

A Low-Cost Colorimetric Cotton Patch for Multiplexed Sweat Analysis of Glucose, Sodium, and Lactate

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Introduction

Monitoring glucose levels is essential in managing diabetes, but current sampling methods are invasive, expensive, and impractical. Sweat sampling is an attractive alternative, as sweat is readily available and carries several relevant biomarkers. However, most wearable sweat sensors require electronics and complex fabrication procedures which increase costs and limit accessibility. Few works have developed electronics-free colorimetric sensors for diabetes monitoring. This research developed a low-cost cotton wearable patch with colorimetric sensing of three diabetes-relevant sweat analytes: glucose, sodium, and lactate.

Methods

A prototype 56×72 mm cotton patch with a 4×3 grid of sensing zones was designed. It was fabricated using simple procedures: cutting, pipetting, and dip-coating. Three distinct sensing chemistries were immobilized onto cotton. Glucose detection involves glucose oxidase and potassium permanganate, where glucose oxidation produces hydrogen peroxide to reduce permanganate through various colored species. Sodium detection involves displacing silver from brick-red silver chromate to release yellow chromate. Lactate detection involves L-lactate reducing an orange iron(III)-phenanthroline complex into red ferroin. The sensors were calibrated by spotting spiked aqueous standards and photographing responding hue shifts after five minutes. Zone color was extracted in linear RGB and quantified using specific CIELAB D65 response metrics to produce the strongest linear fit for each channel.

Results

Calibration resulted in linear responses (Fig. 1B; $R^2 = 0.9865$, 0.9741 , and 0.9019) and limits of detection of 243 mg/L glucose, 359 mg/L NaCl, and 146 mg/L lactate. Compared against physiological sweat levels, the lactate and sodium channels could detect and quantify from the low end of their ranges up until 1000 mg/L lactate and 2000 mg/L NaCl. Their accuracy in the high end of the physiological range was not assessed and remains unvalidated. The glucose sensor is least effective, currently detecting an order of magnitude above sweat levels (1.8–36 mg/L).

Conclusion

This work demonstrates the feasibility of low-cost, electronics-free sweat sensing as a promising diabetes monitoring solution. Nonetheless, further work is still required: adjusting glucose channel sensitivity, recovery testing with artificial sweat, selectivity testing for interferences, and on-body trials compared against blood levels.

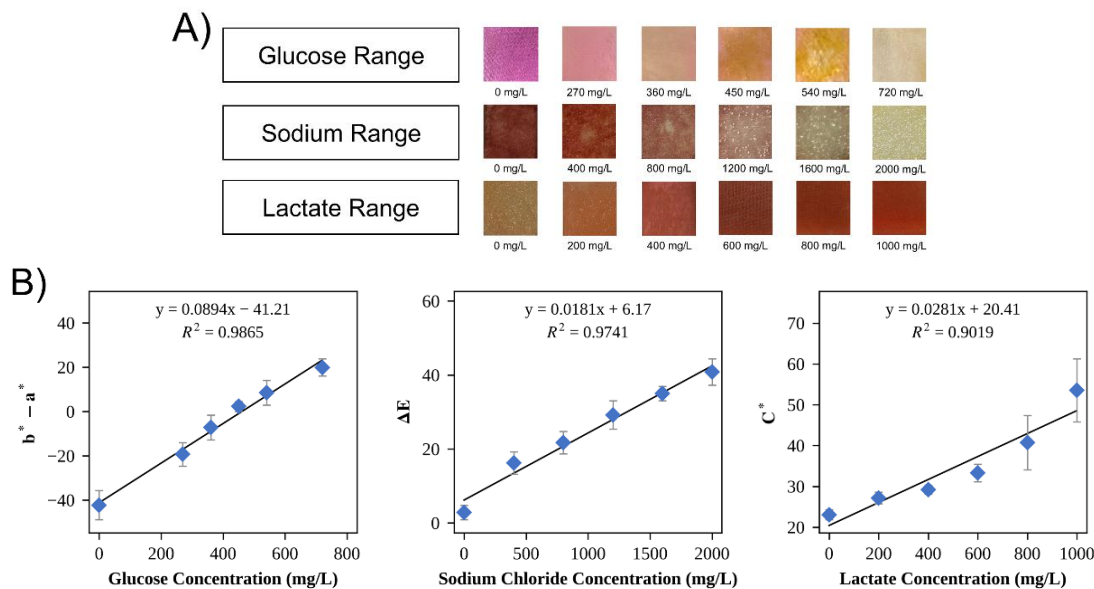


Figure 1. (A) Color response of each sensing zone to varying analyte concentrations. (B) Calibration curves (mean $\pm$ SD) for each channel.