Chapter

Non-Invasive Approach for Glucose Detection in Urine Quality using Its Image Analysis

Anton Yudhana, Liya Yusrina Sabila, Arsyad Cahya Subrata, Hendriana Helda Pratama and Muhammad Syahrul Akbar

Abstract

Human health can be detected through urine content, where metabolic waste in the body is excreted through urination. Glucose in the urine is caused by high levels of glucose in the blood, which can cause poor kidney function. This study aims to detect glucose in urine using non-invasive image analysis. The three measurement parameters in this research consist of Hue (H) is the color portion of the model that is expressed as a number from 0°C to 360, saturation (S) is the amount of gray in a particular color from 0% to 100%, and value/brightness (V) is the intensity of the color from 0% to 100%. Reagent strips for urinalysis with 10 variables are applied in this research, including glucose, bilirubin, ketone, specific gravity, blood, pH, protein, urobilinogen, nitrite, and leukocytes. All reading data from the system is sent to the monitor layer, which uses the python platform with the additional library Open-cv. The results obtained that the urine color is getting dimmer with the addition of 1 g of glucose in each test. This study was able to detect glucose in urine using image analysis.

Keywords: glucose detection, non-invasive, urine quality, image processing, Arduino microcontroller

1. Introduction

Health is one of the important things that need to be maintained and considered. However, the pattern of human consumption of various types of food and beverages is often a major problem for individual health—especially the frequent habits of individuals when consuming food with glucose levels on an irregular basis. The composition of substances in urine varies depending on the type of food and water drunk [1]. One way to find out if the body is healthy can be done by detecting urine. Normal human urine consists of water, urea, uric acid, ammonia, creatinine, lactic acid, phosphoric acid, sulfuric acid, chloride, and salt, under certain conditions, excess substances such as vitamin C, drugs [2, 3].

Glucose in the urine (called glucosuria) is a disease. If diabetes is accompanied by hyperglycemia (increased blood sugar levels), it can be diabetes mellitus (DM), pancreatic disease, central nervous system disease, severe metabolic disorders, or due to corticosteroid drugs, thiazides, oral contraceptives. Diabetes without hyperglycemia is found in situations of abnormal renal tubular function, pregnancy, sugar other than glucose in the urine, or eating lots of fruit.

The renal glucose threshold is in the range of 60–180 mg/dl, and the urine will immediately show a higher number than the glucose value. Therefore, if the positive value is reduced by one (+1), it is estimated that it will enter the range of 160–180 mg/dl, two (+2) range of decrease in blood glucose estimated 180–250 mg/dl, three positive decreases (+3) estimated range of blood glucose 250–300 mg/dl, four positive range of decrease (+4) estimated range of blood glucose >300 mg/dl.

Urine can be used to diagnose several diseases such as diabetes, liver disease, kidney disease, and others. One of the causes of these diseases is high glucose levels [4–7]. Therefore, the need for early detection of glucose levels in the urine. There are many ways to detect glucose levels in the body in the medical field, including invasively, namely taking blood samples which are analyzed through clinical laboratory procedures. However, this method requires medical action by injuring the limbs using a syringe [8]. Then the second method is non-invasive, which is the opposite of the first method, namely, without any medical action to injure the human body. The non-invasive is an option that has not been widely supported by detector/technology that are devoted to detecting/analyzing glucose content, even if it is available on the market but requires a large purchase cost (high cost) [9–11].

Various studies have developed non-invasive methods for glucose detection with various target sites. Some of these studies include reverse iontophoresis and bioimpedance spectroscopy [12, 13] with target site is wrist skin, ultrasound, electromagnetic and heat capacity [14] with target site is ear lobe skin, near-infrared spectroscopy, and photoacoustic spectroscopy [15, 16] with target site is fingertip skin, Raman spectroscopy [17] with target site is fingertip skin, optical coherence tomography [18] with target site is skin, fluorescence technology [19] with target site is intravascular, and thermal emission spectroscopy [20] with target site is tympanic membrane.

The non-invasive method is recommended because it is carried out without medical action that injures the body. However, to overcome the problem of cost due to the large size of the equipment used, a device for detecting glucose in urine that is easy to move has been developed. This detector, which is designed in the form of a mobile detector, is specifically designed to analyze glucose content non-invasively through urine. This detector is in the form of a storage box that is easy to use without the need to be attached to a member of the body by utilizing a temperature sensor to detect glucose content through urine. The urine waste detector system uses infrared spectroscopy in real-time. From the claims of this study, it shows the difference from using a detector system, namely analyzing the signal-to-noise ratio from the input of the IR thermal sensor resulting from the reflection of light in the urine fluid. Therefore, the proposed research does not require light to detect the glucose content in urine.

A robust analysis is needed to obtain accurate results of glucose detection in urine. One of the analytical techniques that are often used is image analysis through image processing techniques. Urine strip test results can be detected using image processing techniques [21]. The results showed that the image quality of the system is quite low because the system uses a webcam that is experiencing interference. In addition, image processing techniques are used for glucose detection for accurate results [22]. Several studies have shown that image processing techniques can be recommended for various needs, such as monitoring the growth of corn sprouts, comparison of image segmentation, batik identification, and others [23–25]. The detector made in this study will be a solution to the shortage of existing detectors with image analysis.

2. Material and methods

2.1 Non-invasive glucose monitoring

The detector will be known as a non-invasive glucose detector as an early diagnosis of glucose content as an alternative to conventional invasive glucose detectors. Technologies used for non-invasive glucose monitoring include optical, transdermal, and thermal techniques [26]. Non-invasive methods are highly sought after to replace traditional fingerprinting methods because they can facilitate continuous glucose monitoring. The research group has been working on developing practical and non-invasive glucose for decades. The challenges associated with non-invasive glucose monitoring are the many factors that contribute to inaccurate measurements [27].

2.2 Microcontroller

Arduino Nano is a complete small microcontroller board that supports the use of PCB boards. Arduino Nano is based on the Atmel AVR microcontrollers. This microcontroller is open source with Arduino Language programming language, which resembles C++. The Arduino Nano doesn't include a barrel jack, but it connects to a computer using the MiniB USB connector. Arduino Nano is equipped with 8 analog pins and 22 digital pins (6 of which is PWM pin) with 16 MHz of clock speed. **Figure 1** shows the shape of the Arduino Nano.

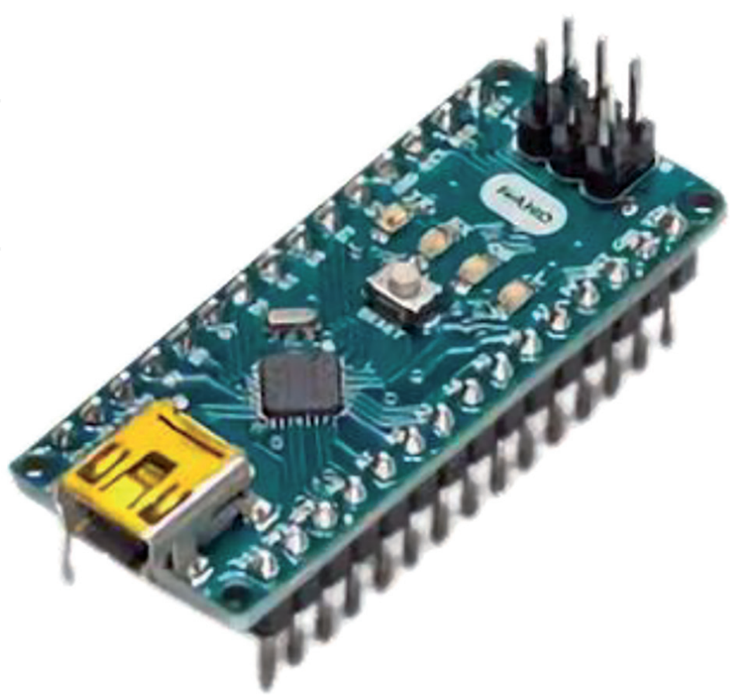


Figure 1.
Arduino Nano.

