A STUDY ON THE RELATION BETWEEN DIGITAL OUTPUT AND URIC ACID IN ARTIFICIAL BLOOD SOLUTION BY USING A URIC ACID DETECTOR

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ABSTRACT

This project aims to study the relationship between digital output and uric acid concentration in artificial blood solution by using a uric acid detector. The light absorption principle is used in this project. The design and construction of the uric acid detector included a near-infrared light source with a wavelength of 1550 nm and a green light source with a wavelength of 570 nm to interact with uric acid. Concentrations of 3, 6, 9, 12 and 15 mg/dL of uric acid were measured. The results demonstrate that the output voltage of this uric acid detector changed in accordance with the uric acid solution concentration. It was also found that the green light was not absorbed by the uric acid solution. At the wavelength of 1550 nm, there is an interaction with uric acid in the absorption of light. At higher concentrations of uric acid, there was less light transmittance, resulting in higher digital output values, whereas at lower concentrations, there was greater light transmittance, resulting in lower digital output values. The relationship between the digital output value and uric acid was $y = 2.7444x + 793.7$, $r = 0.99$, $R^2 = 0.971$, uric acid filled with Albumin was $y = 2.0667x + 805.73$, $r = 0.96$, $R^2 = 0.924$, uric acid filled with Albumin and glucose 70 mg/dL was $y = 2.6333x + 805.7$, $r = 0.99$, $R^2 = 0.9754$, uric acid filled with Albumin and glucose 135 mg/dL was $y = 2.6444x + 805.87$, $r = 0.99$, $R^2 = 0.9827$ and uric acid filled with Albumin and glucose 200 mg/dL was $y = 3.2778x + 802.57$, $r = 0.99$, $R^2 = 0.985$.

Keywords: Uric Acid, Near Infrared

1. INTRODUCTION

Gout is an inflammatory arthritic disease, which is caused by high levels of uric acid in the blood. Long-term hyperuricemia causes the accumulation of urate crystals or monosodium urate crystals (MSU) in joints and body tissues [1]. Gout is a common disease in Thai people. Although the disease does not cause danger to life, it interferes with the daily life of patients who suffer from chronic inflammation. The incidence of gout has been reported as approximately 5 persons per 100,000 in the Thai population [2]. Gout prevalence increases with age, especially in men, in which the risk of gout is approximately 10 times greater than that of women. Females are therefore at lower risk of gout, except after menopause, due to the influence of estrogen on uric acid levels in the blood [3]. Hyperuricemia refers to a condition in which blood serum measurements find uric acid concentrations exceeding 7 mg/dL in males or 6 mg/dL in females [4].

Currently, diagnostic medical tests of blood uric acid levels require a blood sample to be taken [5] or blood to be drawn by the lancet on a point of care (PoC) uric acid meter [6]. Both of these methods are invasive procedures that increase risk of infection and inflict some degree of pain to the patient.

In research by Kim [7], noninvasive uric acid monitoring was investigated using near-infrared spectroscopy with light wavelengths of 1400 to 1700 nm. Based on the principle of light absorbance referred to as the Beer-Lambart law, Kim showed that a linear relationship can be obtained between absorbance and uric acid concentration. It was found that light wavelengths of 1450 nm and 1550 nm were the most sensitive to absorbance by uric acid, and that this absorbance was also specifically caused by uric acid, not other substances [7].

In their review of wearable photoplethsmyography devices, Tamura et al. [8] explained that oxyhemoglobin and deoxyhemoglobin are absorbed by the green light, and how this can be used as a reference in some applications. The reflection of green light is greater than the reflection of infrared light when measured through the skin [8]. However, it remains to be established how uric acid interacts with green light, so in the present study we examined green light absorbance of uric acid, albumin and glucose for prospecting the suitability of using green light as a reference in the design and construction of a non-invasive uric acid meter.

The primary aim of this study was to characterize the relationship between digital output and uric acid concentration in artificial blood solutions using a uric acid detector composed of 1550 nm infrared and 570 nm green light sources. The artificial blood solution used phosphate buffered saline (PBS) combined with difference concentrations of uric acid, albumin and glucose. These solutions were designed to simulate the metabolites in the blood. Light absorption of these solutions in the near-

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infrared and green wavelengths were evaluated, providing a basis for further design improvements and development of noninvasive uric acid monitoring technology.

