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SWEAT GLUCOSE LEVEL DETECTOR USING COPPER ELECTRODES

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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 electrode 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 correlation between salt content in sweat with its corresponding voltage and glucose level is done by interpolation equation. Hence, this method of blood glucose measurement is said to be painless, cost effective and easy monitoring for diabetes person*

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 check the glucose level in blood, we have various methods. There are mainly two types of methods for this, namely

1.1 Invasive method

1.2 Non- Invasive method

1.1 Invasive method is the one in which blood is used to analyze the glucose level. Invasive method is painful method and it needs more blood to analyze every time.

1.2 Non- Invasive method is the one in which glucose measurement is done by collecting samples like

- Sweat
- Saliva
- Tears

Non-Invasive method is stress less and pain-free method in which blood is not used, instead we use samples like sweat, saliva, etc. which comes out from our body after collecting wastes. 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.

Why only Copper Electrodes?[5]

Everyone has a question that why we use copper electrodes instead of other electrodes like platinum, graphite or silver. The reason is the conductivity of copper and also its efficiency. The conductivity rate of copper is 92% and also it is more efficient than other electrodes. Silver also has an efficiency of nearest 100% but the cost of silver electrode is very high and also the error may be high when the efficiency is more or less than 100%. Copper is the only next element that has the conductivity of nearest 100%. Hence, we use copper electrodes for conductivity.

Arduino:

There are many types of arduino like arduino nano, arduino mega, arduino uno, etc. Here we use arduino uno, because it is suitable for this project.

Composition of Sweat:

Sweat has many components like:
- Sodium (0.9 gram/l)
- Potassium (0.2 g/l)
- Calcium (0.015 g/l)
- Magnesium (0.0013 g/l)

The imbalance in **chloride** leads to cystic fibrosis. **Sweat electrolyte test** helps to find the amount of chloride in the sweat and find the disease. The imbalance in **sodium** leads to hyponatremia. **Sweat sodium testing[6]** is a combination of measuring your sweat sodium concentration and your sweat rate. The imbalance in **potassium** leads to heart failure or paralysis. Potassium can also be found using sweat. The imbalance in **calcium** leads to deficiency in bones. Calcium can also be found using sweat test.

Composition of Sweat

	PRIMARY SWEAT	FINAL SWEAT
Sodium	Isotonic to plasma	Hypotonic
Potassium	Nearly isotonic	Slightly higher
Chloride	Isotonic	Hypotonic
Bicarbonate	~14 mmol	Absent
pH	7.2-7.3	5-7

- Isotonic- normal contraction
- Hypotonic- excess contraction

2. LITERATURE WORK

***1*) C.H. Che Haron** describes the conductivity of copper in "**Copper and graphite electrodes performance in electrical-discharge machining of XW42 tool steel"** Article in Journal of Materials Processing Technology · May 2008. He explains the conductivity, resistivity and other parameters of copper and graphite in deep explanation. He also concluded that copper is better than graphite electrode. According to his paper, electrical resistivity of 1.96, electrical conductivity of copper is 92% compared to silver, thermal conductivity of copper is 380.7, melting point is 1083 degree celcius, specific heat is 0.092 cal/g^0 celcius, specific gravity at 20^0 celcius is 8.9 g/cm, coefficient of thermal expansion is 6.6. On compared with these parameters, copper has better values than other elements or compounds. Hence, copper electrodes are better than other elements in testing and also in cost efficiency.

2) Saima jadoon describes the use of sweat for many purposes in **"Recent Developments in Sweat Analysis and its Applications"** Article in international journey of analytical chemistry- April 2015**.** He explains that sweat can be used for finding diseases like cystic fibrosis, liver failure, paralysis, bone deficiency, hyponatremia, etc. He also explains that sweat can be used for finding alcohol content in the body or to find whether the person has taken drugs. He also explains that sweat is a bio-fuel which explains about the body parameters.

3) **James Moyer** explains the correlation between sweat glucose and blood glucose level of a same body in "**Correlation between Sweat glucose and Blood glucose in subject with Diabetes"** in 2012**.** He explains that the sweat glucose and blood glucose are inter-related between each other and he also analyzed the values of the blood glucose and sweat glucose level and the values are similar to each other. According to his sayings, the values vary to the maximum of 0.05 error. The sweat glucose value lags blood glucose value with that 0.05 error. Hence he says that blood glucose can be identified using sweat.

