Abstract

Diabetes is a serious group of diseases that can cause many complicated problems including sudden mortality. Glycated hemoglobin tests are considered as a reliable tool to diagnose diabetes. To estimate amount of glycated hemoglobin (HbA1c) present in Red Blood Cells (RBCs) optically, the molar extinction coefficient of HbA1c is necessary. We require to know the molar absorption coefficient of glycated hemoglobin, a control solution is necessary.

I. Introduction

To diagnose diabetes, random blood sugar test, fasting blood sugar test and oral glucose tolerance tests are used medically [1]–[3]. Recently non-invasive techniques are emerging as an alternative to invasive methods to estimate glucose in a blood stream [4].

In another method of diabetes diagnosis, estimation of HbA1c is performed [5]. There are many methods estimating HbA1c levels in blood stream with blood samples. HbA1c can also be estimated in non-invasive processes. One of these non-invasive processes require to know the molar absorption coefficient of HbA1c.

In this paper, we focus on the estimation of the molar extinction coefficient of HbA1c for non-invasive optical estimation of HbA1c levels.

II. Methodology

To estimate the molar extinction coefficient of glycated hemoglobin, a control solution is necessary. There are many control solutions available for HbA1c. Among those Control FD Glycohemoglobin A1c Level-2 (Audit MicroControls) and pure HbA1c control solution (Lee Biosolutions, Inc.) are common. These samples are then sandwiched between cover glass and poly prep slide. The control solutions used contains water as a solvent. The percent transmittance and absorption can be equated by the following equation.

\[ A = 2 \log(\%T) \]  
(1)

Now, we can write the full equation of absorption of the HbA1c solution as,

\[ A_{HbA1c, sol} = A_w + A_{HbA1c} \]  
(2)

This equation can be rewritten for the absorption of HbA1c as,

\[ A_{HbA1c} = A_{HbA1c, sol} - A_w \]  
(3)

Calculating absorption of a material in the manner, causes scaling error if the transmittance values are normalized. So, now we denote the actual value of absorption of HbA1c as \( A_{HbA1c} \) and we can let,

\[ A_{HbA1c}^R = k \times A_{HbA1c} \]  
(4)

Now from Beer–Lambert Law this Eqn. (4) can be rewritten as

\[ A_{HbA1c}^R = k \times \epsilon_{HbA1c}(\lambda) \times c_{HbA1c} \times d \]  
(5)

\[ A_{HbA1c}^R = k' \times \epsilon_{HbA1c}(\lambda) \]  
(6)

\[ k' = k \times c_{HbA1c} \times d \]  
(7)

Now, we can state that, any value of absorption of HbA1c at a certain wavelength is directly proportional to the molar extinction coefficient of HbA1c of that exact wavelength as shown in (8). The equation (8) can be rewritten for two different wavelengths as (9) shown below.

\[ A_{HbA1c}^R \propto \epsilon_{HbA1c}(\lambda) \]  
(8)

Estimation of Molar Absorption Coefficients of HbA1c in Near UV–Vis–SW NIR Light Spectrum

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Now, we can state that, any value of absorption of HbA1c at a certain wavelength is directly proportional to the molar extinction coefficient of HbA1c of that exact wavelength as shown in (8). The equation (8) can be rewritten for two different wavelengths as (9) shown below.

\[ A_{HbA1c}^R \propto \epsilon_{HbA1c}(\lambda) \]  
(8)
\[ \varepsilon_{\text{HBAlc}}(\lambda_2) = \frac{\varepsilon_{\text{HBAlc}}(\lambda_2)}{\varepsilon_{\text{HBAlc}}(\lambda_1)} \times \varepsilon_{\text{HBAlc}}(\lambda_1) \tag{9} \]

III. Results

According to [6], the percent transmittance of HbAlc solution and water can be found for a wavelength range of 300nm to 1100 nm. In [7], the authors designed a sensor to estimate glycated hemoglobin levels and measured the molar extinction coefficient of HbAlc at two wavelengths of light (535nm and 593nm). They used both 8% and 13% control solution (ControlFD Glycohemoglobin A1c Level 2) to estimate the molar extinction coefficients for those two wavelengths. The molar extinction coefficient values are given below,

\[ \varepsilon_{\text{HBAlc}}^{13\%} (535nm) = 456061 \pm 117823 \text{ M}^{-1}\text{cm}^{-1} \tag{10} \]
\[ \varepsilon_{\text{HBAlc}}^{8\%} (535nm) = 710888 \pm 191458 \text{ M}^{-1}\text{cm}^{-1} \tag{11} \]
\[ \varepsilon_{\text{HBAlc}}^{13\%} (593nm) = 201765 \pm 80037 \text{ M}^{-1}\text{cm}^{-1} \tag{12} \]
\[ \varepsilon_{\text{HBAlc}}^{8\%} (593nm) = 322197 \pm 130060 \text{ M}^{-1}\text{cm}^{-1} \tag{13} \]

These four values of molar extinction coefficients are used as references to calculate the molar extinction coefficient for 300nm to 1100nm using equation (9). The estimated molar extinction coefficient for 300nm to 1100nm is depicted in Fig. 1 alongside with the molar extinction coefficient of Oxy- and Deoxy-hemoglobin molecules.

III. Conclusion

In this research, we have focused on the estimation of the molar extinction coefficient of HbAlc. HbAlc is an important marker for diabetes diagnosis. And the molar extinction coefficient is important for estimating the total amount of glycated hemoglobin present in blood stream. According to our results we have got the characteristic peaks which is consistent with previous studies, but absorption spectrum needs to be investigated further for wavelengths above 650nm. The characteristic peak is found at 411nm. And two following peaks at 540nm and 576nm, respectively.

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References


Figure 1: Molar extinction coefficient of Deoxy-hemoglobin, oxy-hemoglobin and glycated hemoglobin.