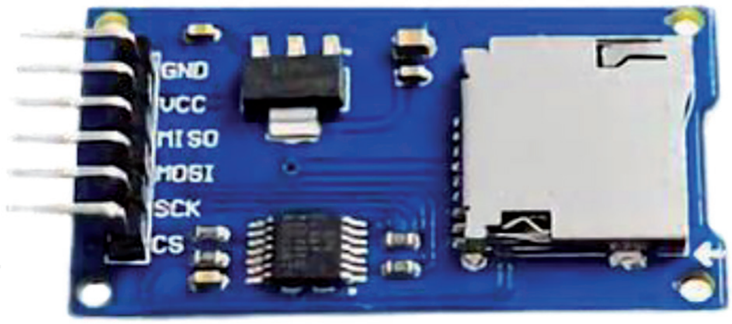


Figure 2.
MicroSD card module.

2.3 Adapter microSD card module

This microSD card adapter module is a microSD card reader module. Through the file system and SPI driver interface, the MCU completes the file system read and write operations of the microSD card. Arduino users can directly use the Arduino IDE, which is equipped with an SD card. The figure of the microSD card module is shown in **Figure 2**.

This communication model is indeed more wasteful in terms of the use of data lines, but it is safer when synchronizing data between data sent from the signal processing module and data received by the data storage module. This is because this model uses synchronous communication with a single clock source originating from the Arduino Nano module. In this study, the data is stored in the form of text files on a microSD card with a capacity of 4 GB. The pins between the Arduino and the microSD card module are VCC to 5 V, GND to ground, Mosi to pin 11, Miso to pin 12, SCK to pin 13, CS to pin four from Arduino.

2.4 I2C (inter integrated circuit) module and LCD 16×2

I2C liquid crystal display (LCD) is an LCD module that is controlled serially synchronously with the I2C/IIC (inter-integrated circuit) or TWI (two wire interface) protocol. The figure of I2C is shown in **Figure 3**. The LCD module is controlled in parallel for both the data and control lines. However, parallel lines will take up a lot of pins on the controller side, so an I2C is needed to save on PIN usage on Arduino. The Arduino is supported I2C. The I2C pin is on pin A4 for serial data and pins A5 for serial clock. The pins between the Arduino and the I2C module are GND to ground, VCC to 5 V, SCL to A5 pin, and SDA to A4 pin from Arduino.

2.5 LCD 16×2

LCD, as shown in **Figure 4**, is an electronic component that can display data in the form of characters, letters, or graphics. The LCD replaces the role of the seven-segment display by providing many advantages, such as a good display form, high energy efficiency, and a small form factor. The features presented in the 16×2 LCD consist of 16 characters and 2 lines, have 192 stored characters, there is a programmable character generator, can be addressed in 4-bit and 8-bit modes, and is equipped with a backlight.

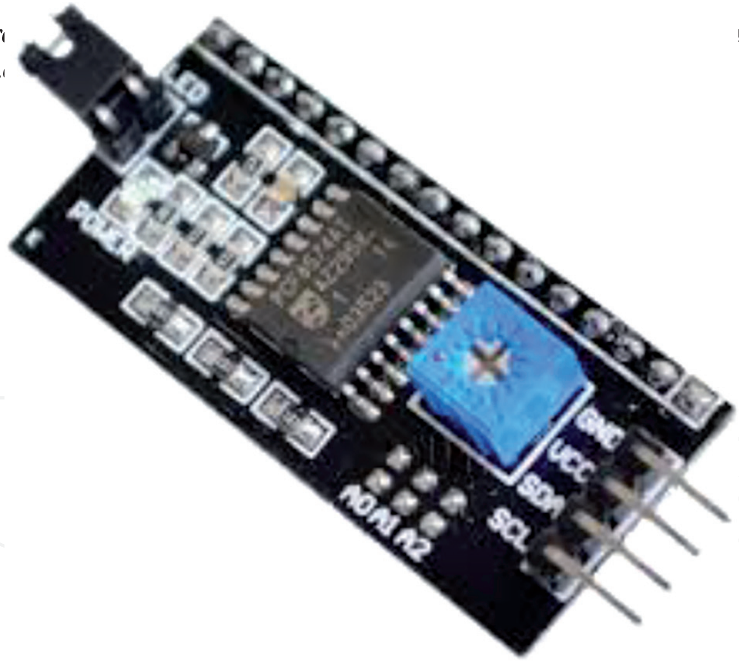


Figure 3.
I2C LCD module.

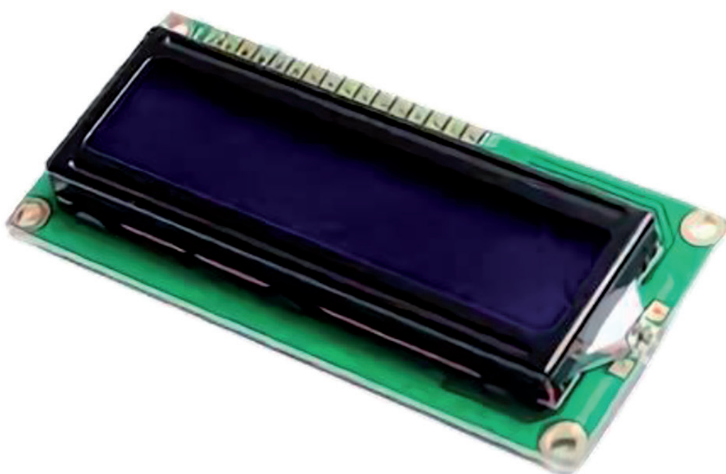


Figure 4.
LCD 16×2.

2.6 IR thermal camera sensor

Thermal imaging is a tool that uses heat energy to detect the surface of an object. Currently, thermal imaging technology has been used in various fields, including engineering, health, military, environment, to health.

IR Thermal Camera is a non-contact sensor device that can detect heat or infrared energy and convert it and convert it into electrical energy or electronic signal, which can then produce a thermal image. In addition to generating thermal images, these electronic signals can also be used to perform temperature calculations or measurements.

Visualization of AMG8833 sensor is shown in **Figure 5**. The AMG8833 is a thermal imaging camera sensor with an 8×8 pixel thermal sensor family manufactured by Panasonic. The AMG8833 only supports I2C and has a configurable interrupt pin, which can be activated when each pixel is above or below the required threshold.

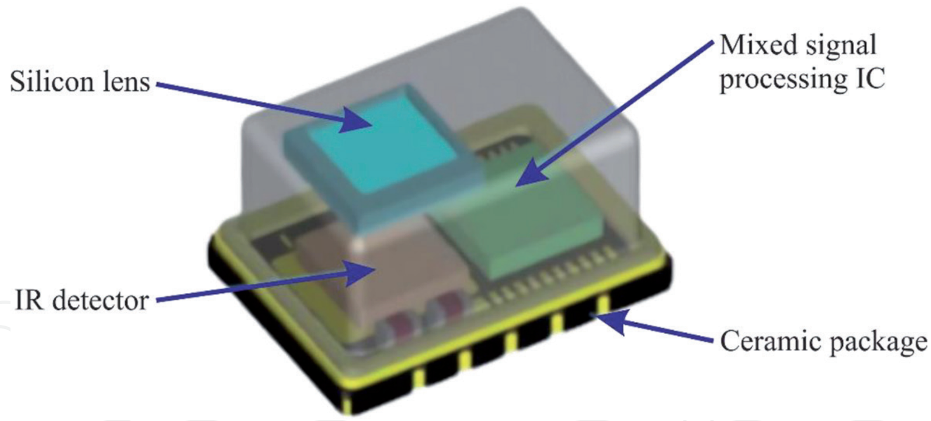


Figure 5.
Visualization of AMG8833 sensor.

