BLOOD GLUCOSE MEASUREMENT BY SWEAT USING ARDUINO

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Abstract*:*

This work investigates the effect of blood glucose measurement by conductivity measurement technique. Sweat contains dissolved ions, which contribute conduction between the two copper electrodes. As the concentration of ions in the sweat increases, conduction increases. The measured parameters such as voltage from the copper sensor is given to Arduino controller and then to the LCD display. Normal person have voltage range of 320 conductivity / sec and its corresponding glucose level is 80mg/dl. For diabetic person the voltage range is 377conductivity/sec and its corresponding glucose level is 141mg/dl. The responses are studied as salt content in the sweat is high, which results in high glucose level. If salt content in the sweat is low, it result in low glucose level. The correlation between salt content in sweat with its corresponding voltage and glucose level is done by interpolation equation. Non-invasive blood glucose estimation framework is utilized to quantify the blood glucose without taking the blood test. Hence, this method of blood glucose measurement is said to be painless, cost effective and easy monitoring for diabetes person.

Key Words: Non-Invasive, Sweat, Glucose Measurement & Arduino Controller

1. Introduction:

One of the biggest health challenges people facing now a days is diabetics due to its exponential increase in the blood glucose level. To prevent such complication due to diabetics it is necessary to monitor the blood glucose level continuously. Most of the regular glucose measurement systems are invasive in nature. Invasive methods cause pain, time consumption, high cost, invading healthy tissue and potential risk of spreading infection diseases. So, blood glucose monitoring by non-invasive method which is reliable, cost effective and comfortable. (Lahoda et al. (1975), Challoner et al. (1979), Clarke et al. (1987), Colwell et al. (1987), Wilson et al. (1992)). Blood glucose monitoring is done by various method. Some of them are UV spectroscopy method, RF Transmission method, Zinc oxide method etc. Researchers had monitored the blood glucose by non-invasive method using sweat. (Carlos et al. (2009), Rujuta et al. (2013), Liu et al. (2016). Diabetes is considered to be chronic metabolic disorder which affects all vital organs. For diabetic person, it is essential for monitoring blood glucose continuously. So, collecting blood by injection method causes blood loss which is essential for body, painful, and invading healthy tissue. Figure 1 shows the classification of glucose measurement. It is done by two methods. Blood glucose measurement is done by various method by collecting sample from

- Tears
- Saliva
- Sweat

Other than blood the remaining samples as above are wastes which are secreted from the body. Blood glucose measurement is essential for diabetes person to monitor glucose level continuously.

- Invasive method

- Non- invasive method

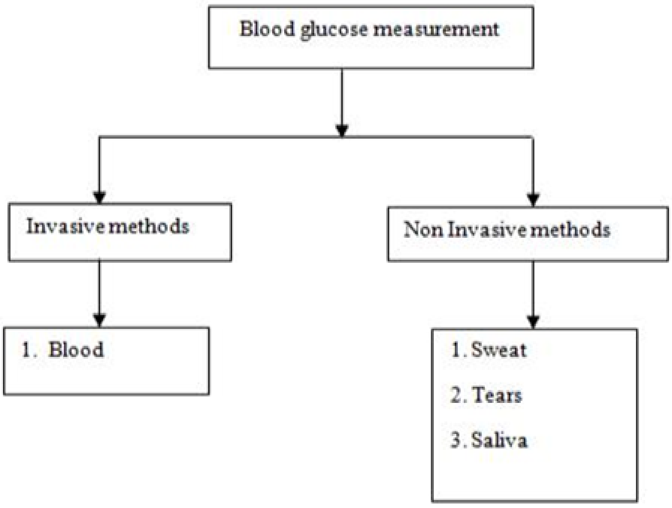


Figure 1: Classification of glucose measurement

Invasive Method:

Invasive method causes pain, loss of blood which is essential to live, invading healthy tissues. It also causes infection spread due to injection. Figure 2 shows the invasive method of blood glucose measurement.

