is the value of the invasive tool used. Furthermore, to obtain accuracy, before that the error value between the invasive tool and the non-invasive research module is calculated. By using equation (3), it is then used to determine the percentage error value using equation (4):

$$\%Error = \frac{Error}{p} \times 100\% \quad (4)$$

After knowing the percentage error value, we can know the accuracy value with a simple formula using equation (5).

$$\%\ Accuracy = 100\% - \%\ Error \quad (5)$$

The accuracy value shows how accurate the tool is with the Easy Touch GCU Glucometer tool comparison. This study shows the accuracy value that is still within the tolerance limit.

III. RESULT

After the design of the non-invasive blood sugar module is complete, the next step is to collect data. This research is to collect data. Data collection was carried out using the comparison method between the non-invasive module and the invasive Easy Touch GCU Glucometer. Data collection was carried out on ten respondents with five times each. During the data collection process, invasive recording is done on a Web Google Sheet that has been programmed so that non-invasive data from the Easy Touch GCU Glucometer is also recorded but automatically when the device records the respondent's blood sugar level.

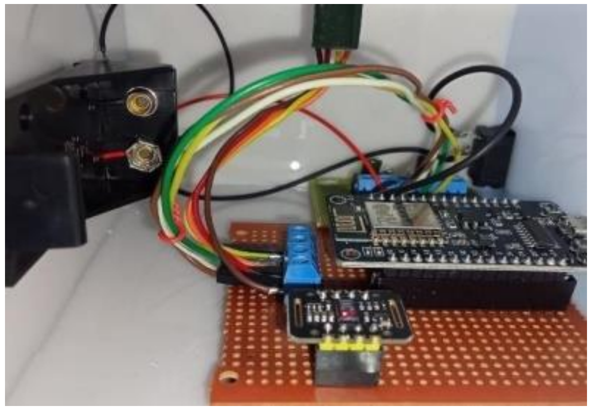

FIGURE 6. Range of Components Used

FIGURE 6 shows the electronic circuit of the non-invasive module by utilizing several components. The non-invasive module in this research uses a power supply in the form of a 9V battery, ESP8266 microcontroller, MAX30102 sensor, amplifier circuit and also OLED LCD as a viewer. Power supply is the main component that provides electrical power to the system. In this study using a power supply in the form of a 9V battery. ESP3266 microcontroller which functions as a data processor utilizes arduino software to provide programs as data processing. MAX30102 sensor which is the main sensor receiving voltage from respondents to process the data. With its two main components, the LED provides a beam of light that hits the hemoglobin in the blood of the respondent's body, which will reflect the voltage conversion received by the photodiode component. The data received by the photodiode will be received by the ESP8266 microcontroller to be processed into ADC values by utilizing regression calculations obtained in advance from several data in the regression process to become an accurate blood sugar level value with close to invasive levels. The measured blood sugar level will then be displayed on the OLED LCD by displaying the value of blood sugar levels and cholesterol levels as well as the IR value. Measured data is also recorded in real time on a Google Sheet Web that has been programmed and connected to wi-fi, so that data results can be monitored via a PC.

FIGURE 7. Non-invasive Measurement Module

TABLE 2
Results of Non-Invasive blood sugar level measurement data

Glucose (Patient)	Invasive (mm/dL)	Error (%)	Accuracy (%)
1	136	3.23	96.77
2	92	3.69	96.31
3	95	7.36	92.64
4	116	4.82	95.18
5	103	0.97	99.03
6	57	10.52	89.48
7	102	2.15	97.85
8	89	9.88	90.12
9	69	8.98	91.02
10	89	8.66	91.34
Mean % Error		6.026 %	
Mean % Accuration		93.974 %	

After the design is complete, the next step in this research is to collect data using FIGURE 7. The method used is to compare the non-invasive module with the Easy Touch GCU Glucometer on ten respondents with each of them done five times. By using this method, data can be collected to analyze the difference between invasive and non-invasive, and between the two will also be obtained in the form of percentage accuracy. This study helps in checking blood sugar levels in patients without hurting the patients.

