Development of Chobmons Prototype: Cholesterol and Blood Sugar Level Monitoring System Based on Internet of Things (IoT) using Blynk Application

Heni Sumarti*,[1] Tria Nurmar'atin,[1] Hamdan Hadi Kusuma,[1] Istikomah,[1] and Irman Said Prastyo[1]

[1]*Department of Physics, Faculty of Science and Technology, Universitas Islam Negeri Walisongo Semarang, Jl. Prof. Dr. Hamka Km. 1, Semarang, Jawa Tengah 50185, Indonesia*

Abstract: In the era of the industrial revolution 4.0, we need remote technology and products that d not created new medical waste piles. An unhealthy lifestyle can cause many diseases, either degenerative diseases, namely over rate cholesterol and blood sugar level. High cholesterol and blood sugar levels are causes of major influence on atherosclerosis, stroke, micro-vascular, and cardiovascular complications. We offer a non-invasive cholesterol and blood sugar monitoring device based on red LED and infrared light absorption using the Nellcor DS-100A sensor. This technology can help reduce cumulative medical waste and help health workers to monitor patients remotely. This study used ten random samples to calibrate cholesterol and blood sugar levels. The coefficient of determination values were 0.9580 and 0.9581, respectively, which gave excellent values so that the study is continued by collecting data. Data retrieval use 20 random sample data to measure cholesterol and blood sugar levels, the average accuracy prototype is 90.26% and 91.16%, respectively. It shows great potential in determining estimation value at cholesterol and blood sugar levels. The monitoring system can show the data on the LCD display in Blynk Application with the average time required of 1.07 s.

Keywords: Nellcor DS-100A; Cholesterol and Blood Sugar; Monitoring system

*Corresponding author: heni_sumarti@walisongo.ac.id

Article history: Received 14 Maret 2022, Accepted 28 September 2022, Published October 2022.
http://dx.doi.org/10.12962/j24604682.v18i3.12532

I. INTRODUCTION

In the era of Industrial Revolution 4.0 and COVID-19 pandemics, we need remote technology and products that have not created new medical waste piles. An unhealthy lifestyle during work from home in COVID-19 pandemics, which is not balanced with exercise and healthy food, can cause many diseases [1–4], including degenerative diseases, namely over rate cholesterol and blood sugar level. High cholesterol and blood sugar levels are causes of major influence on atherosclerosis, stroke, micro-vascular and cardiovascular complications [5, 6]. Preventive measures are needed to regularly check cholesterol and blood sugar levels monitored by health workers, thus their levels can be controlled. Measuring and monitoring tools for cholesterol and blood sugar levels are currently only available in certain health institutions [7]. It generally uses an invasive method and cannot be monitored directly by health workers [6]. Therefore, it is necessary to have a new alternative to make it easier for a health worker to check patients' cholesterol and blood sugar levels remotely.

Changes in blood flow can be detected by providing light from an LED and then measuring the amount of light received by the photodiode [8]. An oximeter sensor can measure oxygen saturation in the blood by using light at a certain wavelength through the tissue (usually the index finger) [8]. Cholesterol deposits associated with atherosclerosis are thought to increase with age [10]; it blocks the blood vessels in the form of plaque [10, 11] . Meanwhile, blood sugar levels cause an increase in blood concentration [12]. There is an opportunity to measure cholesterol and blood sugar levels using an oximeter and the Nellcor DS-100A sensors.

In the previous study, the monitoring system measured the glucose level in the blood using an oximeter sensor resulting in an accuracy of up to 97% [13]. Research by Nurmar'atin et. al. [14] developed a telemedicine system to measure cholesterol levels in the blood delivers an accuracy of 82.76% using the oximeter DS-100A. These results indicate that the oximeter sensor can be developed to measure blood sugar and cholesterol levels non-invasively which can be used for estimation. Therefore, in this research, a monitoring system was developed to estimate blood sugar and cholesterol levels in real-time. This study aims to develop Chobmons prototype and is expected to be used as a reference instrument for health workers to monitor cholesterol and blood sugar levels remotely.

