

Non-Invasive Glucose Monitoring Based on Mid-Infrared Spectroscopy

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Abstract

This paper presents on non-invasive method of glucose monitoring using Mid-Infrared (M-IR) spectroscopy. Glucose samples are prepared and analyzed using M-IR spectroscopy. Using Fourier-transform of the M-IR spectroscopy, we experimentally track variations in the mid-infrared glucose absorption peak. The glucose samples and the relation with diabetic people is also presented in this paper. It is found that as the glucose concentration increases, the wavelengths at which absorbance peaks occur also increase particularly for wavelength range 1400-1470nm.

Keywords: glucose, distilled water, FTIR spectroscopy, absorbance

1. Introduction

Researchers have been working to develop diabetic self-care assessment techniques over time. Many of these therapies call for a blood sample. The number of diabetics has been gradually increasing in recent years due to changes in individual behavior. We place a great deal of importance on it. The 140 million people who require insulin injections globally produce very little insulin on their own. It is referred to as the insulin therapy [1]. They must keep an eye on their own blood sugar levels. They must specifically monitor blood glucose levels all day long. Plus, they required an insulin injection if their blood sugar level increased [1][2].

However, today's technologies for measuring glucose all require patients to prick their fingers and take a blood sample. It causes pain for diabetics and increases their chance of getting an infection [3]. These will thus make the burden heavier.

Since people avoid taking measurements with the uncomfortable finger-stick glucose monitors that are currently available, the development of non-invasive (or minimally invasive) glucose monitoring technologies is inevitable. The most recent efforts made in this area were thoroughly discussed in several review papers [4]. Among the many non-invasive (NI) glucose detection methods, optical sensing has received the most attention due to some potential benefits in terms of sensitivity, response time, and patient comfort.

Several researchers have shown that FT-IR spectroscopy may be utilized to detect glucose in the MIR range [5]. Hardly a few research teams have adapted MIR transmission measurement using FT-IR spectroscopy due to blood's viscosity, high particle content, and strong water background absorption.

In [6], different concentration of ethanol solution is obtained. Using Agilent Cary 630 Fourier Transform Infrared (FTIR) spectroscopy, the absorbance of various concentrations of ethanol solution was measured.

Researchers in [7] deployed A Fourier transform infrared spectroscopic method with attenuated total reflectance (FTIR-ATR) for the prediction of sugar contents in honey samples.

The study of the interaction between matter's electromagnetic radiation in the infrared (IR) range is known as infrared (IR) spectroscopy. Additionally, this spectroscopy has long been a powerful resource for recognizing organic samples, even those in complicated forms. One of the improvements in IR spectroscopy where this method is more widely used in the research of various areas is the Fourier Transform Infrared (FTIR) spectroscopy.

There are several benefits to performing FTIR spectroscopy since it is considered to be a straightforward approach that only needs little sample preparation and can produce immediate results. The FTIR spectroscopy also has a high sensitivity or spectral signal to noise (S/N) ratio [8], which enables the detection of the component in glucose even at extremely low concentrations. It is clear from the reported results that this method is appropriate for determining blood glucose levels [8].

The Beer's Lambert Law is a law which governs the relationship between the absorbance and the concentration of samples. This law states that there is a liner relationship between the absorbance and their concentration [6]. The general equation is written as:

$$A = \epsilon lc \quad (1)$$

Where:

- A = Absorbance of light
- ϵ = Wavelength-dependent molar absorptivity with coefficient (M-1cm-1)
- l = Length of solutions this light passes through (cm)
- c= Concentration of solution (v/v%)

Wavenumber formula:

$$W=1/\lambda \quad (2)$$

Where:

W= wavenumber in cm^{-1} .

λ = wavelength in nm.

The range of the IR bands covers from 70nm to 1000 μ m. The IR region is divided into three sub-regions, namely the Near-IR region (700-2500nm), the middle-IR region (2500-25000nm) and Far-IR region (2500-1000 μ m). In this study, we investigate non-invasive blood glucose testing with infrared radiation to minimize the burden on diabetics. FTIR equipment operates at the Mid-IR region is used for this project [9]. However, due to project limitations, blood glucose solution is replaced with glucose solution. Various glucose concentration represents various diabetic conditions as shown in Table 1.

2. Research Methodology

In this experiment, different concentrations of glucose were prepared by adding the mass of the glucose and diluting the mass in 50 mL of distilled water at room temperature. The prepared concentrations are depicted as in Table 1. Fig. 1 shows the weighting scale and the beaker used to produce the glucose solution.