2. BASIC CONCEPT

The basic concept of the uric acid detector design relies on the principle of light absorption referred to as the Beer-Lambert law. The overall study can be separated into two parts: 1) Design and construction of a uric acid detector circuit to characterize the relationship between voltage and uric acid concentration in artificial blood solution, and 2) the performance Testing of the uric acid detector circuit.

2.1 Design and construction of a uric acid detector circuit

The uric acid detector circuit consists of 4 parts: 1) Signal detector, comprising two light sources, photodiode and phototransistor; 2) Analog signal processing, consisting of current to voltage converter circuit, non-inverting amplifier circuit, and voltage follower circuit; 3) Digital signal processing and control; 4) Display with LCD screen. A diagram of this uric acid detector is shown in Figure 1.

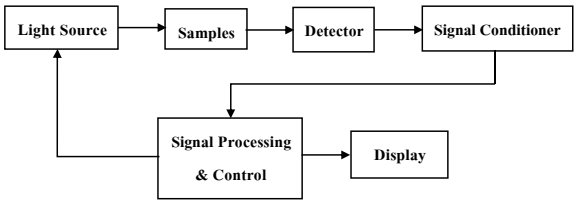

Figure 1. Block diagram of a uric acid detector design

2.1.1 Signal detector

Two LEDs were chosen as the light sources for transmitting light through a test tube placed in a prepared cavity. These light sources had different wavelengths: a near-infrared light at a wavelength of 1550 nm [9], which is a wavelength of light that uric acid can absorb [7], and a green light at a wavelength of 570 nm [10], which can provide light absorption measurement that is less affected by uric acid. The green LED thereby provides a background light for referencing measurements of uric acid. A photodiode was used to detect near-infrared light [11] and a phototransistor was used to detect green light [12]. When near-infrared light and green light pass through a solution containing uric acid, a portion of the two light energies are absorbed, and the transmitted light detected by the photodiode and phototransistor are transformed into current signals. In the signal detector circuit, we took a 5 V supply line from the microcontroller, including current-limiting resistors to protect the LED light sources from damage. These resistances in the circuit of green light (R_G) and near-infrared light (R_{IR}) were calculated using equation (1).

$$R = \frac{V_{DD} - V_f}{I_F} \quad (1)$$

When $R = R_1 = R_{(G)}$ and $R = R_2 = R_{(IR)}$, V_{DD} is the positive DC supply (i.e., 5 V), $V_{f(G)}$ is the forward bias voltage of the green LED (i.e., 2 V), $V_{f(IR)}$ is the infrared LED forward bias voltage (0.93 V), $I_{f(G)}$ is the forward bias current of the green LED (i.e., 10 mA), and $I_{f(IR)}$ is the forward bias current of the infrared LED (i.e., 20 mA). Resistors R_1 and R_2 were 300 Ω and 220 Ω, respectively.

The additional resistances in phototransistor circuit, R_3, was determined from equation (2).

$$R_3 = \frac{V_{out}}{I_{c(sat)}} \quad (2)$$

Where $R_3 = R_{(Phototransistor)}$, the output voltage ($V_{out}$) required was equal to 2 V, and $I_{C(sat)}$ was 0.1 mA. Thus, the resistance R_3 was equal to 20 kΩ.

Therefore, the resistances R_1 = 300 Ω, R_2 = 220 Ω and R_3 = 20 kΩ were used in the signal detector circuit, shown in Figure 2.

2.1.2 Analog signal conditioning

The signal output from the signal detector circuit is an electric current. This current signal is converted into an analog voltage using a current-to-voltage converter circuit. The analog voltage is then amplified using a non-inverting amplifier circuit and a voltage follower circuit to obtain an appropriately conditioned signal for digital conversion.

a. Current-to-voltage circuit

In the signal detector, the light transmitted through a test tube was measured using photodiode and phototransistor receivers. These semiconductor devices convert incident light photons into electron current. The current depends on the intensity of the incident light. Amplifier A shown in Figure 2 is the current-to-voltage circuit, the bias voltage is zero, where the voltage is positive and the output voltage (V_{out}) is equal to 200 mV by setting the value of the dark current in the circuit (I_D) equal to 2 µA. If $V = V_{out}$, $I = I_D$, the resistance R_4 is 100 kΩ, which can be calculated from Ohm's law in equation (3).