4) **A. Gopikrishnan** describes the measurement of blood glucose using sweat in **"Blood Glucose Measurement by Sweat Using Arduino",** Journal of Engineering, Scientific Research and Applications, December 2018. He explains that the blood glucose can be identified using sweat with an experiment using sweat. The experiment contains an arduino, potentiometer, copper electrode, and lcd display. This experiment helps to find the value of sweat glucose with the help of the components and the sweat glucose value is used to measure the blood glucose value. The blood glucose value is found out by using interpolation formula in this experiment. The temperature sensor in the above components is used to identify the temperature of the sample body. He also explains that sweat glucose method is pain free[8] method and non-invasive method too. He also explains that other than sweat we can also conduct the test in other non-invasive methods also. The values of the sweat glucose is clearly explained and the values are similar to the blood glucose value. He also compares the sweat rate values of normal person and sweat rate values of a diabetic person. His paper gives a clear explanation that the sweat glucose value gives proper and approximate result of blood glucose value and it can be done many times without losing any blood in our body.

HARDWARE DESCRIPTION:

The major components of this project are:

1. Copper Electrodes
2. Potentiometer
3. Arduino UNO
4. LCD Display

Copper Electrodes:

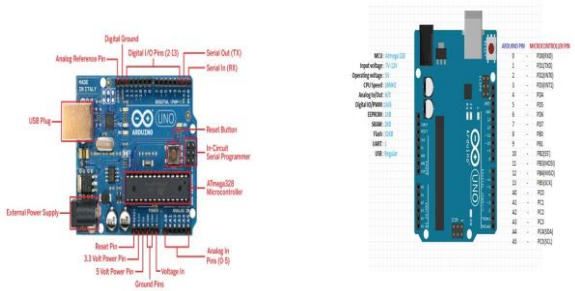
Copper Electrode [9] is used for measuring the conductivity of the sweat. Copper has better strength than silver, but offers inferior oxidation resistance. Copper is a common base metal for electrical contact and electrode applications it is also used in alloys with graphite, tellurium, and tungsten and used to make brass and bronze. Copper electrode is used

for conductivity measurement because it has high tensile strength towards electricity.

Potentiometer:

A **potentiometer** is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider[7]. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. Here potentiometer is used for varying voltage by removing or adding the resistor.

Arduino UNO:

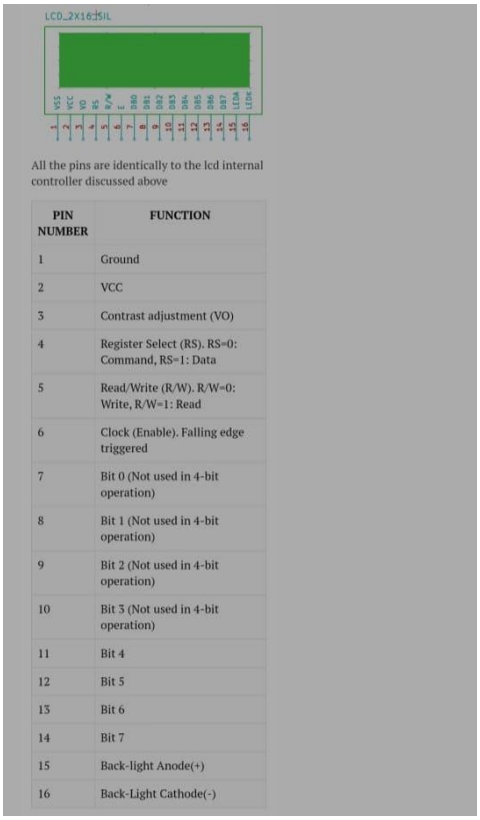


Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It is an open-source electronics platform based on easy-to-**use** hardware and software. **Arduino[11]** boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. Some of the ports in the arduino UNO[10] can be as follows: Power jack-It can be used for supplying 7-12 volts DC supply.ATmega328- It is use to store and run the program the given program USB plug- It is used to connect the arduino to the computer and feed the program to the microcontroller. Reset pin- It is used to reset the arduino program and reuse the arduino for new program.

LCD Display

A **liquid-crystal display** (**LCD**)[12] is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly,[1] instead using a backlight or reflector to produce images in colour or monochrome.

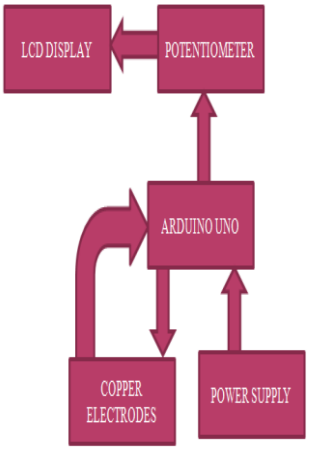
LCD display is used to show the output of the programmed arduino.
Here, port 11 to port 16 is used to connect with the arduino for showing the output