II. METHOD

The research samples were people with normal or high cholesterol and blood sugar levels in the age range of 20-60 years, both male and female. The number of samples was ten random samples for prototype calibration, while the number of samples for the accuracy test of the prototype system was

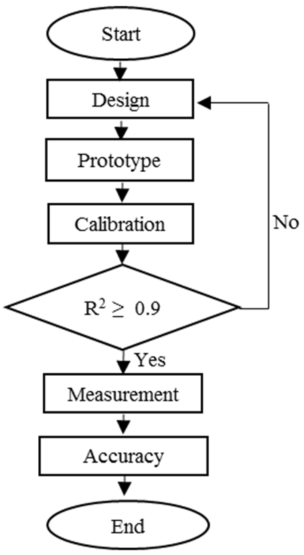

FIG. 1: Schematic of the research procedure.

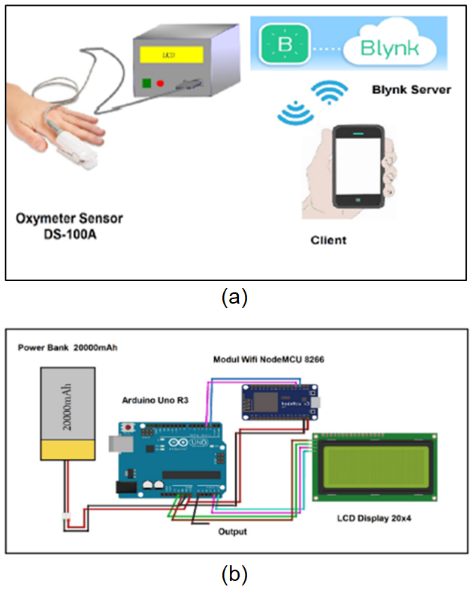

FIG. 2: The Chobmons prototype design: (a) monitoring system and (b) hardware components.

20 random samples. The standard measurement instrument used is Autocheck 3-in-1 to measure cholesterol and blood sugar levels. It has received a distribution permit from the Indonesian Ministry of Health with AKL 20101311321. The sample measured using a standard instrument is a fingertip capillary blood, while prototypes hold fingertips in a Nellcor DS-100A sensor for 5 seconds. The measurement using the prototype system is five times to test the stability of the prototype, then the results is averaged to process the data. Data collection was carried out by measuring blood sugar and cholesterol levels using the Chobmons prototype, followed by taking blood using standard tools.

The schematic of the research procedure is shown in Fig. 1. The first stage is the design of the Chobmons prototype so that the prototype can work properly. The second stage is the manufacture of the prototype instrument, followed by calibration and measurement. Measurement aims to get the accuracy of the prototype system. The last step is to develop the monitoring system by synchronizing the Arduino IDE software and the Blynk application so that the data that appears on the LCD screen of the device can be displayed in the Blynk application.

The Chobmons prototype design is shown in Fig. 2. The object of measurement is the tip of the index finger of the sample to detect cholesterol and blood sugar levels by utilizing absorption from red and infrared light. When the tool is turned on, the power bank provides voltage and runs the transmitter circuit. Analog data is processed by Arduino Uno R3 to be displayed on a 20x4 LCD screen in digital form. Then the data is sent by the Node MCU module to the Blynk Application and can be accessed directly via Android.

Calibration is carried out to obtain a linear tradeline using ten random samples. The linear tradeline is obtained by comparing the ADC (Analog to Digital Converter) value of the prototype system and cholesterol and blood sugar levels on a standard measuring instrument (Autocheck 3-in-1). The degree of relationship value assessment will be served using a simple linear regression formula, $y = a + bx$, where y is the result value of standard measuring instruments, a and b are constant, and x is the ADC value of the prototype system measurement. The linear tradeline obtained is used as a conversion factor for the ACD value (mV) into cholesterol and blood sugar levels (mg/dl), while the coefficient of determination R^2 is used to measure the prototype's success in data converting.