$$V = IR \quad (3)$$

As for the current-to-voltage circuit, to set the cutoff frequency (f_c) equal to 50 Hz, using resistance $R = R_4$ =

100 kΩ, capacitor C = C_1 was determined to be 0.03 μF, calculated according to equation (4).

$$C = \frac{1}{2\pi f_c R} \quad (4)$$

b. AC amplifier circuit

The AC amplifier circuit is used an operational amplifier chip (MC604) to amplify the signal. This component has desirable high input impedance and common-mode rejection ration (CMRR) of 90 dB, which mitigate loss and interference of analog voltage signals representing light absorbance caused by the test-tube sample constituents.

The AC amplifier circuit (B in Figure 2) amplified the voltage signal derived from the photodiode current. The voltage follower (C in Figure 2) buffered the voltage signal obtained from the phototransistor. In the B circuit, an input voltage signal (V_{in}) of 200 mV was amplified to produce an output voltage (V_{out}) of 2.2 V. To achieve this, voltage gain (A_v) was 11. The high frequency cutoff was set to 50 Hz, with R_5 = 4 MΩ, R_6 = 400 kΩ and C_2 = 0.8 nF. In the C circuit, V_{in} = 2 V, V_{out} = 2 V, thus A_v = 1.

2.1.3 Digital signal processing and controlled switch

In the digital signal processing, a microcontroller (Arduino Pro Mini) was selected for its high resolution analog to digital converter circuit with input voltage range maximum of 2 V.

The signal output from the op-amp is an analog voltage that is converted to a digital signal by an analog-to-digital-converter (ADC). It starts with setting the variable value in A/D, then initializes the LED lamps to process the program. Then a message is displayed through the LCD screen to enter the operation. After that the message is displayed via the LCD screen again to confirm the operation by pressing the switch, When the switch is not pressed, it returns to the display screen. When the switch is pressed, the status is active-low, showing the next message and then getting variable values from photodiode and phototransistor. When the microcontroller gets the values from both variables, it enters the calculation of the difference between the digital output value of the green LED and the digital output of the infrared LED. Therefore, the screen displays three values: 1) the digital output value of the green LED, 2) the digital output value of the infrared LED, and 3) the difference between the digital output value of the green light LED and infrared LED, as shown in Figure 3. If the switch is pressed again, then the device resets to the operation screen for reuse.

For control, a microswitch connected with a pull-down resistor was used. This provided control over operation of the device, and was also used to turn it on and off.

The complete circuit design of the uric acid detector is illustrated in Figure 2.

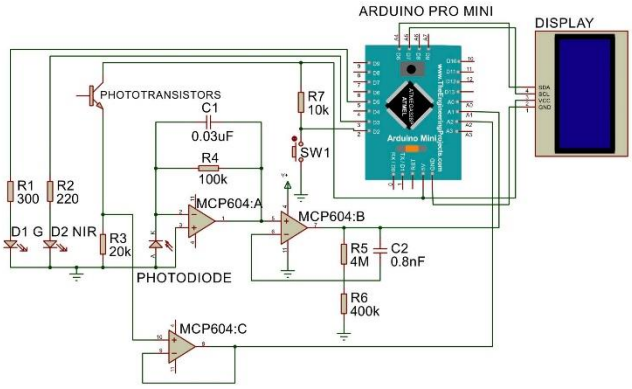

Figure 2. Uric acid detector circuit diagram

2.1.4 Display

A 16x4 LCD was interfaced with the microcontroller to display digital output values. The display shows three digital output values: 1) "Green" is the digital output value of the green LED light. 2) "IR" is the digital output value of the infrared LED, and 3) "Dif" is the difference between digital output values of the green LED and the infrared LED. An example of the display is shown in Figure 3.

Figure 3. Digital output value display on LCD

2.1.5 Power supply

The uric acid detector circuit was powered by a 7.4 V, 2000 mAh rechargeable battery. The current consumption of the microcontroller was rated as 40 mAh, that of the LCD was 50 mAh, and that of the combined integrated circuits was 150 mAh . Therefore, the total current consumption was 240 mA, thus this battery was sufficient for supplying each part of the circuit.