Fig. 1. Chemical weighting scale and beaker

The highest concentration (64,000 mg/dl=3.2 g in 50 ml) of the six various concentrations of aqueous glucose solution made in distilled water. Sample 1 is the highest concentration is at this level which indicates a very high risk diabetic person. Sample 6 represents a low glucose concentration and it is considered high risk due to hypoglycemia condition. Table 1 shows the aqueous solutions samples with different concentration. Each sample represents different characteristics of blood glucose for diabetic people. Fig. 2 displays the schematic

diagram of the FTIR spectroscopy that is connected to a personal computer for further analysis.

Table 1. Aqueous Solutions Sample with Different Concentration and Characteristics

Samples	Characteristic of concentration	In mg/dl	In 50 ml	Risk
Sample 1	Very high concentration	6400	3.2g	Very high
Sample 2	Hyperglycaemic blood	540	0.27g	High
Sample 3	Clinical accuracy	400	0.2g	No risk
Sample 4	Normal human blood	160	0.08g	No risk
Sample 5	Normal human blood	70	0.035g	No risk
Sample 6	Low concentration	30	0.015g	High

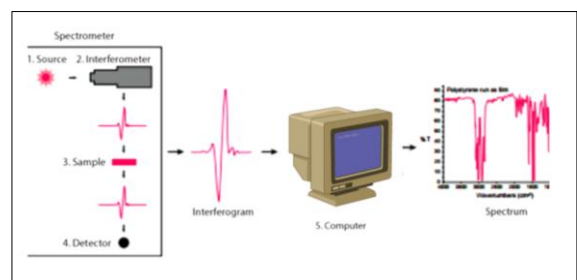


Fig. 2. Schematic diagram of the FTIR spectroscopy

The following weight of aqueous glucose solution are prepared: 3.2g, 0.27g, 0.2g, 0.08g, 0.035g and 0.015g. First and foremost, study into the various glucose concentrations must be conducted by reviewing earlier research papers. This procedure must be followed to guarantee that the glucose measurement is based on optical absorbance and that the result is nearly identical to the blood concentration reading obtained using a glucometer.

Following that, data analysis can be carried out by varying the optical absorbance intensity in distilled water for various concentration values. The relationship between absorbance intensity and glucose concentrations can then be plotted using Excel for all samples after receiving the Cary 630 FTIR spectroscopy results. Fig. 3 shows the Cary 630 FTIR Spectroscopy used in this experiment.

By examining the absorbance on the selected peaks, it is then possible to validate the data with regard to its various peaks at various concentrations. This makes it possible to confirm the validity of the experiment and the accuracy of the results at all concentrations.

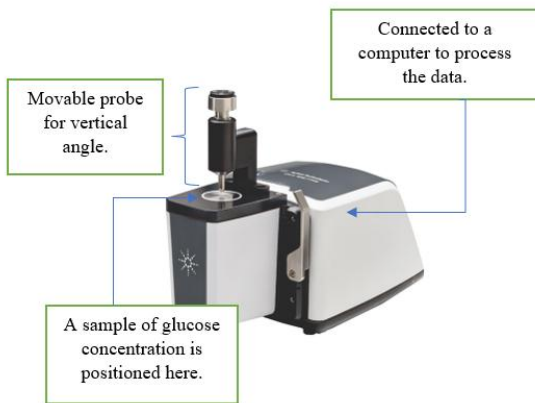


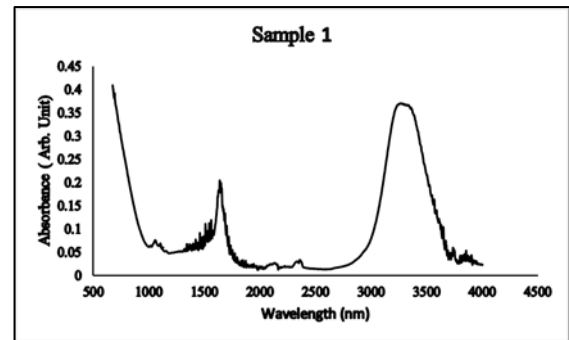
Fig. 3. Cary 630 FTIR Spectroscopy

The Cary 630 FTIR instrument needs to be connected to the computer that has its data processing software loaded before it can measure the optical of glucose. The glucose concentration sample needs to be set up on the platform as shown in the figure in order to begin the measuring process. The instrument's platform needs to be cleaned beforehand since it will affect the undesirable elements that are captured during data collection. The probe accessory for liquid samples can be adjusted up and down without contacting the sample. Typically, a solvent of the chemical in which the researcher is interested is used as the background sample. Air serves as another backdrop example. When the platform detects no background sample, it is automatically set.