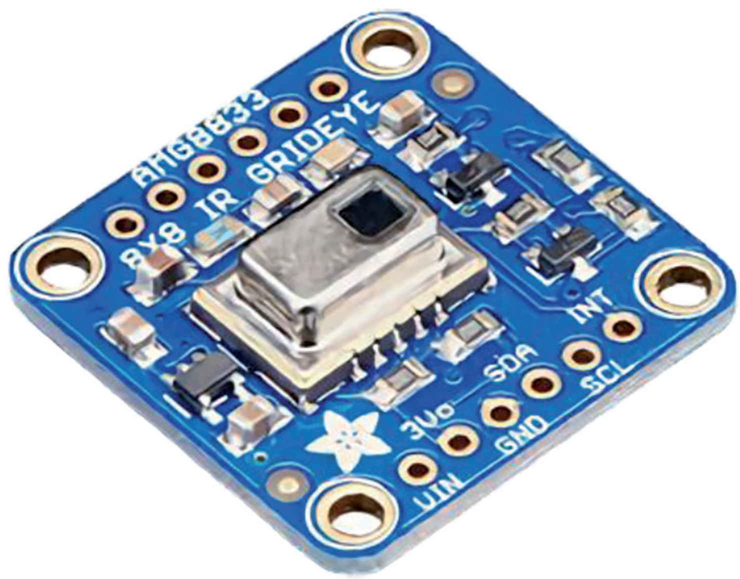


Figure 6.
Sensor IR thermal camera AMG8833.

The detector on the AMG8833, as shown in **Figure 6**, consists of a thermopile sensor using MEMS (micro electro mechanical system) technology which is arranged in an 8×8 pixel array. A thermopile is a temperature sensor composed of a layer of the silicon film, which contains many thermocouples so that the infrared energy emitted from the object will be absorbed and converted into electrical energy. After turning into electrical energy, signal processing is carried out. In the signal processing process, first, amplify the electrical energy or electrical signal obtained, then use an analog-to-digital converter (ADC) to convert it into a digital signal. Then the digital signal enters the control system for calculation, comparison, and correction so that the output temperature is Celsius.

2.7 UBEC regulator module

UBEC, as shown in **Figure 7**, is a circuit to change the voltage, high to low or vice versa, requires the right circuit, so that power can be delivered with the highest possible efficiency level. However, there is also switching battery elimination circuit

Figure 7.
UBEC regulator module 3 A 5–6 V.

(SBEC) where the overall use is the same as UBEC, and only SBEC has quality below UBEC. The 7805 regulator IC is very commonly used to lower the voltage. This regulator has the ability to handle currents up to 3 A, with a V_{in} of 5.5–26 V, for 5–6 V output.

2.8 Block diagram and flowchart portable urine quality detector

Figure 8 shows that the tool is fully integrated with all the components used. The thermal sensor has an 8×8 infrared sensor array that measures the temperature of urine in a non-contact container by detecting infrared energy or thermal energy emitted from the urine sample. The reading results produce an electrical signal and amplify it and then convert it into a digital signal using ADC.

A digital signal is sent to the control system for calculation, comparison, and correction so that the output temperature is expressed in degrees Celsius (°C). When connected to the Arduino Nano microcontroller, it displays an array of individual infrared temperature readings of 64 pixels per pixel display the Arduino readings. There is an interpolation scheme that connects to Matlab via serial communication and improves pixel scaling from 8×8 to 100×100.

Flowchart portable urine quality detector can be seen in **Figure 9**. The first stage is to take a urine sample and put it in a reservoir. Urine was taken in three variations, namely urine taken in the morning, urine taken at any time, and postprandial urine with urine composition consisting of mineral water and some drinks containing glucose. Inside the portable detector, the IR Thermal sensor will detect the urine temperature. Furthermore, the system will analyze the temperature data captured by the IR Thermal sensor. The diagnosis results will be displayed through the Matlab software and also the LCD.

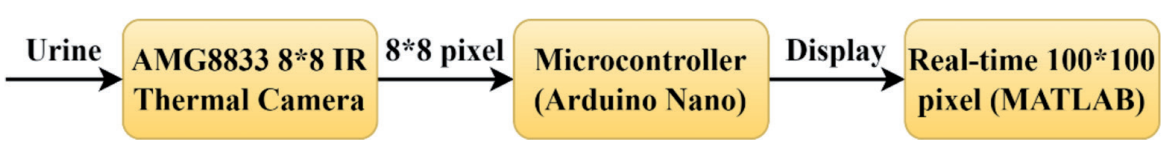


Figure 8.
Block diagram of portable urine quality detector.

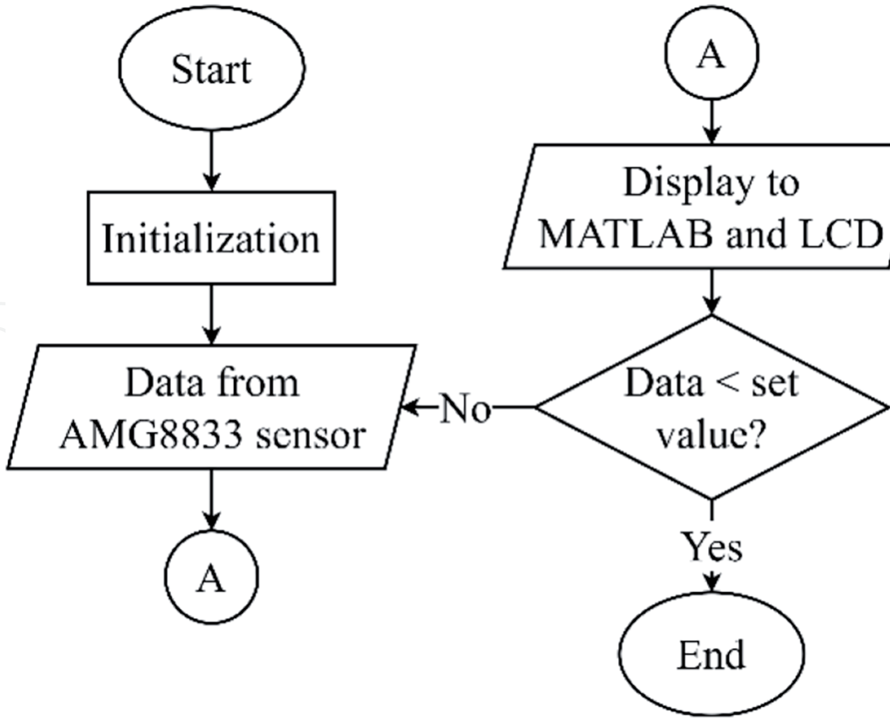


Figure 9.
Flowchart portable urine quality detector.

2.9 Schematic diagram of portable urine quality detector

Figure 10 shows a schematic of the portable urine quality detector circuit using the Proteus application software. In the schematic of the circuit, the voltage source in the circuit is lowered using a DC-to-DC step-down, then the AMG8833 sensor is connected to the Arduino Nano microcontroller after that from the Arduino Nano, it is connected to the microSD card.