2.2 Uric acid detector test

In order to verify the suitability of this design for further development as a non-invasive uric meter, performance testing was established calibration curve of the relationship between the digital output value from the device and uric acid concentration in artificial blood solutions. To make the artificial blood solution, uric acid, albumin and glucose were combined in PBS. Uric acid at concentrations of 3, 6, 9, 12 and 15 mg/dL were used in the test, covering the range of uric acid concentrations

found in blood (normally from 3.5 to 7 mg/dl). Albumin was used because it is the most abundant protein found in human serum [13]. Blood albumin concentrations are found in the range of 3400 to 5400 mg/dL. As such, albumin concentrations of 2000, 3000, 4000, 5000 and 6000 mg/dL were tested. Glucose was also used in the test because it is another principal blood constituent, which can also affect infrared light absorption [14, 15]. In the test, glucose levels from 70 to 200 mg/dL were used, covering the range found in human blood.

The objective of this experiment was to characterize the light absorbance affected by these different substances using the device described above. After obtaining measurements of infrared and green light absorption, linear regression analysis was used to characterize the relationships between concentrations of these substances (independent variables) and light absorption (dependent variable). The following steps were taken to conduct this experiment.

1) Preparation of artificial blood solution in 3.00 mL samples and place inside cuvettes. Five sample sets were prepared as follows.

Set 1 (U): Uric acid at concentrations of 3, 6, 9, 12 and 15 mg/dL; albumin solution at concentrations of 2000, 3000, 4000, 5000 and 6000 mg/dL; glucose solution at concentrations of 70, 105, 135, 170 and 200 mg/dL.

Set 2 (U+A): Uric acid at concentrations of 3, 6, 9, 12 and 15 mg/dL mixed with albumin solution of 3500 mg/dL.

Set 3 (U+A+G70): same as Set 2 combined with glucose solution of 70 mg/dL.

Set 4 (U+A+G135): same as Set 2 combined with glucose solution of 135 mg/dL.

Set 5 (U+A+G200): same as Set 2 combined with glucose solution of 200 mg/dL

2) Turn on the uric acid detector, test the green light and infrared light which was passed through a blank cuvette test. Put the sample in the cuvette into the compartment then test the green light and infrared light which was passed through a cuvette that contained a solution of uric acid (U), albumin (A), and glucose (G) and was tested 3 times each. Record the digital output values reflecting absorbance of green light and infrared light. Find the mean and standard deviation of these three measurements.

3) Perform linear regression analysis to find the relationship between concentration(s) of constituents in different solutions and the digital output.

3. RESULTS

From the study of the relationship between digital out and uric acid concentration in artificial blood solution by using a uric acid detector that used light absorption and electronic principles. The project was divided 2 parts: 1) Design and construction of a uric acid detector circuit and 2) Testing the efficiency of the uric acid detector circuit. For the design and construction of a uric acid detector circuit was selected a circuit to measure the light transmitted in a cuvette that contained a solution of uric acid, albumin, and glucose. The prototype of uric acid detector is shown in Figure 4.

Figure 4. Prototype uric acid detector

1) The prototype of uric acid detector used the light sources which were an LED with a wavelength of 1550 nm as infrared light and green light at a wavelength of 570 nm. It was able to display digital value and battery status on the LCD screen. It showed three digital output values: Green is the digital output value of the green LED light, IR is the digital output value of the infrared LED light and Dif is the difference between the digital output value of the 2 LEDs light which was expressed as a number. It was able to measure the digital output value of the transmission light from the sample compared to the uric acid concentration.
2) The functional testing of green light at 570 nm and Infrared light at 1550 nm in the uric acid detector circuit was tested in Set 1 of the artificial blood solution. The results of this project were collected from uric acid, albumin and glucose solutions that were shown in Table 1.