The accuracy system test compares the Chobmons prototype and standard measuring instruments in the mg/dl unit. Sampling was done by measuring cholesterol and blood sugar levels in 20 random samples, respectively. Sampling was carried out in two ways: (1) taking a blood sample at the tip of the finger artery using a standard invasive measuring instrument (Autocheck 3-in-1); and (2) attaching the finger to the Nellcor DS-100A sensor on a non-invasive measuring instrument to measure cholesterol and blood sugar levels within 5 seconds. The accuracy of the prototype can be calculated using Eq. (1).

$$Accuracy = 100\% - \frac{Standard - measurement - prototype}{Standard - measurement} \times 100\% \quad (1)$$

The manufacture of the monitoring system in this study was designed using Arduino IDE 1.8.13 software and Blynk Apps. This software is used to program a microcontroller used in non-invasive measurement devices using the Internet of Things (IoT). The data is connected to the server to be displayed in the Blynk application. The function test of the monitoring system is carried out by looking at the data display on the Blynk application. The system can function properly if the data displayed on the LCD screen can appear in the Blynk application display with the same value. Data retrieval was carried out ten times to test the display and speed of data transfer displayed in the Blynk application.

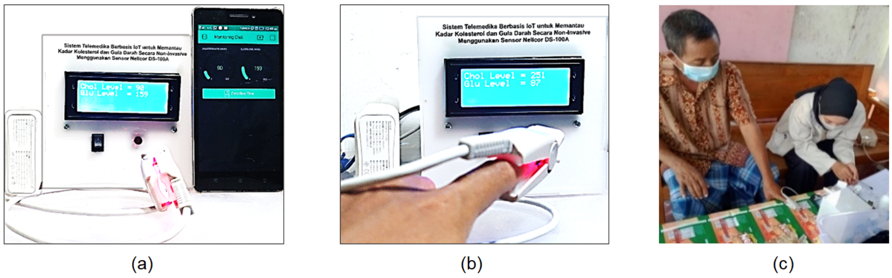

FIG. 3: (a) The Chobmons prototype instrument, (b) measurements of cholesterol and blood sugar levels using the Nellcor DS-100A sensor via fingertip, and (c)an illustration of data collecting process.

III. RESULTS AND DISCUSSION

A. Results

The prepared Chobmons prototype for measuring cholesterol and blood sugar levels using the Nellcor DS-100A sensor is shown in Fig. 3. The Chobmons prototype consists of a Nellcor DS-100A sensor, 20x4 LCD, an on/off button, a reset button, a power bank, and a microcontroller unit. The Nellcor DS-100A sensor is used as a finger scanner to detect cholesterol and blood sugar levels by utilizing red and infrared light at certain wavelengths. The 20x4 LCD screen displays the values of cholesterol and blood sugar levels. The on/off button turns the appliance on and off. The reset button is used to set the device back to its initial state. The power bank is used as a voltage source to power the device. The microcontroller unit is the main part that runs the tool, or it can be said the brain of the tool.

The calibration result by taking ten random samples data is plotted in a graph using the Microsoft Excel program, then a linear tradeline and the coefficient of determination are generated. Fig. 4(a) shows the relationship between the average ADC value of red LED and cholesterol levels in 10 random samples. The linear tradeline obtained is $y = 0.124x + 90.376$, while the coefficient determination is 0.958. The linear relationship between ADC of red LED and cholesterol levels in the blood is directly proportional, so the higher the cholesterol levels in the blood, the higher the ADC value of red LED. Fig. 4(b) presents the relationship between the average ADC value of infrared light and blood sugar levels in 10 random samples. The linear tradeline obtained is $y = -0.114x + 159.04$, while the coefficient determination is 0.9581. The linear relationship between ADC of infrared light and blood sugar levels is inversely proportional, so the higher the blood sugar level in the blood, the lower ADC value of infrared light value, and vice versa. This linear tradeline equation is the formula for converting the ADC value into the cholesterol and blood sugar level. Based on the coefficient determination, the linear relationship between the ADC value of the prototype instrument and cholesterol and blood sugar levels value of the standard instrument is compelling [15], so the testing of the prototype instrument can continue at the next stage.