2.10 Urine quality detector portable design

This device as shown in **Figure 11** has a fairly small form which has the advantage of being easy to move so that it can be used anywhere. The closed box enables this invention to work without being affected by the external light intervention. The sensor used is a camera sensor as a component to take pictures from the reaction strip. This urine glucose detector hardware is integrated with software that functions to analyze the data that has been obtained.

The device consists of a camera sensor, an LED module, a filament box, and a reaction strip slider. The ELP USB industrial camera type camera sensor is used as a sensor to take image data obtained from the reaction strip. The reaction strip consists of 10 variables, namely glucose, bilirubin, ketones, specific gravity, blood, pH, protein, urobilinogen, nitrite, and leukocytes. The reaction strip slider is made in such a way that its size matches the medical standard reaction strip. The camera sensor is equipped with a convex lens so that it can cover a wide area and can capture data from 10 variables simultaneously. The LED used in the LED module is a Super Bright LED type with a diameter of 3 mm. The LED module acts as a reaction strip light and adds light that enters the camera sensor. The LED module is also used to minimize the intervention of light entering the glucose detector in the urine. The LED module gets a

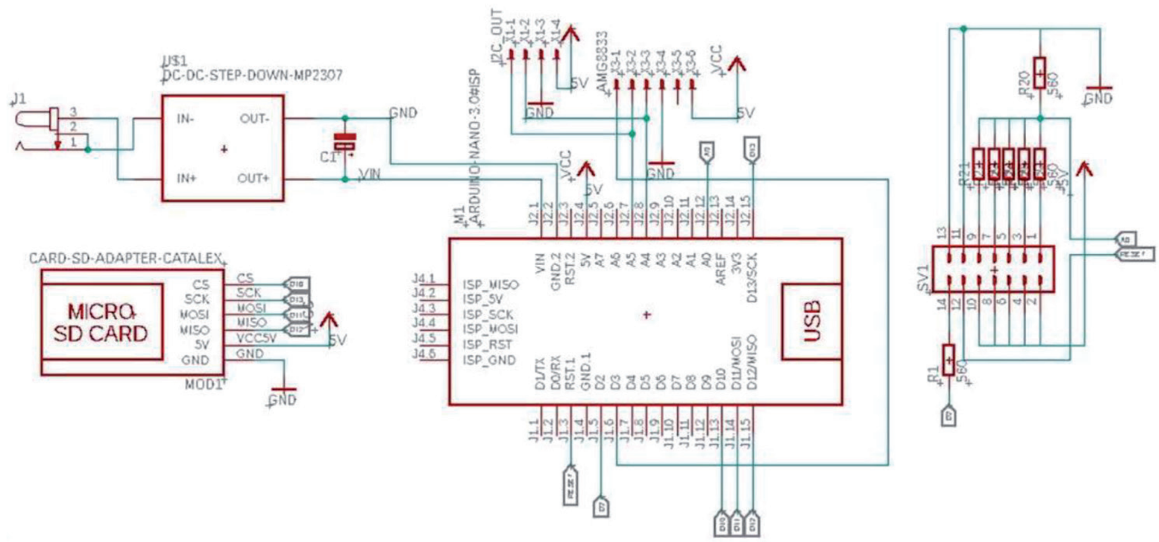
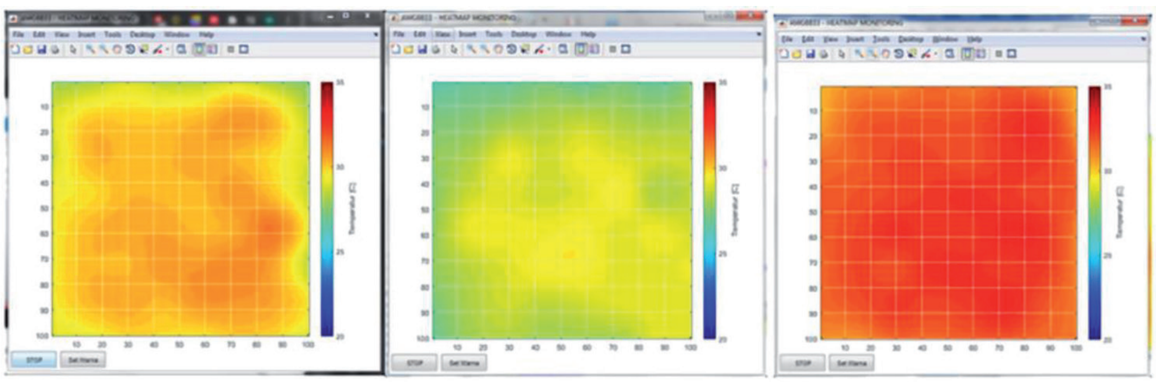


Figure 10.
Circuit schematic of portable urine quality detector.



Morning urine | Urine at any time | Postprandial urine

Figure 11.
Temperature display on sample 2.

voltage supply through an AC to DC power source with a working voltage of 12 V. The input of the power source is an alternating voltage type with a voltage value of 220 V. The output of the power source is a direct voltage of 12 V, 2 A. The camera sensor does not is always on to retrieve data, but the camera sensor starts capturing data on a command from the software. The test strip is dipped in a tube containing urine, and then the test strip enters the glucose detector through the test strip slide. When the reaction strip is in the correct position, the software will instruct the camera sensor to start taking pictures. The software takes an image through the camera sensor for 30 s from the moment the test strip is inserted into the glucose detector. The data that has been taken is stored on the computer. The software has been equipped with an algorithm to analyze the data that has been taken. The software converts image data into value data from the 10 variables mentioned above. The output of this system is an early diagnosis of diabetes. The software will provide analysis results in the form of two choices, namely diabetes, and non-diabetes. The data that has been obtained in the software is also uploaded to the server, which will be used as a machine learning data set. The system on the server continues to study the data that has been collected, which is then used as a parameter in making decisions for the early diagnosis of diabetes. The box is made of a 3-dimensional mold with the type of PLA+ material. The box is made in such a way that it can accommodate the components used. Furthermore, the box also functions to reduce the intervention of light from outside so that the glucose detector in urine can be used anywhere and anytime.

3. Result and discussion

The test is carried out using three types of urine, namely morning urine, which is the first urine excreted in the morning when you wake up. This urine is more concentrated than urine that comes out during the day, so it's great for checking sediment, specific gravity, protein, etc., and also great for pregnancy tests based on the presence of HCG (human chorionic gonadotrophins) in urine. Urine at any time where this urine can be used for various instantaneous tests, i.e., urine excreted at an unspecified time. Urine at this time is usually good enough for examination. Then the postprandial urine, where this urine sample can be used to check for glucosuria. Postprandial urine is the first urine excreted 1½–3 h after eating.

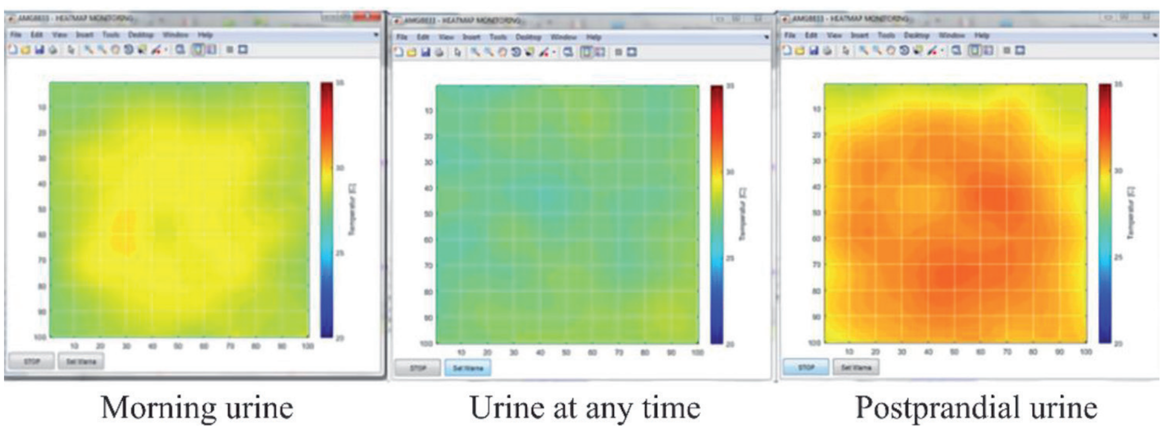


Figure 9.
Temperature display on sample 1.