Table 1. Functional testing results

Concentration of substance (mg/dL)			Digital Output of Green light at 570 nm	Digital Output of infrared light at 1550 nm
Uric Acid (U)	Albumin (A)	Glucose (G)		
-	-	-	505±0.00	1023.00±0.00
3	-	-	505±0.00	802.67±0.58
6	-	-	505±0.00	807.33±0.58
9	-	-	505±0.00	821.67±0.58
12	-	-	505±0.00	825.67±0.58
15	-	-	505±0.00	834.67±0.58
-	2000	-	505±0.00	797.67±0.58
-	3000	-	505±0.00	807.33±0.58
-	4000	-	505±0.00	812.00±0.00
-	5000	-	505±0.00	812.33±0.58
-	6000	-	505±0.00	812.33±0.58
-	-	70	505±0.00	795.33±0.58
-	-	105	505±0.00	793.00±0.00
-	-	135	505±0.00	793.00±0.00

Concentration of substance (mg/dL)			Digital Output of Green light at 570 nm	Digital Output of infrared light at 1550 nm
Uric Acid (U)	Albumin (A)	Glucose (G)		
-	-	170	505±0.00	794.00±0.00
	-	200	505±0.00	793.00±0.00

From Table 1, the green light absorbance of uric acid concentrations of 3, 6, 9, 12 and 15 mg/dL which were measured 3 times found that the digital output values of green light were constant, they were 505±0.00. The green light absorbance of albumin was tested at concentrations of 2000, 3000, 4000, 5000 and 6000 mg/dL by 3 measurements. In green light, the digital output was equal to 505±0.00, the green light output digital value is unchanged. When testing the green light absorption of glucose solutions at concentrations of 70, 105, 135, 170 and 200 mg/dL, 3 measurements were performed. In green light, the digital output was equal to 505±0.00.

The infrared light absorbance of uric acid concentrations which were measured 3 times found that concentrations of 3, 6, 9, 12 and 15 mg/dL found that the digital output values of infrared light were 802.67±0.58, 807.33±0.58, 821.67±0.58, 825.67±0.58 and 34.67±0.58 respectively. The infrared light absorbance of albumin at concentrations of 2000, 3000, 4000, 5000 and 6000 mg/dL, the digital output values of infrared light was 797.67±0.58, 807.33±0.58, 812.00±0.00, 812.33±0.58 and 812.33±0.58. In albumin solution at a concentration of 2000 mg/dL and 3000 mg/dL, the digital output value was increased. For concentrations of 4000 mg/dL and above, the digital output value is constant. Therefore, to determine the infrared absorption, the highest concentration of albumin that affects the absorbance is selected. at a concentration of 3500 mg/dL used in the next step of testing.

When testing the infrared light absorption of glucose solutions at concentrations of 70, 105, 135, 170 and 200 mg/dL, the values of digital output were 795.33±0.58, 793.00±0.00, 793.00±0.00, 794.00±0.00 and 793.00 ±0.00. From the test, it was found that Glucose does not absorb infrared light at a wavelength of 1550 nm.

3) The functional testing of infrared light at 1550 nm in the uric acid detector circuit was tested in the sample set 2, 3, 4 and 5 of the artificial blood solution. The results of this project were shown in Table 2.

Table 2. Test results from the sample set 2, 3, 4 and 5

Concentration of substance (mg/dL)			Digital Output of infrared light at 1550 nm
Uric Acid (U)	Albumin (A)	Glucose (G)	
Set 2			
3	3500	-	813.67±0.58
6	3500	-	817.33±0.58
9	3500	-	820.33±0.58
12	3500	-	834.00±0.00
15	3500	-	836.33±0.58
Set 3			
3	3500	70	812.33±0.58
6	3500	70	824.00±0.00
9	3500	70	827.33±0.58
12	3500	70	839.00±0.00
15	3500	70	844.33±0.58
Set 4			
3	3500	135	815.00±0.00
6	3500	135	822.00±0.00
9	3500	135	827.33±0.58
12	3500	135	836.67±0.58
15	3500	135	847.33±0.58
Set 5			
3	3500	200	813.00±0.00
6	3500	200	821.33±0.58
9	3500	200	830.67±0.58
12	3500	200	845.00±0.00
15	3500	200	850.33±0.58