Figure 2: Invasive method of glucose measurement

Non-Invasive Method:

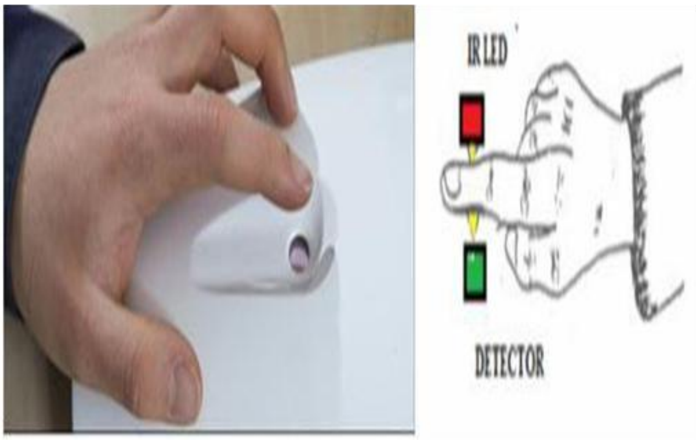


Figure 3: Non-invasive method of glucose measurement

Non-invasive method is painless. There is no break in the skin is created and there is no contact with the mucosa, or skin break, or internal body cavity beyond a natural or artificial body orifice. In this type of method have a advantage of not entering or penetrating the body. Some of the non-invasive method techniques are UV spectroscopy method, optical spectroscopy method, glucose oxidation method etc. But such method causes harmful to radiation which affects human being. Figure 3 shows the techniques for blood glucose measurement which is non-invasive.

2. Literature Survey:

Literature review shows the blood glucose measurement by various techniques such as UV spectroscopy method, bio impedance method, RF transmission method etc. (Rao et al. (1993), Li et al. (1994), Gabriel et al. (1996), Heise et al. (1998), Omar et al. (1999)). Carlos et al. (2009) have developed a method based on bio-electrical impedance analysis (BIA) which uses electrodes to apply low intensity currents in physiological fluids or tissues. The resulting voltage reflects changes in dielectric or dimensions of the target, therefore, being able to monitor chemical compositions or even physiological events in the organism.

Rujuta et al. (2013) have monitored the blood glucose level based on sensor fabricated on a flexible nano porous polyamide substrate with the electrodes and active region of ZnO. Gold measurement electrodes were used using shadow mask in e-beam cryo-evaporator which glucose level in sweat. ZnO thin films were sputtered onto patterned in the area between the two gold electrodes to get maximum overlap using an AJA Orion RF magnetron with a 99.99% ZnO target (Kurt J. Lesker) at room temperature.

Maximilian et al. (2014) proposed a new approach to non-invasive blood glucose parameter measurement, which consists of two matched antennas for transmission, based two port measurements. Liu et al. (2016) had monitor the glucose value and overall emphasis is laid on the development of NIRS (near-infrared spectroscopy) based on non-invasive glucose monitoring. Wenjun et al. (2015) had developed glucose monitoring based on saliva nano-bio sensor. The correlation is done between glucose values of saliva and in blood. Brince et al. (2014) had proposed a non-invasive optical technique for monitoring and studying of the pulsations associated with peripheral vascular blood volume changes using Photoplethy smography to determine blood glucose. From the literature survey, it is observed that blood glucose has been measured in various methods such as saliva, blood, tears and sweat. Hence, in this work, a blood glucose is measured by sweat using Arduino.

3. Experimental Procedure:

The following section deals with the methodology used for the glucose measurement, and hardware components used in this work.