The result of measurement on 20 random samples is shown

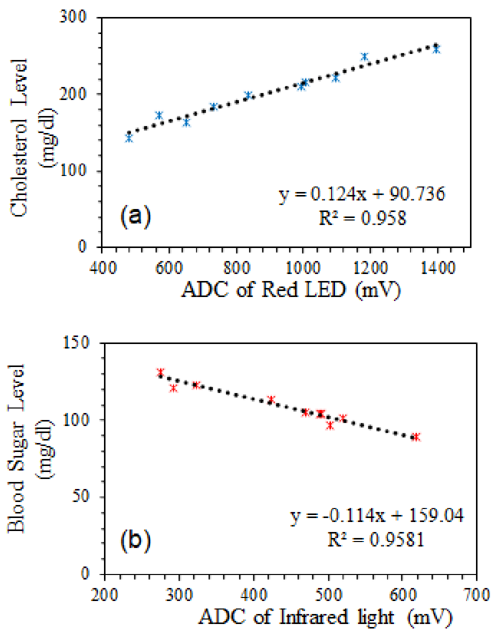

FIG. 4: The graph of calibration in measurement at (a) cholesterol level and (b) blood sugar level.

in Table I. The measurement results of maximum cholesterol and blood sugar levels can be achieved if the subject does not perform strenuous physical activity at least 15 minutes before the measurement begins [16], so that during the measurement process, the subject is ensured to be at rest. The measurement of cholesterol and sugar levels using the prototype instrument is the average value of five data. The average accuracy in cholesterol level measurement is 90.26%, while the average accuracy in sugar level measurement is 91.16%.

Furthermore, the experiment was carried out by measuring the data transfer time from the LCD display to the Blynk application. Table II shows the screen display test of the blynk application and also the data transfer speed. The seven data that appeared on the LCD screen managed to appear on the Blynk application screen with an average speed of 1.07 s. The results show that all the data that appears on the LCD screen of the prototype tool can be displayed in the Blynk application.

TABLE I: The Accuracy of the designed Chobmons prototype.

No	Cholesterol level		Accuracy (%)	Blood Sugar level		Accuracy (%)
	Autocheck 3-in-1 (mg/dl)	Prototype (mg/dl)		Autocheck 3-in-1 (mg/dl)	Prototype (mg/dl)	
1	241	196.01	81.33	69	68.39	99.10
2	225	261.09	83.96	98	120.60	81.26
3	198	194.55	98.26	104	109.95	94.59
4	183	204.05	88.50	123	122.15	99.30
5	167	128.13	76.73	109	136.42	79.90
6	143	150.38	94.84	107	122.15	87.60
7	210	180.26	85.84	106	125.07	84.75
8	173	161.39	93.29	121	125.71	96.26
9	184	181.53	98.66	124	111.66	88.95
10	163	171.48	94.79	106	122.67	86.41
11	215	215.55	99.74	95	129.86	73.16
12	147	165.71	87.27	131	127.80	97.50
13	184	220.54	80.14	119	129.38	91.98
14	154	176.54	85.36	105	105.48	99.54
15	237	194.47	82.06	101	104.43	96.71
16	194	165.93	85.53	89	88.43	99.35
17	222	226.99	97.75	91	74.20	77.36
18	258	264.06	97.65	117	126.60	92.42
19	250	237.16	94.86	104	103.13	99.16
20	211	214.04	98.56	113	110.73	97.95

TABLE II: Monitoring system test.