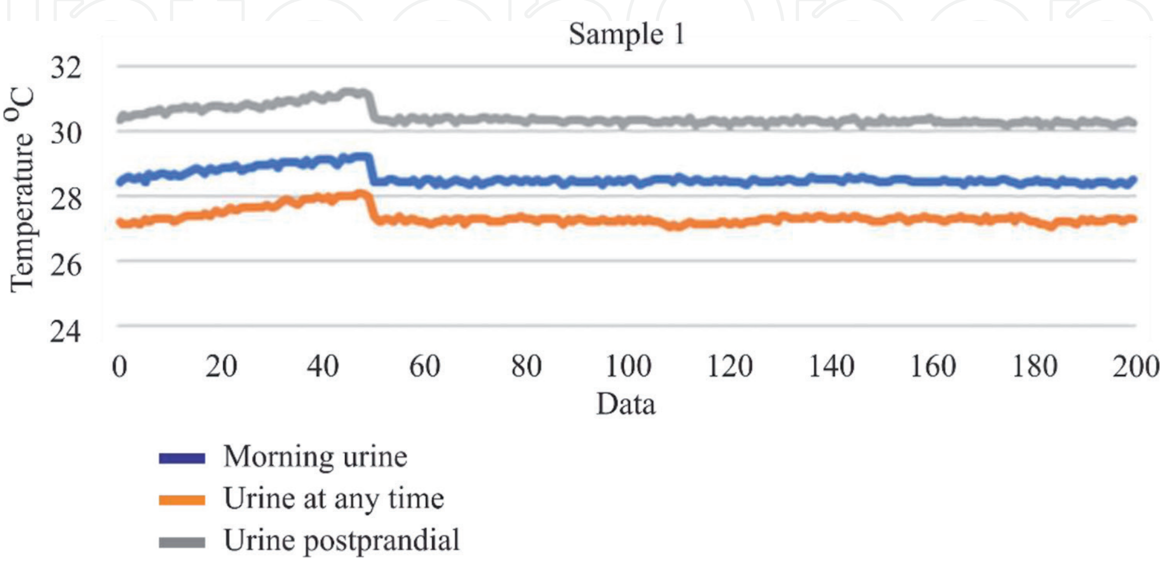


Figure 10.
Graph of sample test results 1.

Test results data on urine temperature from several samples of the morning urine, urine at any time, postprandial urine. The urine sample is accommodated 20–30 ml in a urine collection container that is directly removed from the urethra and in real-time can be seen in **Figure 9**. In testing sample 1, urine collection was taken in the morning at 06.14, random urine at 13.20, postprandial urine at 20.13. The result for consumption of water and drinks containing glucose 1 × 24 h, namely 600 ml bottled water, 15 g warm tea, 10 g iced tea, 22 g Velluto Tango Drink, can be seen in **Figure 10**. It is known that the temperature of the morning urine is 28°C, the urine at any time is 27°C, and the postprandial urine is 30°C.

The next data is the test of sample 2 with the same dose directly removed from the urethra and in real-time in **Figure 11**. In the second sample test, urine collection was taken in the morning at 05.34, random urine at 16.20, postprandial urine at 22.07 WIT. The result for consumption of water and drinks containing glucose 1 × 24 h, namely one glass of 330 ml bottled water, good day cappuccino 25 g, iced tea 15 g, orange ice 10 g, soya bean V-soy 19.8 g, that can be seen in **Figure 12**. It is known that the temperature of morning urine is 28°C, intermittent urine is 31°C, postprandial urine is 32°C.

The next data is testing sample 3 with the same dose directly removed from the urethra and in real-time in **Figure 13**. In the third sample test, urine collection was taken in the morning at 06.47, random urine at 21.46, postprandial urine at 16.44. The result for consumption of water and drinks containing glucose 1 × 24 h, namely 250 ml of water, 15 ml of reject wind, 23 g of Kopiko Coffee, can be seen in **Figure 14**.

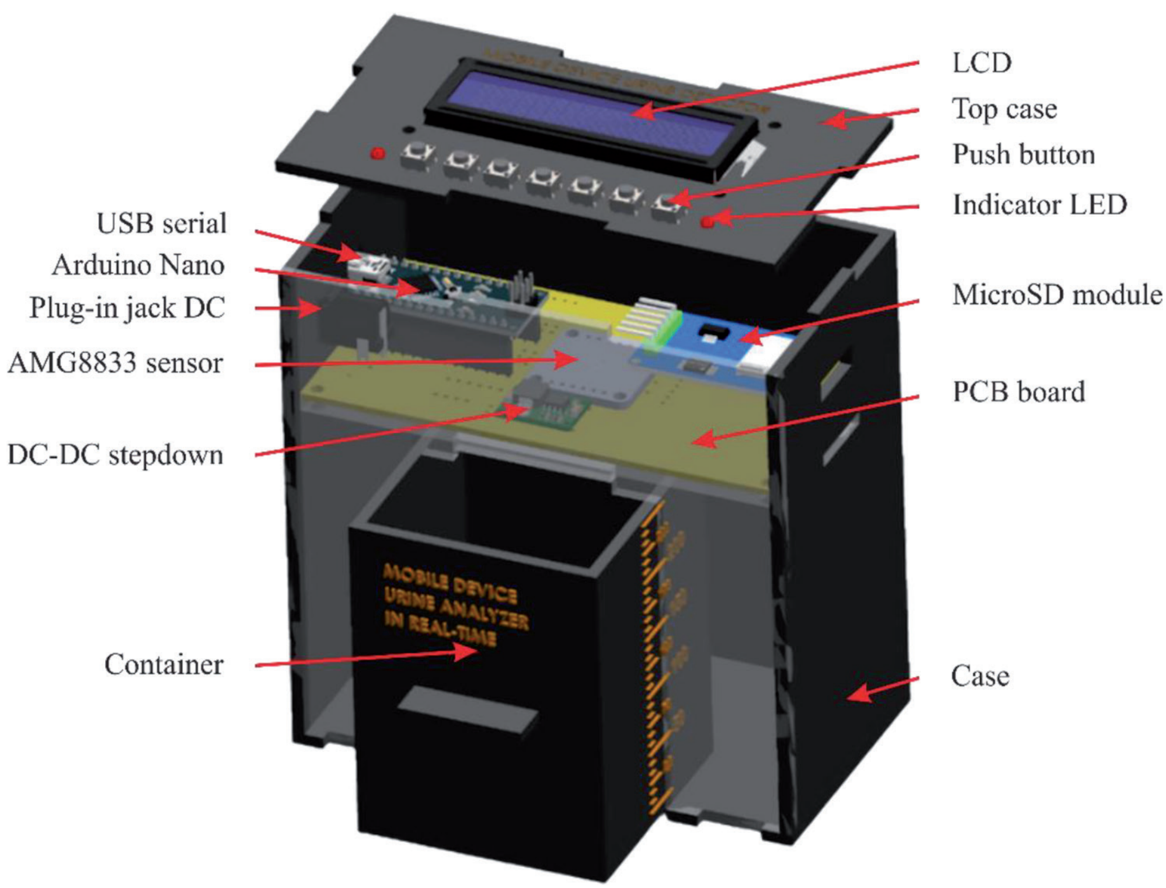


Figure 11.
Design of urine quality detector portable.