From Table 2, the testing results of set 2: the infrared light absorbance of uric acid concentrations of 3, 6, 9, 12 and 15 mg/dL mixed with albumin solution at a concentration of 3500 mg/dL., it was found that the digital output values were 813.67±0.58, 817.33±0.58, 820.33±0.58, 834.00±0.00 and 836.33±0.58 respectively. The testing results of set 3: Uric acid at concentrations in the range 3, 6, 9, 12 and 15 mg/dL mixed with 3500 mg/dL albumin solution and 70 mg/dL glucose solution, it was found that the digital output values were 812.33±0.58, 824.00±0.00, 827.33±0.58, 839.00±0.00 and 844.33±0.58. The testing results of set 4: Uric acid at concentrations in the range 3 6 9 12 and 15 mg/dL mixed with 3500 mg/dL albumin solution and 135 mg/dL glucose solution, it was found that the digital output values were 815.00±0.00, 822.00±0.00, 827.33±0.58, 836.67±0.58 and 847.33±0.58. The testing results of set 5: Uric acid at concentrations in the range 3 6 9 12 and 15 mg/dL mixed with 3500 mg/dL albumin solution and 200 mg/dL glucose solution, it was found that the digital output values are 813.00±0.00, 821.33±0.58, 830.67±0.58, 845.00±0.00 and 850.33±0.58.

4) The relationship between the digital output value with the uric acid (U), the digital output value with uric acid mixed with albumin (U+A), the digital output value with uric acid, albumin and glucose at a concentration of 70 mg/dL (U+A+G70), the digital output values with uric acid, albumin and glucose at a concentration of 135 mg/dL (U+A+G135) and the digital output values and the intensity of uric acid, albumin and glucose at a concentration of 200 mg/dL (U+A+G200) were shown in this Figure 5, 6, 7, 8, 9.

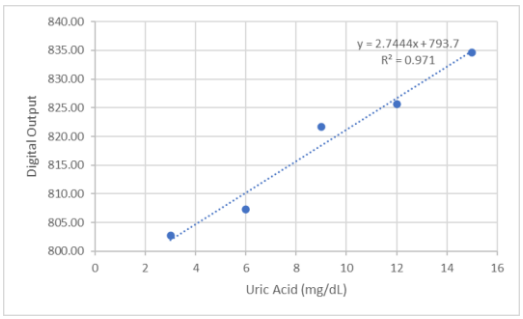

Figure 5. Graph of the relation between digital output and the uric acid (U).

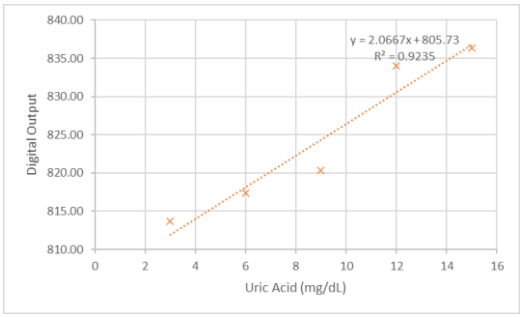

Figure 6. Graph of the relation between digital output and the uric acid mixed with albumin (U+A)

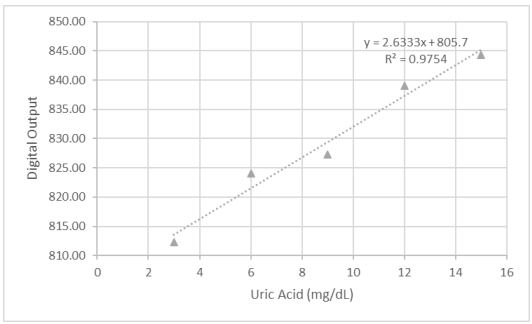

Figure 7. Graph of the relation between digital output and uric acid, albumin and glucose at a concentration of 70 mg/dL (U+A+G70)

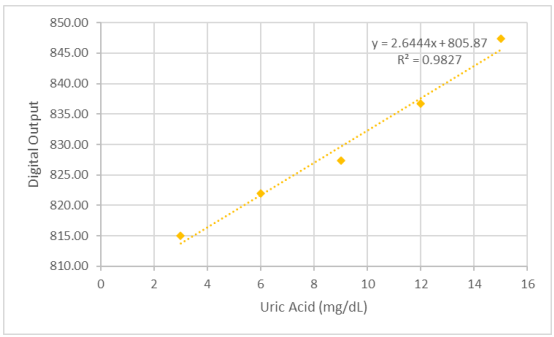

Figure 8. Graph of the relation between digital output and uric acid, albumin, glucose at a concentration of 135 mg/dL (U+A+G135)