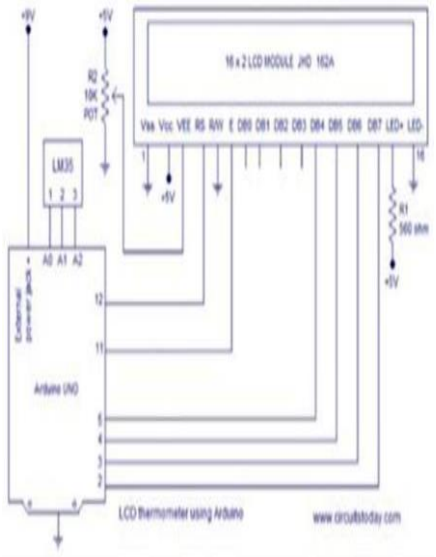
All the pins are identically to the lcd internal controller discussed above

PIN NUMBER	FUNCTION
1	Ground
2	VCC
3	Contrast adjustment (VO)
4	Register Select (RS). RS=0: Command, RS=1: Data
5	Read/Write (R/W). R/W=0: Write, R/W=1: Read
6	Clock (Enable). Falling edge triggered
7	Bit 0 (Not used in 4-bit operation)
8	Bit 1 (Not used in 4-bit operation)
9	Bit 2 (Not used in 4-bit operation)
10	Bit 3 (Not used in 4-bit operation)
11	Bit 4
12	Bit 5
13	Bit 6
14	Bit 7
15	Back-light Anode(+)
16	Back-Light Cathode(-)

Block Diagram



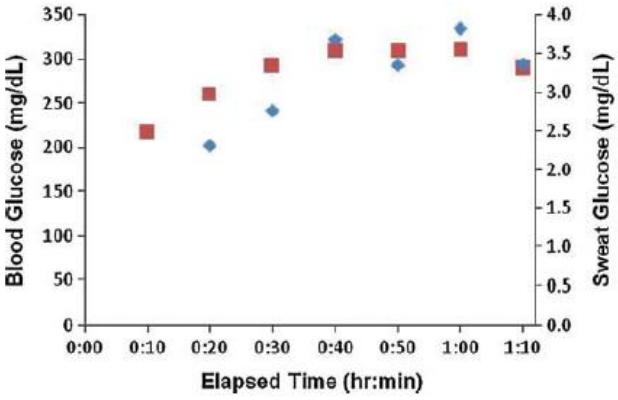
Schematic Diagram



COMPARISON BETWEEN SWEAT GLUCOSE AND BLOOD GLUCOSE LEVEL

Subject number	Study	SG/BG		BG (mg/dL)	
		Right	Left	Minimum	Maximum
1	A	0.160	0.110	192	311
	B	0.170	0.120	134	268
	C	0.190	0.200	86	176
2		0.090	0.090	112	214
3		0.010	0.010	60	235
4	A	0.023	0.014	90	270
	B	0.016	0.014	95	286
5	A	0.006	0.009	102	294
	B	0.010	0.011	57	220
6		0.019	0.013	99	197
7	A	0.022	0.023	210	312
	B	0.017	—	166	261

The sweat glucose (SG)/blood glucose (BG) ratio is presented for data obtained on the right and left arms.



Diamond Shape Figure- sweat glucose
Square Shape Figure -blood glucose
This fig shows the graph between sweat glucose and blood glucose.

RESULTS AND DISCUSSION

In order to complete the project, we need to understand about interpolation formula. The interpolation formula can be understood as follows:
The voltage from the sweat determine only salt content present in the sweat. In order to monitor glucose level correlation [15]between sweat rate in terms of voltage and glucose level is done by using interpolation equation
Where,
Out – Acquire from sensor

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

In this project, determination of blood glucose level by non-invasive method is carried out. Copper electrode[14] 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 [13] 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. The obtained value is as follows:

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

The above result is for normal 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)

The above result is for diabetic person

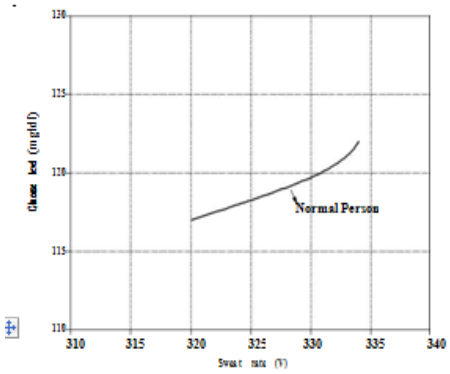
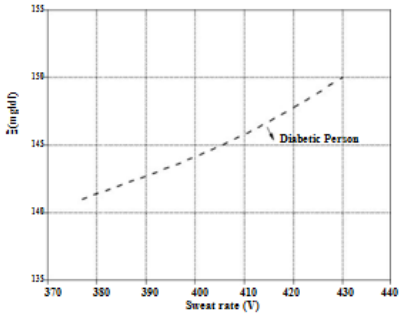


Figure 10: Sweat rate versus glucose level



The graphical representation of the obtained result

3. 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. This process helps us for faster identification of the glucose content in the body using sweat alone.

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