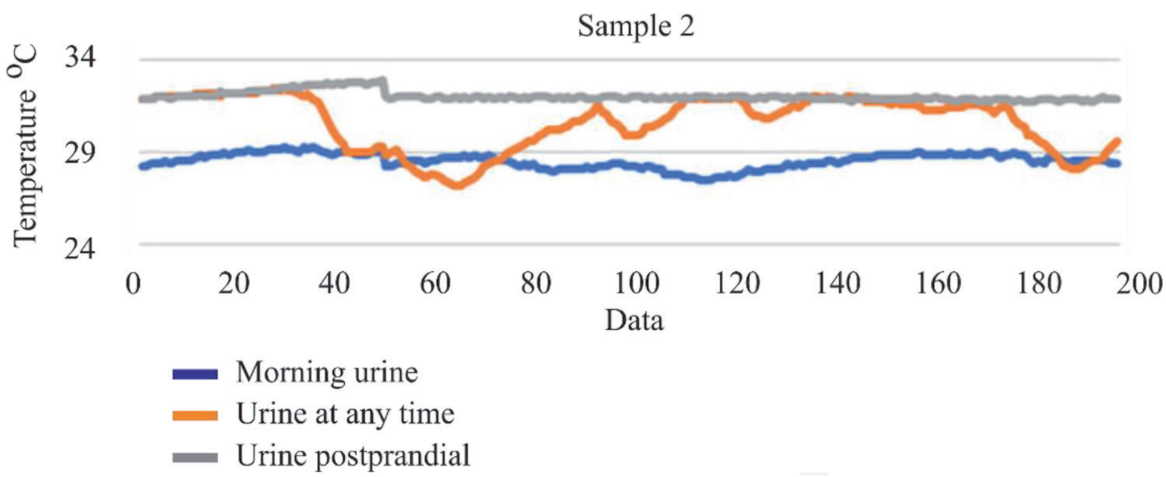


Figure 12.
Graph of sample test results 2.

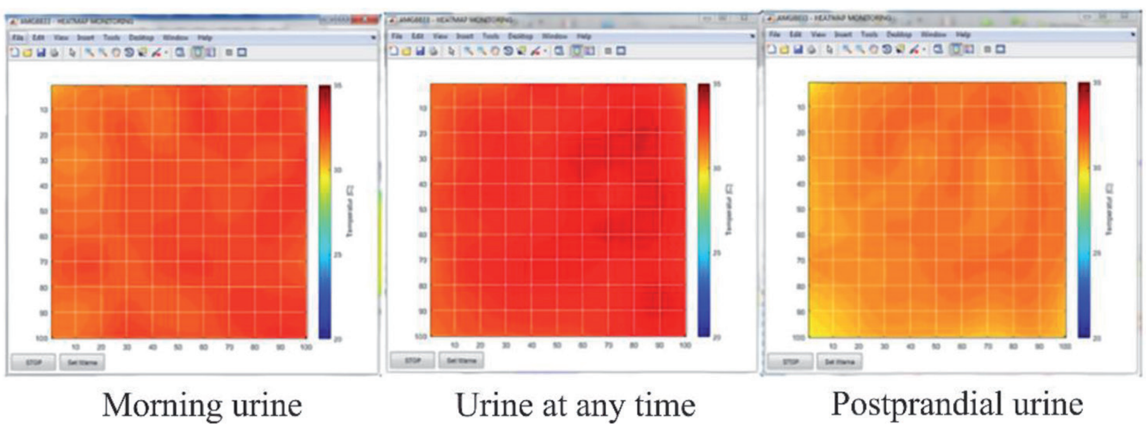


Figure 13.
Temperature display on sample 3.

It is known that the temperature of morning urine is 32°C, intermittent urine is 33°C, postprandial urine is 32°C.

The data from the test results of the Urine Quality Detector tool have an average conductivity value which can be seen in **Figure 15**. **Figure 15** is a graph of the average temperature conductivity value in urine from three different samples with consumption of various types of drinks that contain glucose. The graph shows that postprandial urine temperature has the highest average temperature value, which is between 30°C and 32°C compared to morning urine and occasional urine.

Captured samples were processed in the HSV color space. **Figure 16** shows the HVS values generated in several types of samples, including without artificial glucose, with artificial glucose of 1, 2, and 3 g. At the same time, the distribution of HVS values is shown in **Figure 17**.

Finally, a urine test strip treated with a urine sample can be detected. Glucose levels can be detected through the color on the glucose indicator box (GLU). It can be seen the difference in the color of the GLU indicator affects the HSV combination. **Figure 18** shows the different levels of glucose levels, (a) level 1 is indicated by "+", (b) level 2 is indicated by "++", and (c) level 3 is indicated by "+++".

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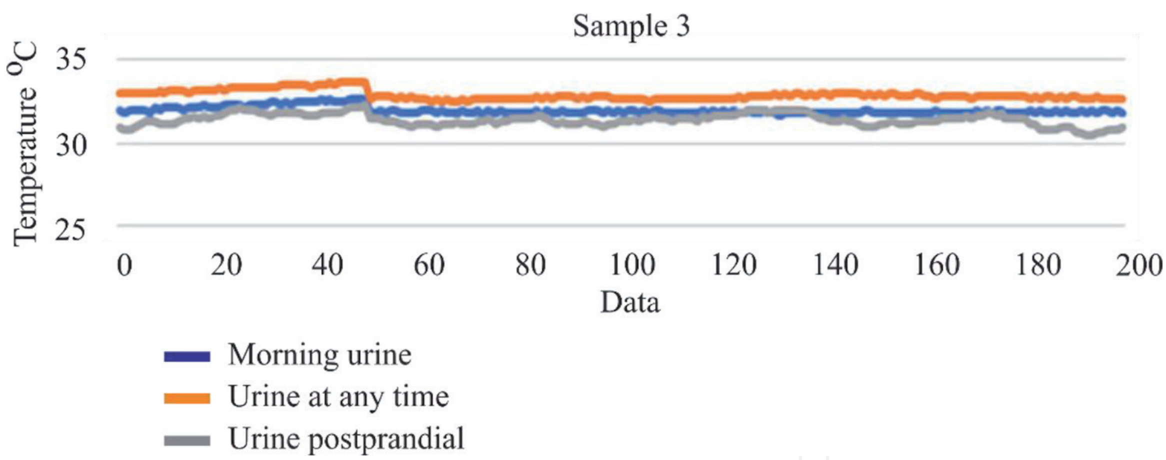

Figure 14.
Graph of sample test results 3.

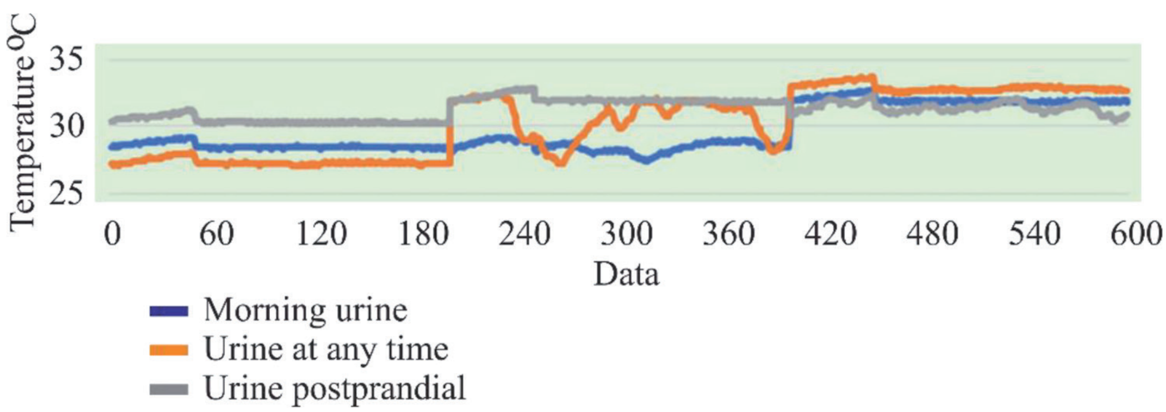

Figure 15.
Graph of measuring average.

