In vitro polarimetric blood component determination in pretreated plasma samples

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Introduction

- Glucose and lactate determination in blood samples gain importance in clinical medicine since many years.
- Different measurement techniques like encymatic-amperometric systems, absorbance spectroscopy or polarimetry are widely investigated [1,2].
- Glucose determination via polarimetry was explored only for clear media with low protein concentrations, especially at the humor of the eye by reason of strong optical activity of protein containing plasma.
- It was demonstrated that correlation between glucose concentration and polarimeter signal can be achieved for ultrafiltrated plasma samples [3].

Objectives

- Concentration determination in pretreated protein-free plasma-samples was not further pursued, so we aimed to continue this research.
- Only glucose determination was regarded, but other optically active blood constituents like lactate were neglected due to smaller rotation [4].

Measurement setup

- Sample was located between 2 crossed polarizers to measure sample depending optical rotation.
- Polarized light was modulated by a Faraday-Rotator at 2.134 kHz.

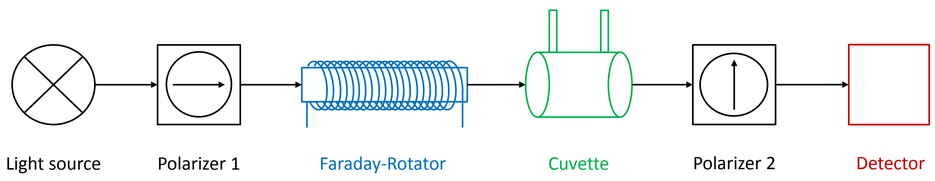

Fig. 1 – Polarizer measurement setup: Emitted light is polarized by polarizer 1 and modulated by Faraday-Rotator. Polarization is influenced by sample concentration, so that only rotated polarization can pass perpendicular polarizer 2. Signal is detected and further processed.

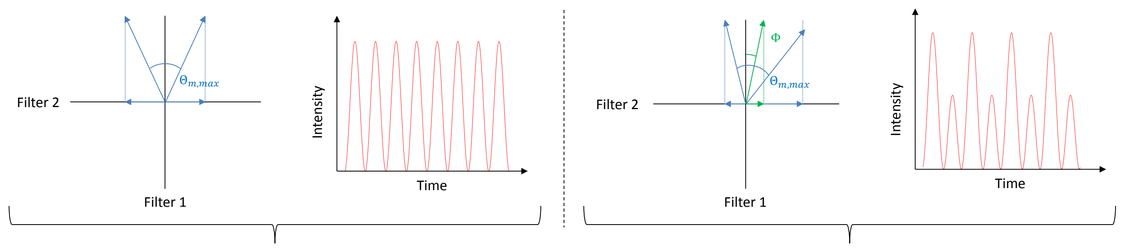

Fig. 2 – Principle of relation between optical rotation and detector intensity.

- Intensity I on detector depending on sample rotation Φ, max. Faraday-rotation $\Theta_{m,max}$, and modulation frequency ω_m can be described by the following equation [2].

$$I \propto \underbrace{\left(\Phi^2 + \frac{\Theta_{m,max}^2}{2}\right)}_{DC} + \underbrace{2 \cdot \Phi \cdot \Theta_{m,max}^2 \cdot \sin(\omega_m \cdot t)}_{\omega} - \underbrace{\frac{\Theta_{m,max}^2}{2} \cdot \cos(2 \cdot \omega_m \cdot t)}_{2\omega}$$

- Sample-depending intensity of ω was used for measurements with concentration independent 2ω-part for compensation purposes.

Measurements

- Physiological concentrations of sodium L-lactate and D-glucose were diluted in distilled water and protein-reduced plasma.
- Ratio of frequency components ω and 2ω was recorded.

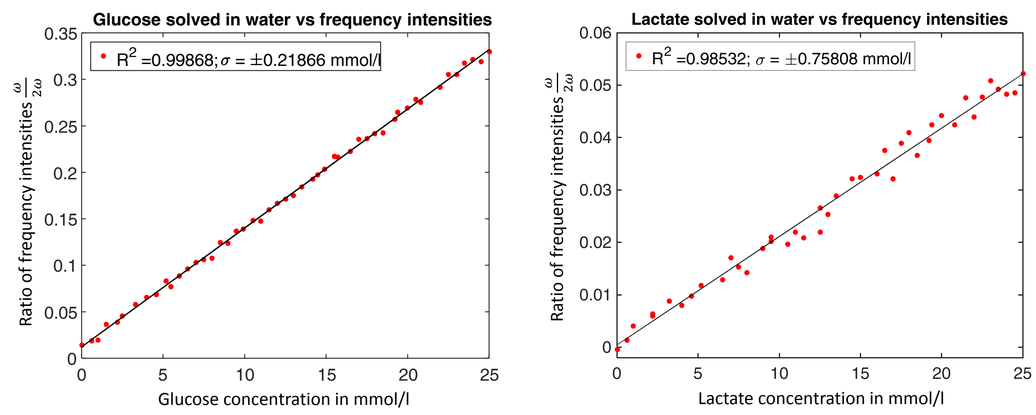

Fig. 3 – Correlation between concentration and intensity ratio of ω and 2ω in water-solutions, left: D-glucose, right: sodium L-lactate.

Fig. 4 – Correlation between concentration and intensity ratio of ω and 2ω in protein-reduced spiked plasma samples. Left: glucose-spiked, right: lactate-spiked protein-reduced plasma. Faulty value caused by air bubble was omitted for R^2 and σ-calculation.

Results

- High correlation between measurement signal and sample concentration was achieved for glucose solved in water as well as for glucose-spiked protein-reduced plasma samples.
- Lactate shows good correlation in both solutions but due to slight optical rotation it was more sensitive to external influences like air bubbles. Nevertheless, predictability of lactate was demonstrated.
- Sample absorbance and radiation source drift could be partially compensated with sample independent 2ω amplitude.

Discussion and Outlook

- Spectral overlap of different optically active blood components impedes reliable concentration prediction for untreated plasma samples, so that proteins have to be removed from samples.
- Expanding the measurement setup by more wavelengths is supposed to overcome these limitations and reduce sensitivity to environment condition fluctuations.

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References

[1] Denis LaFrance, *Near Infrared Determination of Lactate in Biological Fluids and Tissues*. PhD thesis, McGill University, 2003.
[2] Justin S. Baba, Brent D. Cameron, Sangeeta Theru, Gerard L. Cote, "*Effect of temperature, pH, and corneal birefringence on polarimetric glucose monitoring in the eye*," Journal of Biomedical Optics, vol. 7, no. 3, pp. 321–328, 2002.
[3] W.K.R. Barnikol, N. Weiler, "*Experimente zur Entwicklung eines implantierbaren und dauernd funktionsfähigen Glukose-Sensors auf Basis der Polarimetrie*," Biomedizinische Technik, vol. 40, no. 5, pp. 114–120, 1995.
[4] B. Jirgensons, *Optical Rotatory Dispersion of Proteins and Other Macromolecules*. Springer-Verlag - Berlin - Heidelberg - New York, 1969.