Pengembangan Alat Pengukuran Resistansi Listrik Transepitelial untuk Evaluasi Integritas Sawar Secara In Vitro

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Abstract

Transepithelial Electrical Resistance (TEER) measurement provides a non-destructive means of monitoring epithelial barrier integrity and is routinely applied in pharmacological, toxicological, and tissue engineering studies. However, access to this technique remains limited in some laboratories due to the cost of commercially available instruments. In this study, we developed and evaluated an Arduino-based, low-cost system for TEER measurement. The system uses a voltage divider with a 4.7 kΩ reference resistor, low-frequency pulsed bipolar excitation through two platinum electrodes and a web-based interface for data acquisition and processing. The prototype was evaluated through electrical calibration, testing its ability to distinguish cell-seeded from cell-free samples, and use with Caco-2 cell cultures. The system showed linear response during calibration (R^2 = 0.9961), can distinguish samples with and without cells. It was also capable of recording TEER changes during Caco-2 culture following barrier-modulating treatement. These results show that a low-cost TEER measurement system can be built with common electronic parts. However, the system still needs better measurement resolution and more stable baselines to improve its performance.

Keywords : TEER, epithelial cell barrier, Caco-2, Arduino, resistance.

Introduction

- Tight junctions maintain epithelial barrier integrity; their disruption increases paracellular permeability.
- TEER provides a non-invasive, real-time measure of cell barrier integrity in drug-delivery studies.
- Commercial TEER meters are costly, limiting access in many laboratories.

This study developed and evaluated a low-cost Arduino-based TEER system using Caco-2 cell models.

Research Method

System Development (Software and Hardware)

- Arduino Nano microcontroller
- 4.7 kΩ voltage-divider resistor
- Pulsed bipolar excitation (<1 Hz)
- Two platinum electrodes in Transwell

Electrical Calibration

- Nine precision resistors
- Range: 1–10 kΩ
- Linear regression calibration
- Evaluation of measurement response

Biological Evaluation

- In vitro cell culture (Transwell)
- Barrier-modulating treatments
- TEER changes recorded over time

Discussion and Results

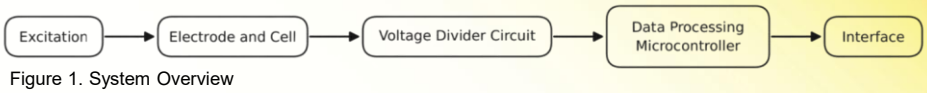


Figure 1. System Overview

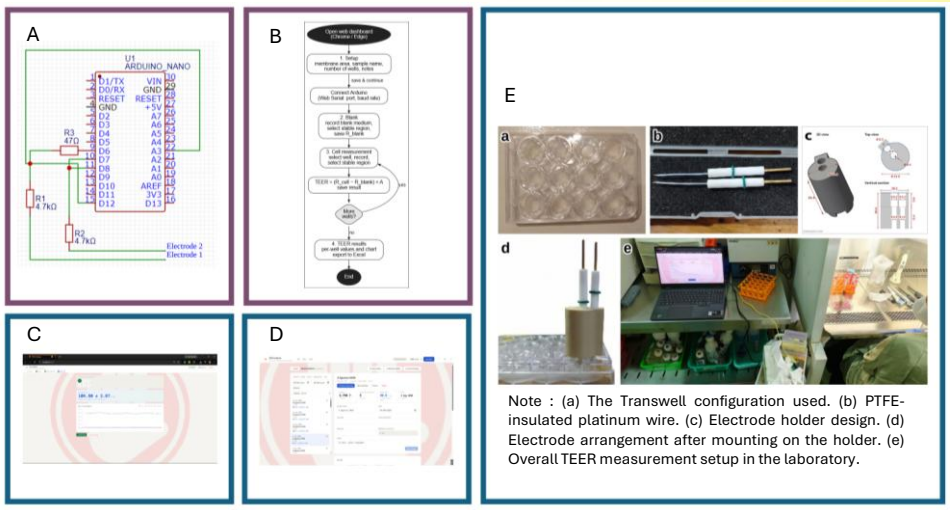
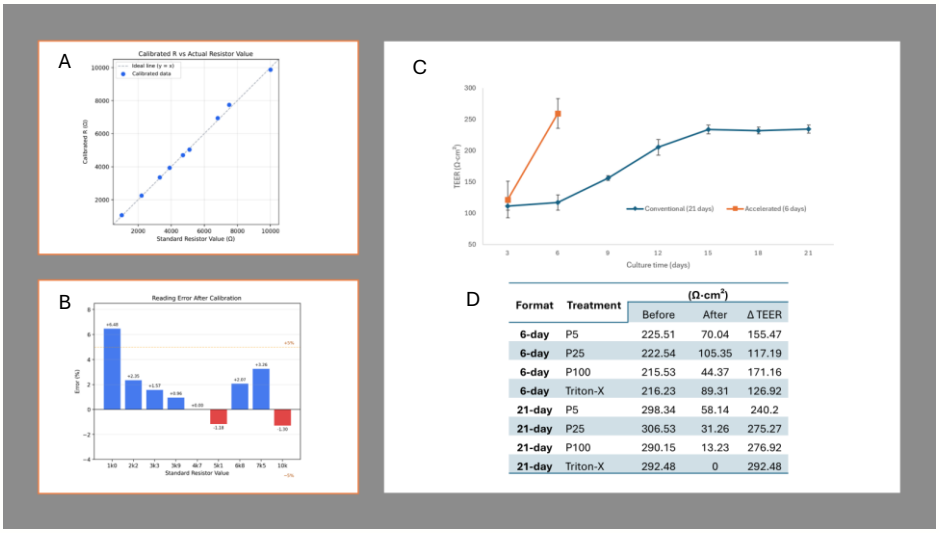


Figure 2. Development of the Arduino-Based TEER Measurement System: A.Circuit Design, B.Measurement Workflow, C,D. User Interface, and E.Prototype Setup



Format	Treatment	(Ω·cm²) Before	After	Δ TEER
6-day	P5	225.51	70.04	155.47
6-day	P25	222.54	105.35	117.19
6-day	P100	215.53	44.37	171.16
6-day	Triton-X	216.23	89.31	126.92
21-day	P5	298.34	58.14	240.2
21-day	P25	306.53	31.26	275.27
21-day	P100	290.15	13.23	276.92
21-day	Triton-X	292.48	0	292.48

Figure 3. Calibration and Performance Evaluation of the Arduino-Based TEER Measurement System. A. Electrical calibration. B. Post-calibration measurement results against the standard resistor values and the distribution of reading errors. C. Monitoring of Caco-2 Barrier Development Using the Arduino-Based TEER System. D. TEER value before and after a barrier-modulating treatment

Conclusion

A simple Arduino-based acquisition system was successfully designed to obtain a resistance signal representing the cell barrier condition. The system integrates a voltage divider circuit, pulsed bipolar excitation to suppress electrode polarization, Arduino Nano-based acquisition with oversampling and a moving average, and a web-based interface. Testing against standard resistors showed excellent linearity (R^2 = 0.9961), demonstrating that the core resistance-measurement function can be realized with simple, affordable components.

For further development, improving baseline stability becomes the top priority, for instance through consistency of electrode geometry and position, a more precise holder, and more controlled electrode conditioning before measurement. Increasing acquisition resolution through a higher-resolution external ADC could help distinguish finer resistance changes. In addition, biological testing should be extended to include monitoring cell growth over time until confluence, so the dynamics of barrier maturation can be evaluated.