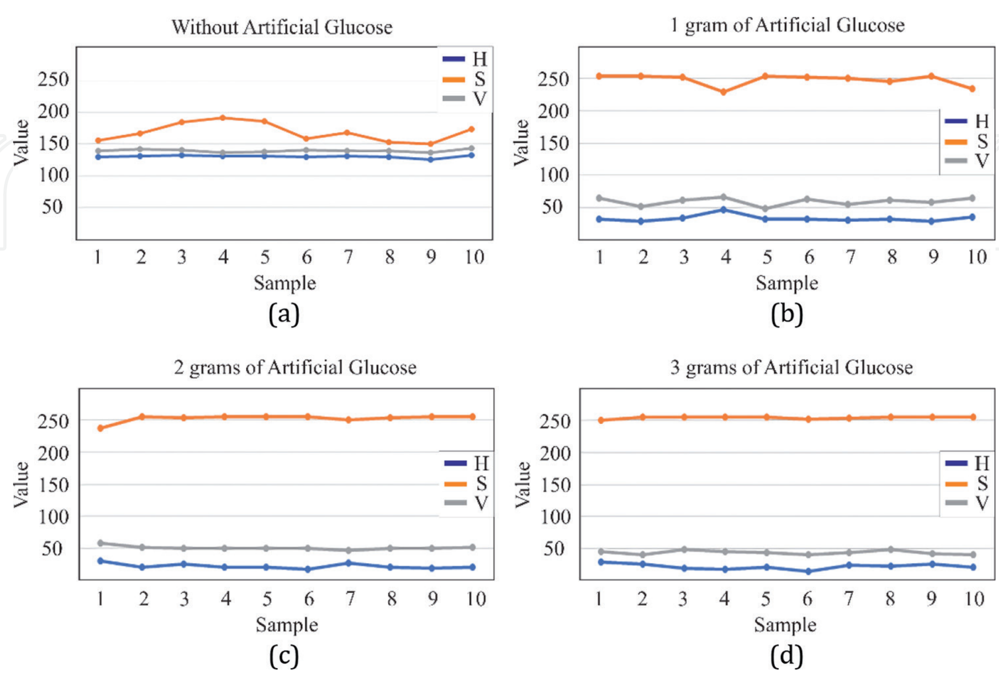

Figure 16.
HSV value of samples, (a) without, (b) 1 g, (c) 2 g, and (d) 3 g of artificial glucose.

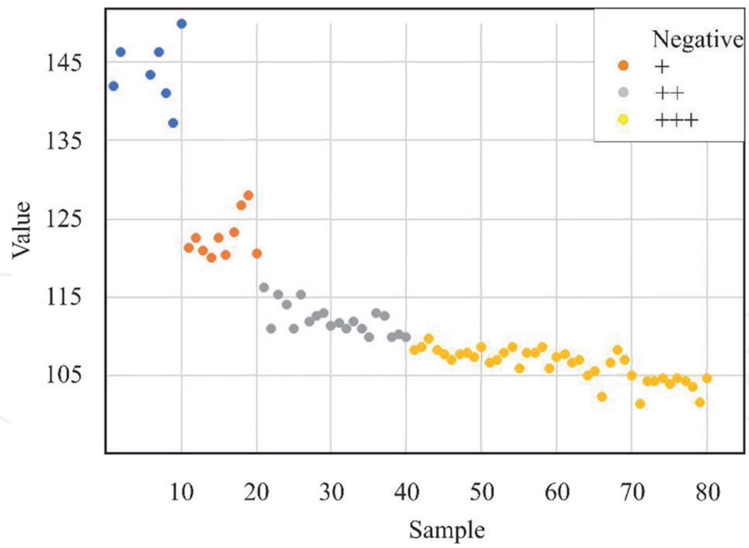

Figure 17.
Distribution of HSV values.

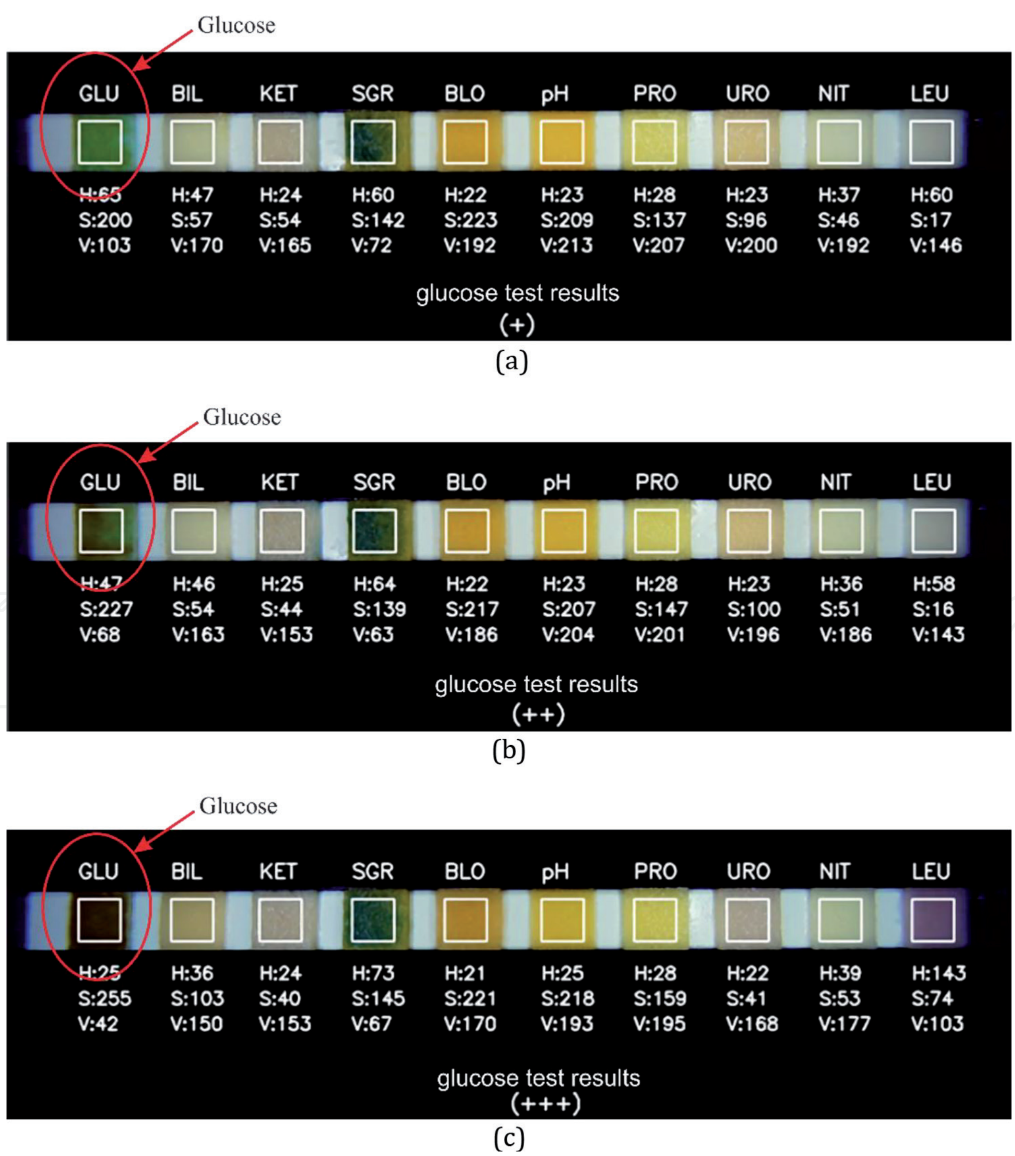

Figure 18.
Glucose test result with three different levels (a) level 1 or +, (b) level 2 or ++, and (c) level 3 or +++.