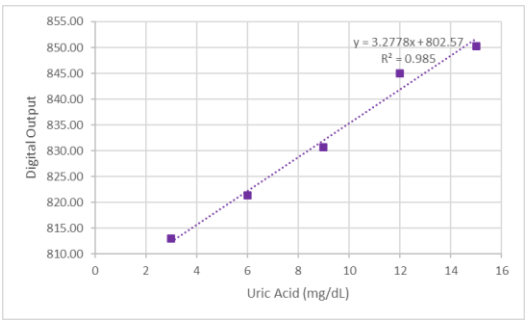

Figure 9. Graph of the relation between digital output and uric acid, albumin and glucose at a concentration of 200 mg/dL (U+A+G200)

From Figure 5, 6,7,8 and 9, the equation of each line, the correlation coefficient (r) and the coefficient of determination (R^2) were shown in below:

U: y = 2.7444x + 793.7, r = 0.99, R^2 = 0.971
U+A: y = 2.0667x + 805.73, r = 0.96, R^2 = 0.924
U+A+G70: y = 2.6333x + 805.7, r = 0.99, R^2 = 0.9754
U+A+G135: y = 2.6444x + 805.87, r = 0.99, R^2 = 0.9827
U+A+G200: y = 3.2778x + 802.57, r = 0.99, R^2 = 0.985

4. DISCUSSION

The main objective of this project was to characterise the relation between digital output and uric acid concentration in artificial blood solution using the described uric acid detector. At first, the prototype of the uric acid sensor was designed and constructed to measure uric acid solution. The artificial blood solution consisted of PBS combined with uric acid, albumin and glucose, designed to find the effect of light absorption of near-infrared and green light by these substances.

A near-infrared light source with a wavelength of 1550 nm was used, along with a photodiode detector to measure the light absorbance. Through the Beer-Lambert principle of light absorption, the photodiode signal that was related to the amount of light absorbance at the wavelength of interest, which was correlated with the concentration of uric acid. The control system for this uric acid detector, built around the Arduino Pro Mini family of microcontrollers, derived a digital output signal from photodiode signal. Higher concentrations of uric acid caused this digital output signal from the sensing device to increase, whereas lower concentrations of uric acid caused the digital output to decrease.

From the series of experiments performed testing the absorption of green light in uric acid, albumin and glucose artificial blood solutions, it was found that the digital output from the device was constant. Therefore, green light absorbance was not impacted by uric acid, albumin and glucose solutions in the concentrations tested.

When testing with albumin solutions at concentrations ranging from 2000 mg/dL to 4000 mg/dL, it was found that the concentration of albumin affected the digital output. When the albumin concentration is low, the digital output

is low and albumin at concentrations ranging from 4000 mg/dL to 6000 mg/dL results in unchanged digital output values. When testing glucose solutions at concentrations ranging from 70 mg/dL to 105 mg/dL, glucose concentration was inversely related to digital output. As glucose concentrations decreased, digital output increased, and vice versa, for glucose concentrations ranging from 105 mg/dL to 200 mg/dL. Therefore, the near-infrared light at 1550 nm can be used as a light source for detecting uric acid, but this wavelength is also absorbed by albumin, as found in previous studies of noninvasive uric acid monitoring [7].

When this method of uric acid detector compared with other non-invasive methods such as urine testing found that need to collect all urine passed in a 24-hour period to complete urinalysis is done in a laboratory. Although the results are highly accurate but it takes a long time to wait for results[16]. And when this method compared with the saliva, salivary uric acid can used with a diagnosis of serious illness but this technique has limitations such as saliva collection and sample processing issues[17]. Therefore, the light absorption method of uric acid detector is more advantage in more comfortable and convenient for uric acid detecting.

In future work, we recommend the use of a near-infrared light source at 1550 nm for detecting uric acid, and a green light source for background reference measurement, in the further development of noninvasive uric acid sensing technology. This will reduce the amount of interference caused by light absorbance of albumin, resulting in more accurate noninvasive uric acid measurements.