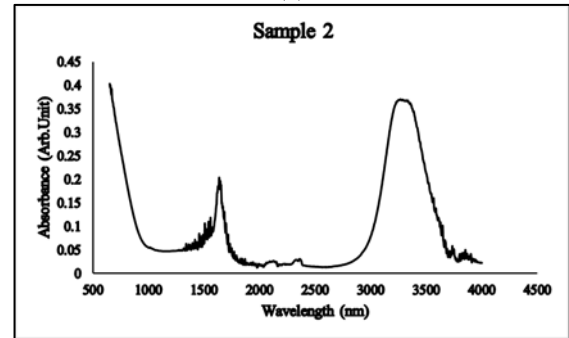
Once the background sample is recognized, the glucose sample can be placed on the same platform for the measurement process by dropping a few drops of the sample. However, the platform must be cleaned again before placing another concentration to make sure the measurement is not mixed with other concentration. The spectroscopy will automatically remove the background data from the testing sample. Therefore, the researcher will obtain the measurement results without the solvent of the glucose.

3. Result and Discussion

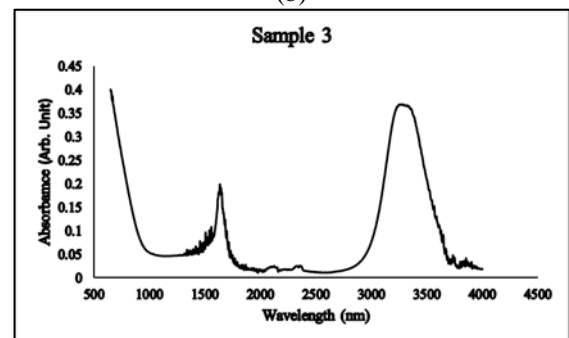
Using MIR-spectroscopy, the absorbance of the samples are obtained. Fig. 4 shows the graph of each sample with various absorbance intensity and glucose concentration. Each sample has different peak value, whereas the sample with the highest concentration having the highest peak value.



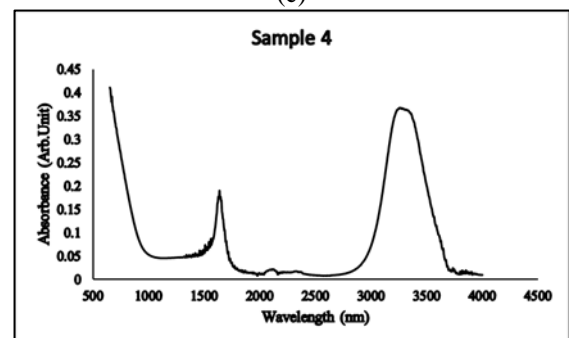
(a)



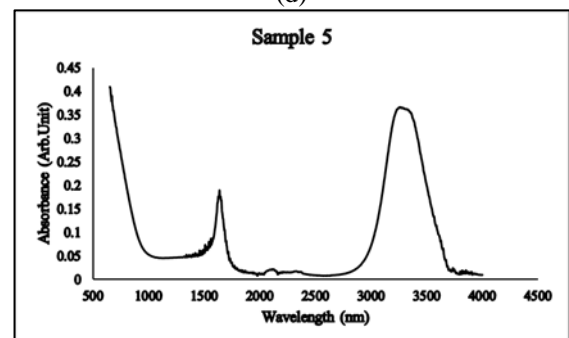
(b)



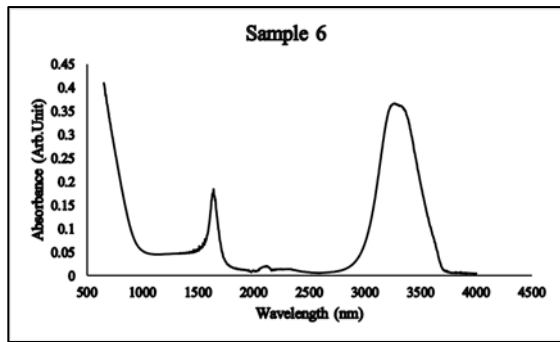
(c)



(d)



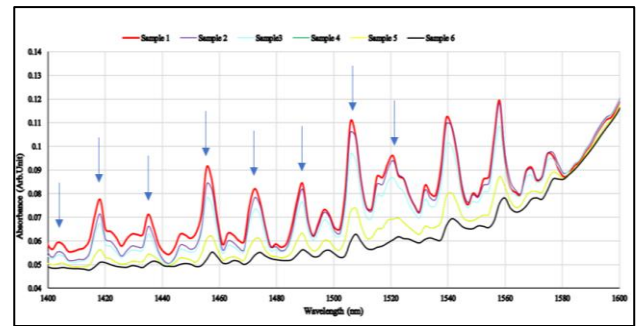
(e)