The data results in Table 2 are the results of data from the non-invasive module for measuring blood sugar levels. Seen in table 2, of the ten respondents with five measurements each, an error value of 6.942% was obtained. Therefore, overall based on the data that has been measured, the accuracy between the Easy Touch GCU Glucometer invasive tool and the non-invasive tool conducted by the research is 93.971%.

IV. DISCUSSION

After conducting research experiments to obtain the accuracy of non-invasive tools in measuring blood sugar levels. Researchers have conducted research in making a non-invasive blood sugar level measuring device by taking measurements on ten respondents where each of them was measured five times. From all the data that has been managed, the error value in the form of a percentage of 6.942% is obtained. Overall, the tool that the researcher created has an accuracy rate of 93.971%. In research conducted by Asmat Nawaz [5], entitled Non-invasive Continuous Blood Glucose Measurement Techniques, said that this review article is to describe brief and organized information about the differences in non-invasive continuous blood glucose monitoring techniques. Many research groups have been working to develop wearable sensors for continuous blood glucose monitoring, but currently, there is to our knowledge no commercially successful non-invasive glucose monitor on the market. In further development, the continuous glucose sensor system is predictable, selective, reliable and acceptable for patient use. In his research, Redho Yurizal [3], in his study titled "Design and Analysis Photoplethysmograph Signal for Blood Glucose Measurements" highlighted that the information contained in the blood volume change signal during the cardiac cycle can be the key to calculating blood sugar levels. He emphasized that each wave peak in the signal has a significant correlation with blood sugar concentration, opening up new potential for innovative measurement methods. Indras Marhaendrajaya [4], in his research titled "Design and Realization of a Non-Invasive Blood Cholesterol Measurement Device" suggests that the measurement of cholesterol content in the blood can be done non-invasively through the utilization of NIR laser absorption from an oximeter sensor.

While glucose monitoring has numerous benefits in managing diabetes, there are also some limitations and weaknesses associated with current monitoring methods. Here are some of them since the sensor isn’t too accurate and need to get a lot of regressions to get good accuracy value. When taking data, the respondent's finger is not expected to move much. Due to instability can affect the results of the value obtained it seems the sensitivity from the sensor is good enaugh. Delay in results, although the delay still in tolerance but sometime, the tool is in delay obtaining information about the current glucose levels, calibration of devices, can lead to inaccurate results. External factors such as temperature, humidity, and the presence of substances on the skin (like lotions or dirt) can potentially affect the accuracy of glucose monitoring devices. Regular monitoring depends on the individual's willingness and ability to comply with recommended testing frequencies, and some people may find it challenging to adhere to a consistent monitoring routine.

This research is expected to be able to provide a new view for the development of technology, especially in the health sector and of course the author has several suggestions for future research, including using a more accurate sensor so that the patient's blood hemoglobin detection results are more accurate, then doing as many regressions as possible so that the value of the non-invasive module can be closer to the accurate value of the non-invasive tool, then when detecting the patient's finger because when there is movement on the sensor it will also affect the value of blood sugar levels, and finally taking each respondent five times or more to get a good average value.

It's important to note that advancements in technology are continually addressing some of these weaknesses. For example, the development of non-invasive or minimally invasive glucose monitoring technologies aims to reduce discomfort and improve user compliance. Despite these limitations, glucose monitoring remains a crucial tool for diabetes management, and this research seeks to enhance the reliability and convenience of monitoring methods.

V. CONCLUSION

Based on the results of the discussion and the purpose of making the module, it can be concluded that this module are non-invasive module that can be usefull tools, the sensor voltage amplifier circuit can be used by this tools for helping to reach the sensor voltage value can be read and managed by the ESP8266. The amplifier circuit is made analog by utilizing capacitor, resistor and LM358 components. With this amplifier circuit, the amplifier circuit produces an amplifier of 10 times. The Google sheets can be utilized as real-time data storage via the web provided that ESP is connected to the internet. And the creation of a non-invasive module using ESP8266 and MAX30102 sensors as blood sugar level sensors obtained an accuracy of 93.974% using the Easy Touch GCU Glucometer tool which uses an OLED LCD display.

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