No	Display on LCD	Display on Blynk	Average data transfer (s)
1	Cholesterol	Succeed	1.4
2	Blood Sugar	Succeed	1.1
	Average		1.07

B. Discussions

The ADC value in cholesterol level measurement is using LED red based on the cholesterol maximum absorbance-value in the wavelength range of 550-750 nm [17–19]. Meanwhile, blood sugar level measurement is using ADC value at near-infrared. This is based on measuring blood sugar levels which is effective using near-infrared at wavelengths between 850-1650 nm [18–21]. The Nellcor DS-100A sensor emits the red and infrared light alternately, then captured by a photodiode. Several body parts absorb the light from the red and infrared LEDs at the measurement location (fingertip), referred to as light absorbers. These components are skin, tissue, venous blood, and arterial blood. If the light absorption in the valley (which includes all light absorbers) is subtracted from the light absorption at the peak, then, in theory, the resulting value represents the blood absorption characteristic and is considered as arterial blood flow [8].

The relationship between ADC in red light and cholesterol levels is directly proportional; the higher the cholesterol level, the less red light is absorbed, and the photodiode captures the more light after passing through the finger. In reverse, the lower the cholesterol level in the blood, the lower the red light that passes through the finger and is detected by the photodiode. The type of cholesterol in the blood that flows the most in the arteries is LDL (Low-Density Lipoprotein) cholesterol, which is about 66% of the total cholesterol in the blood [24]; it is also known as bad cholesterol with a low density. LDL cholesterol is the cause of several heart diseases [24], so this is the most important part that must be monitored to always be in normal condition. LDL cholesterol is a plaque that sticks to the arteries of the blood [25], so it does not increase blood concentration. This condition follows Beer Lambert's law; the absorbance value of light absorbed by the material in a particular solution will be equal to the concentration of the solution [26].

The ADC value in infrared light is inversely proportional to blood sugar levels; the higher the blood sugar level, the higher the infrared light is absorbed so that only a small amount passes through the finger and is detected by the photodiode. Otherwise, the lower the blood sugar level, the higher the infrared light that the photodiode can detect after passing through the finger. Blood sugar refers to the level of sugar in the blood formed by carbohydrates in the food and drinks we consume, excess blood sugar in the body causes diabetes mellitus [27], increasing blood concentration. This condition follows Beer Lambert's law; the magnitude of the absorption value will be proportional to the concentration of the test substance [26].

The average of accuracy Chobmons prototype to measuring cholesterol and blood sugar levels is 90.26% and 91.16%, respectively. It is indicating that the prototype of this instrument cannot be used as a standard measuring instrument on medical instruments yet, which is must be more than 95% [28, 29]. The results of this study show an increase in the accuracy compared to previous studies on measuring cholesterol levels by 7.5% [14]. While the highest level of accuracy in blood sugar is 99.54% with an increase of 2.54% [30]. This condition is because the light on the skin layer can interfere, affecting the sensor's intensity; correction is an important way to get good measurement results [13]. Nevertheless, it shows great potential in determining estimation value at cholesterol and blood sugar levels. We can improve accuracy by providing corrections to the algorithm and or circuit on the prototype. The monitoring system can work well by displaying real-time data monitored using Android on the Blynk application. This condition can make it easier for health workers to remotely monitor high cholesterol and blood sugar levels with a fairly high data transfer speed.

IV. CONCLUSION

The development of a monitoring system to measure cholesterol and blood sugar levels has been successfully using the Nellcor DS-100A sensor based on the Blynk application. Equipment testing was carried out on 20 random samples by comparing prototype instruments and standard instruments (Autocheck 3-in-1). The results showed that the average accuracy of the prototype instrument to measure cholesterol and blood sugar level is 90.26% and 91.16%, respectively. It shows great potential in determining the estimation value at cholesterol and blood sugar levels. The monitoring system can show the data on the LCD display in Blynk Apps with the average time required of 1.07 s.

Acknowledgment

This work was supported by the financial aid from the DIPA BOPTN LP2M 2021, Universitas Islam Negeri Walisongo Semarang.

[1] L. J. Utama, "Gaya Hidup Mayarakat Nusa Tenggara Timur dalam Menghadapi Pandemi Corona Virus Disease 19 (Covid-19)," *Annada - Jurnal Kesehatan Masyarakat*, vol. 7, no. 1, pp. 34-40, 2020.

