Detection of Lactate in Human Sweat via Better Surface-Modified Screen-Printed Carbon Electrodes

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Abstract

- Lactate levels in sera are usually low in normal individuals. Real-time and continuous monitoring of lactate levels in sweat has been applied as an indicator of physiological information to evaluate the exercise outcome and sports performance.
- The sweat gland produces a small amount of lactate under physiological conditions, the baseline lactate levels in human sweat are from 10 to 30 mM but can rise up to 100 mM during intense exertion.
- We developed an enzyme-based lactate biosensor to detect the concentrations of lactate in different fluids (i.e. buffer solution and human sweat).
- Our preliminary results showed that the response of LDH-modified SPCE biosensors is a function of the concentration of lactate with a dynamic range of 0.1 – 100 mM (R^2>0.9).

Research Methodology

- Oxygen plasma can not only clean the surface of SPCEs but also add oxygenated functionalities and free radicals to their surface.
- The LDH enzyme was directly immobilized using an EDC-NHS coupling agent over the active layer of SPCE to achieve guaranteed stability and selectivity.
- The prepared biosensor was connected to an LCR meter and the performance was tested at different concentrations of lactate through impedimetric analysis.

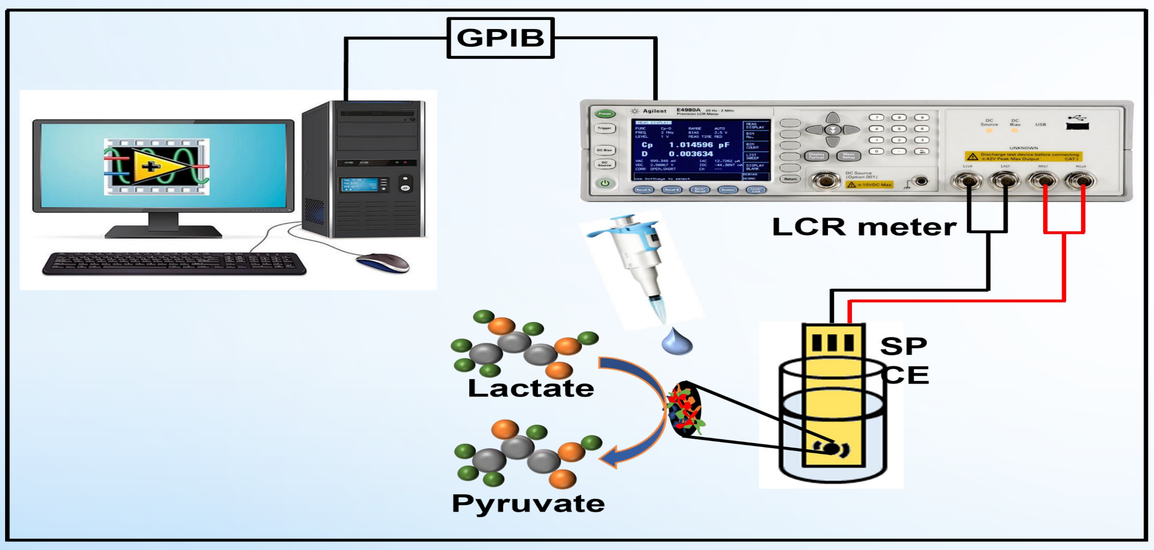

Figure 1. Systematic representation of lactate detection via LDH enzyme modified SPCE.