5. CONCLUSION

This paper has presented a study of the relationship between digital output and uric acid concentration in artificial blood solution using a uric acid detector based on the principle of light absorption. The light sources used in the uric acid detection circuit were near-infrared light at a wavelength of 1550 nm and green light at a wavelength of 570 nm. Uric acid solutions were measured at concentrations of 3, 6, 9, 12 and 15 mg/dL. In addition, albumin solutions were measured at concentrations of 2000, 3000, 4000, 5000 and 6000 mg/dL and glucose solutions at concentrations 70, 135 and 200 mg/dL. From the results of testing, near-infrared light at a wavelength of 1550 nm was absorbed by uric acid. When the concentration of uric acid increases, the digital output value increases, and conversely, when the concentration of uric acid decreases, the digital measuring device output also decreases. Albumin and glucose in solution also affected the absorption of near-infrared light at a wavelength of 1550 nm, but green light absorbance was not affected by uric acid, albumin or glucose at the concentrations tested. In addition, the equation relating voltage value and uric acid concentration was derived. The relationship between the digital output value and uric acid (U) was $y = 2.7444x + 793.7$, $r = 0.99$, $R^2 = 0.971$, uric acid filled with Albumin (U+A) was $y = 2.0667x + 805.73$, $r = 0.96$, $R^2 = 0.924$, uric acid filled with Albumin and glucose 70 mg/dL (U+A+G70) was $y = 2.6333x + 805.7$, $r = 0.99$, $R^2 = 0.9754$, uric acid filled with Albumin and glucose 135 mg/dL (U+A+G135) was $y = 2.6444x + 805.87$, $r = 0.99$, $R^2 = 0.9827$ and uric acid filled with Albumin and glucose 200 mg/dL (U+A+G200) was $y = 3.2778x + 802.57$, $r = 0.99$, $R^2 = 0.985$. This provides a foundation for further development of a noninvasive uric acid meter.

REFERENCES

1. Martillo, M.A., L. Nazzal, and D.B. Crittenden, *The crystallization of monosodium urate.* Curr Rheumatol Rep, 2014. **16**(2): p. 400.
2. *Guideline for Management of Gout.* 2012.
3. MacFarlane, L.A. and S.C. Kim, *Gout: a review of nonmodifiable and modifiable risk factors.* Rheum Dis Clin North Am, 2014. **40**(4): p. 581-604.
4. Jin, M., et al., *Uric acid, hyperuricemia and vascular diseases.* Front Biosci (Landmark Ed), 2012. **17**(2): p. 656-69.
5. Dalbeth, N., et al., *Urate testing in gout: why, when and how.* N Z Med J, 2015. **128**(1420): p. 65-8.
6. Paraskos, J., et al., *An analytical comparison between point-of-care uric acid testing meters.* Expert Rev Mol Diagn, 2016. **16**(3): p. 373-82.
7. Kim, J.M., *Noninvasive Uric acid Monitoring Device using Near-Infrared Spectroscopy.* Journal of Biosensors and Bioelectronics, 2015. **6**: p. 1-6.
8. Tamura, T., et al., *Wearable Photoplethysmographic Sensors—Past and Present.* Electronics, 2014. **3**(2): p. 282-302.
9. *MTE5115C2, Marktech Optoelectronics.* 2022.
10. *WP7113GD, Kingbright.* 2022.
11. *MTPD1346D-100, Marktech Optoelectronics.* 2022.
12. *PT334-6C, EVERLIGHT.* 2022.
13. Feldman, D., *Adhesion and Hemostasis in Surgery*, in *Encyclopedia of Materials: Science and Technology*, K.H.J. Buschow, et al., Editors. 2001, Elsevier: Oxford. p. 38-43.
14. Hantzidiamantis, P.J. and S.L. Lappin, *Physiology, Glucose*, in *StatPearls*. 2022: Treasure Island (FL).
15. Anupongongarch, P., T. Kaewgun, and J.A. O'Reilly, *DESIGN AND CONSTRUCTION OF A NON-INVASIVE BLOOD GLUCOSE METER.* INTERNATIONAL JOURNAL OF APPLIED, 2020. **13**(2).
16. Wang, Q., X. Wen, and J. Kong, *Recent Progress on Uric Acid Detection: A Review.* Crit Rev Anal Chem, 2020. **50**(4): p. 359-375.
17. Vernerova, A., et al., *Non-invasive determination of uric acid in human saliva in the diagnosis of serious disorders.* Clin Chem Lab Med, 2021. **59**(5): p. 797-812.

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