Methodology:

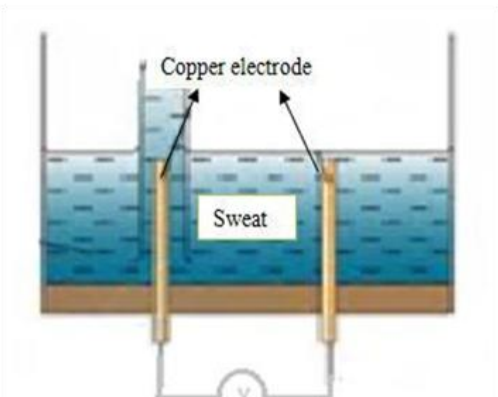


Figure 4: Conductivity measurement technique

Blood glucose measurement is done by using electrical conductivity measurement. Conductivity of the sweat sample is a measure of its ability to conduct the electricity. Sodium content from the sweat is measured in terms of voltage. The sugar level is being correlated by voltage range with the help of interpolation equation. The electrical conductivity of a solution of an electrolyte is measured by determining the resistance of the solution between two plate electrodes separated by a fixed distance. Figure 4 shows the conductivity measurement technique.

Hardware Description:

The following section deals with the hardware components of copper electrode, Arduino kit, and LCD display.

(i). Copper Electrode:

Copper has better strength than silver, but offers inferior oxidation resistance. Copper is a common base metal for electrical contact and electrode applications it is also used in alloys with graphite, tellurium, and tungsten and used to make brass and bronze. Copper electrode is used for conductivity measurement because it has high tensile strength towards electricity. Figure 5 shows the copper electrode.

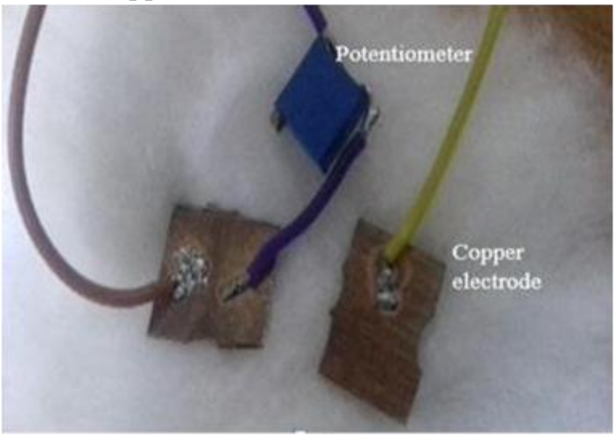


Figure 5: Copper Electrode

(ii) Arduino UNO:

The Arduino UNO is microcontroller board based on the AT Mega 328. It has 14 digital input/output pins, 6 analog inputs, 16 MHz ceramic resonaters, a USB connection, a power jack, an ICSP header and a reset button. Here, a arduino is used as controller. It get the analog signal from the electrode and then it will converted into digital form. Figure 6 shows the Arduino controller.

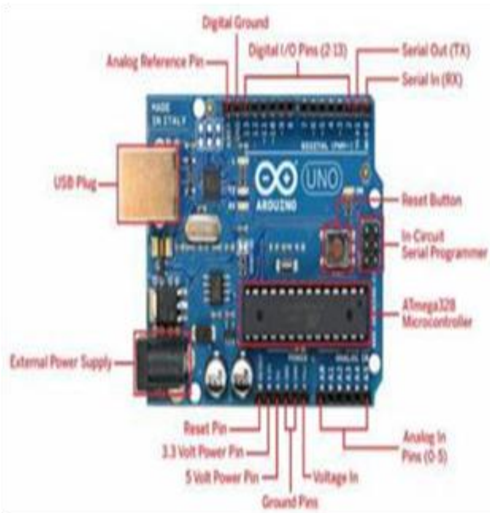


Figure 6: Arduino controller

(iii) LCD Display:

LCD (Liquid Crystal Display) is the technology used for display in notebook and other smaller computers. LCD is a flat-panel display or other electronic visual display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly. Figure 7 shows the LCD display device.