(f)

Fig. 4. Relationship between the absorbance intensity and glucose concentration for (a) 3.2g, (b) 0.27g, (c) 0.2g, (c) 0.08g, (d) 0.035g & (d) 0.015g

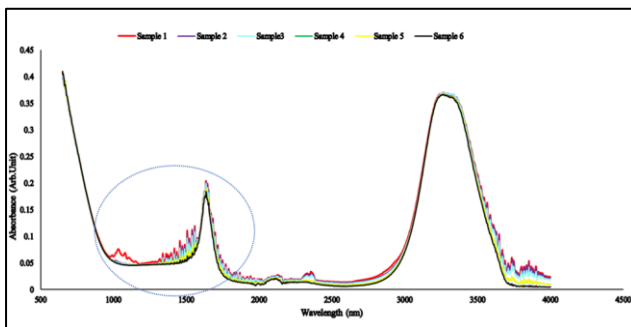
When all the graphs for all the samples have been obtained, the data must then be merged to analyze the peaks for various aqueous glucose solutions. Fig. 5 (a) shows the combination of all spectra and the dotted circles shows the spectra that will be analyzed as it shows significance difference of the samples. Fig. 5 (b) shows the zoom in spectra that will be analyzed. Four peaks are identified and can be further analyzed. Fig. 5 (c) shows the close up look of Peak 3. The wavelength ranges for Peak 3 is from 1400 nm until 1530 nm.



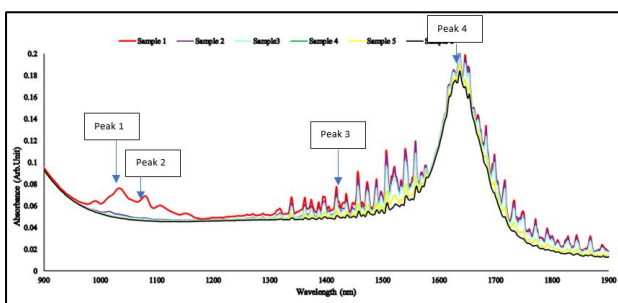
(c)

Fig. 5. (a) Absorbance spectra of combination of all glucose samples, (b) Zoom in the peaks spectra of the glucose concentration, (c) Spectra of Peak 3 with close-up look

Fig. 6 shows the absorption change of small peaks in broader Peak 3, which are marked as arrows in Fig. 6 from left to right designed as Peak3-1, Peak3-2, Peak3-3, Peak3-4, and Peak3-5. Each peak corresponding to the absorption wavelength of 1400nm, 1420nm, 1440nm, 1460m, and 1470nm, respectively. It can be observed that the higher the concentration, the higher the absorption power is. Table 2 shows the concentration and the absorbance for all samples. The findings demonstrate that the -CHO bond present in the FTIR spectrum transmission spectrum from glucose-water solution at different concentrations can be used to identify the glucose component.



(a)



(b)

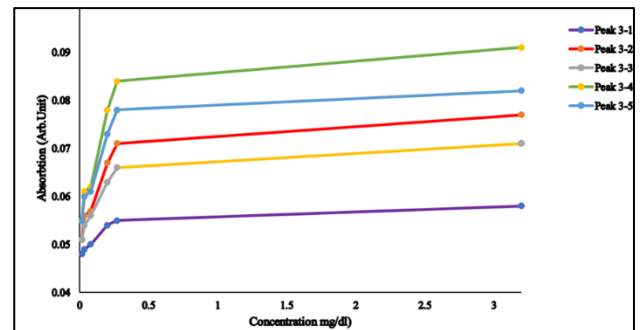


Fig. 6. The change of selected Peak 3 as function of glucose concentration

Table 2. Absorbance Intensities Of Glucose For Various Concentration

Samples	Total Absorbance Intensity (Au)
Sample 1	175.3459
Sample 2	171.3098
Sample 3	168.0368
Sample 4	159.3074
Sample 5	159.3074
Sample 6	154.7048

4. Conclusion

A non-invasive glucose monitoring has been successfully demonstrated. It demonstrates that the -CHO bond present in the FTIR spectrum transmission spectrum from glucose-water solution at different concentrations can be used to identify the glucose component. It is found that as the glucose concentration increases, the wavelengths at which absorbance peaks occur also increase particularly for wavelength range 1400-1470nm. The outcomes demonstrated that various glucose-specific peaks had various absorption values; therefore, by measuring these values, we can establish the correct correlations for the concentration-to-absorption relation, which can be applied for a high-precision glucose measurement.

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Authors Introduction

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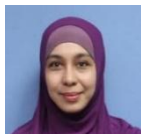
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