[2] T. Suryadin, S. Arhesa, and D. Febriana, "Gaya Hidup Sehat Masyarakat Desa Maja Selatan Pada Masa Pandemi Covid 19," *J. Educ.*, vol. 7, no. 3, pp. 657661, 2021.

[3] T. F. A. Atmadja et al., "Description of attitudes and healthy lifestyle of Indonesian community during pandemic Covid-19," *AcTion Aceh Nutr. J.*, vol. 5, no. 2, pp. 195202, 2020.

[4] M. Muslim, "Manajemen Stress pada Masa Pandemi Covid-19, *ESENSI J. Manaj. Bisnis*, vol. 23, no. 2, pp. 192201, 2020.

[5] R. Khan, "Postprandial blood glucose," *Diabetes Care*, vol. 24, no. 4, pp. 775778, 2001.

[6] D. R. Prasetyo, "Rancang Bangun Telemedicine Pengukur Kadar Kolesterol dalam Darah Berbasis Internet of Things," Tugas Akhir, Universitas Semarang, Semarang, Indonesia, 2019.

[7] W. F. Ramadhan, "Rancang Bangun Alat Ukur Detak Jantung Menggunakan Pulse Sensor Sen-11574 Berbasis Arduino Pro Mini Dengan Smartphone Android dan Oled SSD1306," Tugas Akhir, Universitas Islam Negeri Sunan Kalijaga, Yogyakarta, Indonesia, 2018.

[8] M. Elgendi, *PPG Signal Analysis: An Introduction Using MATLAB* (First Edit, Vol. 53, Issue 9). India: CRC Press, 2021.

[9] V. C. S. T. Sanders, "List of Boxes Clinical applications of the book s anatomical and physiological information are set apart from the text in boxed inserts and often deal with aspects of pathophysiology . A list of these boxes is presented here for your convenience," 2007.

[10] B. Tamarappoo et al., "Improvement in LDL is associated with decrease in non-calcified plaque volume on coronary CTA as measured by automated quantitative software," *Journal of Cardiovascular Computed Tomography*, vol. 12, no. 5. pp. 385390, 2018.

[11] K. Nishi et al., "Oxidized LDL in carotid plaques and plasma associates with plaque instability," *Arteriosclerosis, Thrombosis, and Vascular Biology*, vol. 22, no. 10. pp. 16491654, 2002.

[12] R. S. Dillon, "Importance of the hematocrit in interpretation of blood sugar.," *Diabetes*, vol. 14, no. 10, pp. 672674, 1965.

[13] R. Ekawita, A. A. Nasution, E. Yuliza, N. Suardi, and S. Suwarsono, "Development of Non-Invasive Blood Glucose Level Monitoring System using Phone as a Patient Data Storage," *J. Penelit. Fis. dan Apl.*, vol. 10, no. 2, p. 103, 2020.

[14] T. Nurmar'atin, H. Sumarti, and M. Ardhi, "Design and Implementation of Non-Invasive Telemedicine System for Detecting Cholesterol Levels in Blood as a Solution during the Covid-19 Pandemic," *Adv. Eng. Res.*, vol. 211, *Int. Conf. Sci. Eng.* (ICSE-UIN-SUKA 2021) Des., vol. 211, pp. 8691, 2021.

[15] G. Ndruru, R. E., Situmorang, M. and Tarigan, "Analisa Faktor-Faktor Yang Mempengaruhi Hasil Produksi Padi di Deli Serdang," *Saintia Mat.*, vol. 2, no. 1, pp. 7183, 2014.

[16] L. Agustine,i. Muljono, P.R. Angka, A. Gunadhi, D. Lestariningsih, W.A. Weliamto, "Heart Rate Monitoring Device for Arrhythmia Using Pulse Oximeter Sensor Based on Android," in *2018 International Conference on Computer Engineering, Network and Intelligent Multimedia, CENIM*, Surabaya, Indonesia, 2018, pp. 106-111.