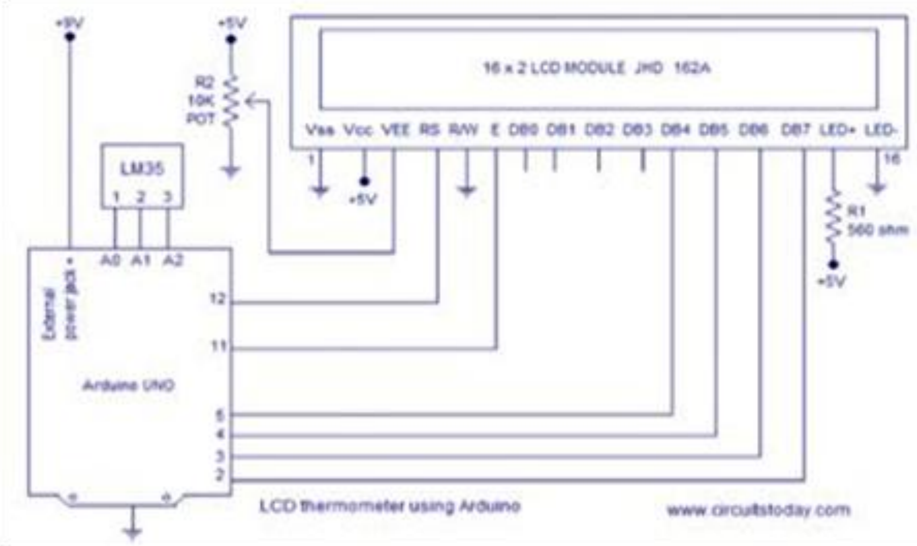


Figure 7: LCD Display

Schematic Diagram:

The block diagram consists of several components used for measuring the glucose level. The electrode acts as a sensor. The sweat sample from human body is sensed by using copper electrode. Due to the salt content in the sweat conductivity increases. Hence some amount of voltage will produce. The voltage is given to the amplifier which is used to convert low level signal voltage into high level signal voltage. The high voltage is given to the Arduino kit. The external power supply is given to the Arduino kit. The Arduino is used to convert analog signal into digital signal. The Arduino kit is connected with LCD display.

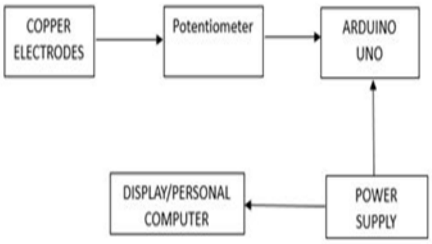


Figure 8: Block diagram of sweat glucose measurement

Implementation:

In this project, determination of blood glucose level by non-invasive method is carried out. Copper electrode is to monitor the patients sweat sample. In a study it is found that high sugar patients have high salt content in their body fluid due to kidney malfunctioning. Hence, this idea of experiment the glucose level. Salt has high conductivity and by measuring the conductance salt level is measured and calibrated with sugar level. Here, copper electrode for measuring the conductance is carried out. Higher the salt contents higher the conductance. The output is taken in V and fed into the arduino to the Rx pin. The voltage ranges from 200V to 500V and using this interpolation is made for glucose values in sweat. Figure 9 shows the experimental setup of blood glucose measurement using sweat.

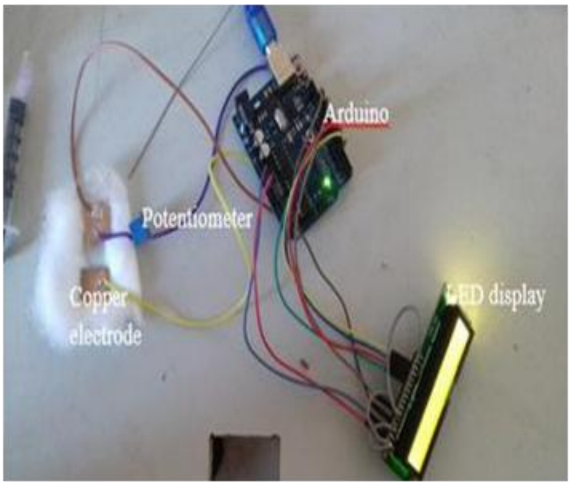


Figure 9: Experimental setup

Interpolation:

The voltage from the sweat determine only salt content present in the sweat. In order to monitor glucose level correlation between sweat rate in terms of voltage and glucose level is done by using interpolation equation

$$\frac{\mathrm{Out} - X_n}{X_{n+1} - X_n} * (Y_{n+1} - Y_n) + Y_n^{(1)}$$

Where,
Out – Acquire from sensor
Xn – Minimum voltage
Xn+1- Maximum voltage
Yn+1 – Maximum sugar value
Yn – Minimum sugar

4. Result and Discussion:

This paper presents an approach to non-invasive blood glucose parameter determination. New simulation using Arduino and measurement models in bio-medical applications has been shown. Here copper electrode is used as a sensor which readily react with sweat and a voltage from that blood glucose is said to be determined. Table 1 and 2 show the sweat rate versus glucose level for normal person and diabetes person respectively.

Table 1: Sweat rate versus glucose level for normal person

	Samples	**Sweat rate (conductivity/sec)**	**Glucose level (mg/dl)**
1	(men)	320	85 (normal)
2	(women)	332	90 (normal)
3	(women)	334	95 (normal)

Table 2: Sweat rate versus glucose level for diabetes person

	Samples	**Sweat rate (conductivity/sec)**	**Glucose level (mg/dl)**
1	(Women)	377	141 (high sugar)
2	(Men)	408	145 (high sugar)
3	(Women)	430	150 (high sugar)

Discussion:

Figure 10 represents the conductivity of sweat for the normal person (70-140mg/dl). As the sweat rate increases, the glucose level is also increases. If the salt content in the sweat is decreases, the conductivity also decreases. Figure 11 shows the increase in the value of glucose for diabetes person (above 140mg/dl) with respect to sweat rate.

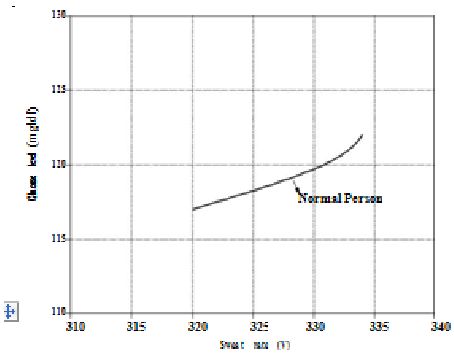
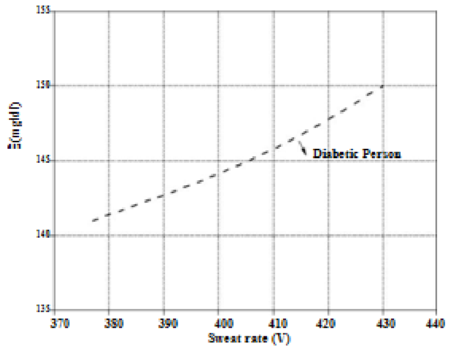


Figure 10: Sweat rate versus glucose level



5. Conclusion:

Hence, this project can prove a major out through for measuring blood glucose. A cost-successful, non-invasive blood glucose estimation model was created by taking into account the connection between blood glucose fixation and salt content in the sweat. Sweat analysis is a useful technique to monitor the performance of the athletes. It provides advantages like non-invasive monitoring and is performed with reduced discomfort. The analysis of individual constituents in the sweat can be used to diagnose various diseases. Sodium is considered to be an important electrolyte in the body, when excessive amount of sodium is detected in sweat, the condition is termed as hyponatremia. Hence it will be very useful to provide a cost effective technique to determine the individual constituents of sweat. A method to be incorporated to diagnose sweat gland disorders

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