4. Conclusion

The IR Thermal Camera sensor AMG8833 was applied in this study to detect urine temperature from the experiment. Three experimental conditions were carried out, namely morning urine, intermittent urine, and postprandial urine, with a combination of drink consumption on the respondents. Postprandial urine showed the highest temperature in samples 1 and 2, around more than equal to 30°C, while urine at any time showed the highest temperature in sample 3 with a value of 30°C. This proves that the glucose detector in the urine can function properly.

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References

[1] Li N, Ho KWK, Ying GG, Deng WJ. Veterinary antibiotics in food, drinking water, and the urine of preschool children in Hong Kong. Environment International. 2017;**108**(April):246-252. DOI: 10.1016/j.envint.2017.08.014

[2] Zulyadi R. Obstacle factors on evidence system of urine test result on drugs cases in national narcotics board of North Sumatera Province, Indonesia. Budapest International Research and Critics Institute. 2020;**3**(2):1316-1324. DOI: 10.33258/birci.v3i2.976

[3] Mir C et al. Analysis of urine composition from split 24-h samples: Use of 12-h overnight samples to evaluate risk factors for calcium stones in healthy and stone-forming children. Journal of Pediatric Urology. 2020;**16**(3):371.e1-371.e7. DOI: 10.1016/j.jpurol.2020.02.011

[4] Rowe I et al. Defective glucose metabolism in polycystic kidney disease identifies a new therapeutic strategy. Nature Medicine. 2013;**19**(4):488-493. DOI: 10.1038/nm.3092

[5] Hu T et al. Portable and intelligent urine glucose analyzer based on a cdte qds@gox aerogel circular array sensor. ACS Omega. 2021;**6**(48):32655-32662. DOI: 10.1021/acsomega.1c03449

[6] Fünfstück R, Nicolle LE, Hanefeld M, Naber KG. Urinary tract infection in patients with diabetes mellitus. Clinical Nephrology. 2012;**77**(1):40-48. DOI: 10.5414/CN107216

[7] Bechmann LP, Hannivoort RA, Gerken G, Hotamisligil GS, Trauner M, Canbay A. The interaction of hepatic lipid and glucose metabolism in liver diseases. Journal of Hepatology. 2012;**56**(4):952-964. DOI: 10.1016/j.jhep.2011.08.025

[8] Gonzales WV, Mobashsher AT, Abbosh A. "The progress of glucose monitoring—A review of invasive to minimally and non-invasive techniques, devices and sensors", Sensors (Switzerland). 2019;**19**(4)

[9] Shokrekhodaei M, Quinones S. Review of non-invasive glucose sensing techniques: Optical, electrical and breath acetone. Sensors (Switzerland). 2020;**20**(5). DOI: 10.3390/s20051251

[10] Tang L, Chang SJ, Chen CJ, Liu JT. Non-invasive blood glucose monitoring technology: A review. Sensors (Switzerland). 2020;**20**(23):1-32. DOI: 10.3390/s20236925

[11] Yudhana A et al. Multi sensor application-based for measuring the quality of human urine on first-void urine. Sensing and Bio-Sensing Research. 2021;**34**:100461. DOI: 10.1016/j.sbsr.2021.100461

[12] Leboulanger B, Guy RH, Delgado-Charro MB. Reverse iontophoresis for non-invasive transdermal monitoring. Physiological Measurement. 2004;**25**(3):R35

[13] Hillier TA, Abbott RD, Barrett EJ. Hyponatremia: Evaluating the correction factor for hyperglycemia. The American Journal of Medicine. 1999;**106**(4):399-403

[14] Lee S, Nayak V, Dodds J, Pishko M, Smith NB. Glucose measurements with sensors and ultrasound. Ultrasound in Medicine & Biology. 2005;**31**(7):971-977

[15] Allen TJ, Cox BT, Beard PC. "Generating photoacoustic signals using high-peak power pulsed laser diodes,"

In: Photons Plus Ultrasound: Imaging and Sensing 2005: The Sixth Conference on Biomedical Thermoacoustics, Optoacoustics, and Acousto-Optics. 2005;**5697**:233-242

[16] Alavi SM, Gourzi M, Rouane A, Nadi M. "An original method for non-invasive glucose measurement: Preliminary results," In: 2001 Conference Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society. Istanbul, Turkey. 2001;**4**:3318-3320

[17] Ellis DI, Goodacre R. Metabolic fingerprinting in disease diagnosis: Biomedical applications of infrared and Raman spectroscopy. Analyst. 2006;**131**(8):875-885

[18] Larin KV, Eledrisi MS, Motamedi M, Esenaliev RO. Noninvasive blood glucose monitoring with optical coherence tomography: A pilot study in human subjects. Diabetes Care. 2002;**25**(12):2263-2267

[19] Fusman R et al. Image analysis for the detection of increased erythrocyte, leukocyte and platelet adhesiveness/aggregation in the peripheral blood of patients with diabetes mellitus. Acta Diabetologica. 2001;**38**(3):129-134

[20] Khalil OS. Noninvasive photonic-crystal material for sensing glucose in tears. Clinical Chemistry. 2004;**50**(12):2236-2237 Oxford University Press.

[21] Ongkum C, Keawmitr K, Boonchieng E. "Analysis system for urine strip test using image processing technique," In: BMEiCON 2016 - 9th Biomedical Engineering International Conference. Laung Prabang, Laos. pp. 3-7. DOI: 10.1109/BMEiCON.2016.7859610

[22] Xia ML, Wang L, Yang ZX, Chen HZ. A novel digital color analysis method for rapid glucose detection. Analytical Methods. 2015;**7**(16):6654-6663. DOI: 10.1039/c5ay01233c

[23] Yudhana A, Umar R, Ayudewi FM. The monitoring of corn sprouts growth using the region growing methods. Journal of Physics Conference Series. 2019;**1373**(1). DOI: 10.1088/1742-6596/1373/1/012054.

[24] Yudhana A, Sunardi S, Saifullah S. Segmentation comparing eggs watermarking image and original image. Bulletin of Electrical Engineering and Informatics. 2017;**6**(1):47-53. DOI: 10.11591/eei.v6i1.595

[25] Surya RA, Fadlil A, Yudhana A. Identification of Pekalongan Batik images using Backpropagation method. Journal of Physics Conference Series. 2019;**1373**(1). DOI: 10.1088/1742-6596/1373/1/012049

[26] Lin T. Non-invasive glucose monitoring: A review of challenges and recent advances. Current Trends in Biomedical Engineering & Biosciences. 2017;**6**(5):1-8. DOI: 10.19080/ctbeb.2017.06.555696

[27] Soni A, Jha SK. A paper strip based non-invasive glucose biosensor for salivary analysis. Biosensors & Bioelectronics. 2015;**67**:763-768. DOI: 10.1016/j.bios.2014.09.042