[17] A. Microspheres, J. Prasad, A. Joshi, R. D. Jayant, and R. Srivastava, "Cholesterol Biosensors Based on Oxygen Sensing," *Biotechnol. Bioeng.*, vol. 108, no. 9, pp. 20112021, 2011.

[18] V. Semwal and B. D. Gupta, "LSPR- and SPR-Based Fiber-Optic Cholesterol Sensor Using Immobilization of Cholesterol Oxidase over Silver Nanoparticles Coated Graphene Oxide Nanosheets," *IEEE Sens. J.*, vol. 18, no. 3, pp. 10391046, 2018.

[19] S. Mukherjee, H. Raghuraman, and A. Chattopadhyay, "Membrane localization and dynamics of Nile Red: Effect of cholesterol," B*iochim. Biophys. Acta*, vol. 1768, pp. 5966, 2007.

[20] A. Mason, *Sensing Technology: Current Status and Future Trends IV*. New York: Springer Cham Heidelberg, 2015.

[21] X. Zhang, J. Chen, J.H. Yeo, "Blood sugar monitoring with laser diode," in *Proceedings Volume 6047, Fourth International Conference on Photonics and Imaging in Biology and Medicine*, 2006, p. 604741.

[22] K. Song, U. Ha, S. Park, J. Bae, H.-J. Yoo, "An Impedance and Multi-Wavelength Near-Infrared Spectroscopy IC for Non-Invasive Blood Glucose Estimation," *IEEE J. Solid-State Circuits*, vol. 50, no. 4, pp. 10251037, 2015.

[23] G Santoso, S Hani, S. Kristiyana, Y.A. Saputra, "Design Non-Invasive of Blood Sugar Detector Prototypes Using Cellular Technology GPS-Based," in J*Journal of Physics: Conference Series*, 2019, Madiun, Indonesia, vol. 1381, p. 012032.

[24] C. A. Vanstone, M. Raeini-sarjaz, W. E. Parsons, and P. J. H. Jones, "Unesterified plant sterols and stanols lower LDL-cholesterol concentrations equivalently in hypercholesterolemic persons 1 3," *Am J Clin Nutr*, vol. 76, pp. 12721278, 2002.

[25] M. S. Sandhu et al., ”LDL-cholesterol concentrations: a genome-wide association study,” *Nutr. Metab. Cardiovasc. Dis.*, vol. 371, pp. 483491, 2008.

[26] W. B. Baker, A. B. Parthasarathy, D. R. Busch, R. C. Mesquita, J. H. Greenberg, and A. G. Yodh, ”Modified Beer-Lambert law for blood flow,” *Biomed. Opt. Express*, vol. 5, no. 11, pp. 44074424, 2014.

[27] W. Lösche, F. Karapetow, A. Pohl, C. Pohl, T. Kocher, ”Plasma lipid and blood glucose levels in patients with destructive periodontal disease,” *J. Clin. Periodontol.*, vol. 27, no. 8, pp. 537-541, 2000.

[28] M. Sulehu and A. H. Senrimang, ”Program Aplikasi Alat Pengukur Kadar Glukosa Dalam Darah Non Invasive Bebasis Desktop,” *Inspir. J. Teknol. Inf. dan Komun.*, vol. 8, no. 1, pp. 1624, 2018.

[29] H. Suyono and Hambali, ”Perancangan Alat Pengukur Kadar Gula dalam Darah Menggunakan Teknik Non-Invasive Berbasis Mikrokontroler Arduino Uno,” *JTEV (Jurnal Tek. Elektro dan Vokasional)*, vol. 06, no. 01, pp. 6976, 2020.

[30] I. Marhaendrajaya, E. Hidayanto, and Z. Arifin, ”Desain dan realisasi alat pengukur kandungan kolesterol dalam darah non-invasive,” Y*oungster Phys. J.*, vol. 6, no. 3, pp. 290295, 2017.