Results

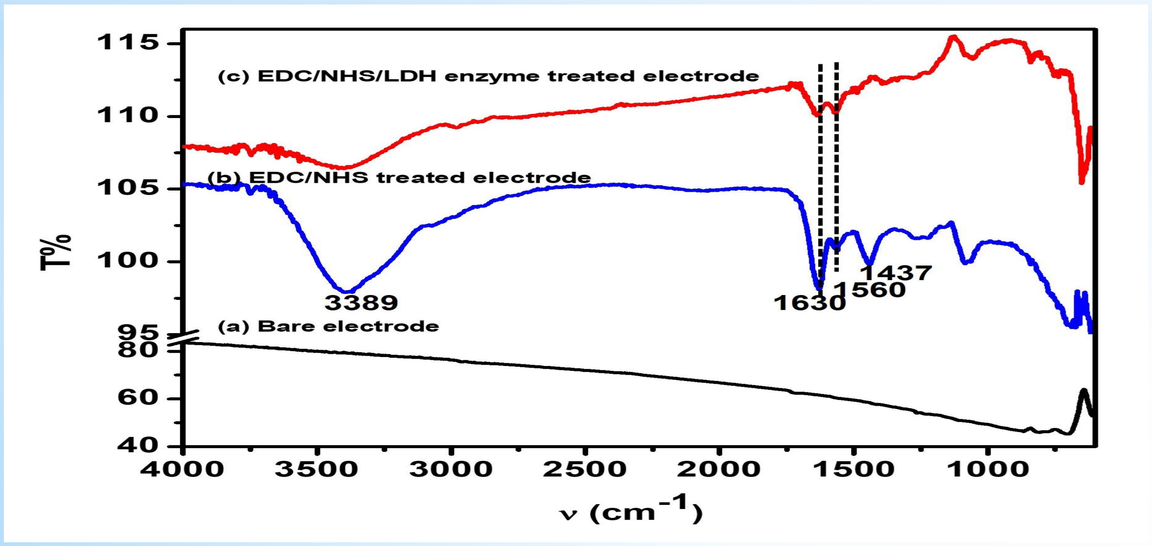

Figure 2. FTIR spectra of SPCE at different modification steps. In comparing Figures (b and c), the two peaks of amide I (C=O in O=C–NH, at 1,630 cm^{-1}) and II (–NH in O=C–NH, at 1,560 cm^{-1}) were observed and attributed to the formation of carbodiimide bonding. The reduction of the peak at 1430 cm^{-1} (-C-N-C-) in Figure (c) shows the successful immobilization of the LDH enzyme over the active surface.

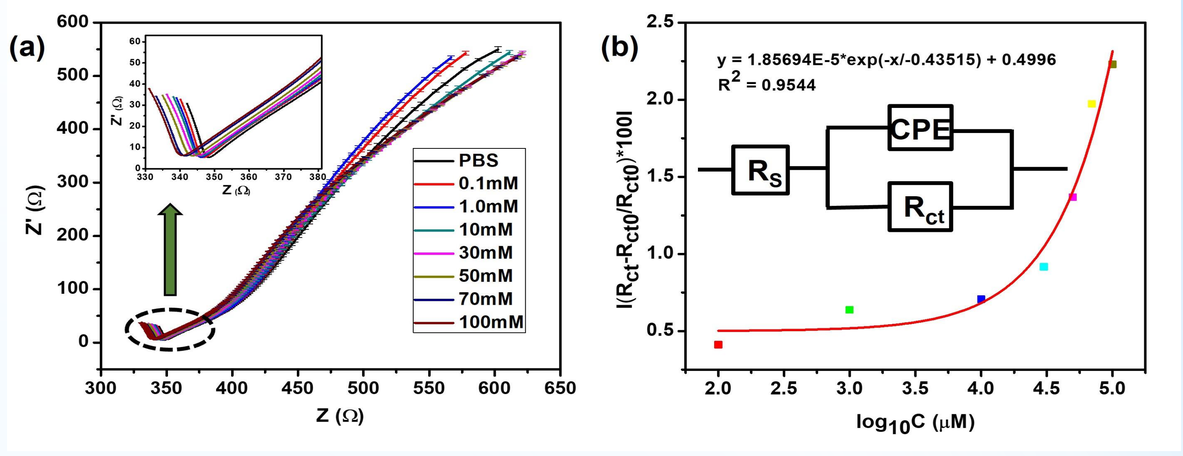

Figure 3. (a) Nyquist plots at different concentrations of lactate (0.1-100 mM) in PBS solution (pH 7.4), and show that there was a significant reduction in charge transfer resistance (R_{ct}) with the increasing lactate concentration. (b) calibration curve at different concentrations of lactate solution, and the inset shows the equivalent Randles circuit of this measurement.

Table 1. Determination of lactate in human sweat samples.

Sample type	By our biosensor (mM)	By commercial biosensor (mM)	Recovery (%)	RSD (%)
S1 (field track running)	57.31	55.33	103.58	27.30
S2 (treadmill running)	34.47	38.40	89.77	42.01

Table 2. Comparison of lactate biosensor used for Human sweat analysis.

Immobilization matrix	Sensor type	Linearity	Reference
CNT and Ag/AgCl	Flexible	1 – 20 mM	[1]
e-RGO	strip	0.5 – 25 mM	[2]
PVC/DOS/ETH500	Wearable	1 – 50 mM	[3]
Printed carbon	Strip	0.1 – 100 mM	This work

Conclusion

- We have successfully demonstrated the impedimetric detection of lactate using an oxygen plasma activated electrochemical biosensor, immobilized with lactate dehydrogenase enzyme.
- A linear response was observed over a wide range of lactate concentrations (0.1 – 100 mM). The average recovery was found ~97% with < 40% of RSD, which supports the statement that the proposed biosensor is reliable for real-life applications and can facilitate the development of medical devices for continuous lactate monitoring in the future.

Acknowledgment

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Reference

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