Enzymatic Microfluidic Measurement Apparatus (EMMA)

SUTD EPD TERM 5 | FM GROUP 11 | AUGUST 2025
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BACKGROUND

Over 537 million adults worldwide are living with diabetes (IDF, 2021), with high sugar intake being a major contributor to the onset of Type 2 diabetes.

While pre-packaged beverages in Singapore now include Nutri-Grade labels to indicate sugar levels, many drinks from canteens, hawker centres lack such nutritional transparency.

OBJECTIVE

Inspired by the intent behind the Nutri-Grade system, we aim to create a simple and portable test kit that allows consumers to visually assess the sugar content of unlabelled drinks on the spot, empowering more informed dietary choices in a fun intuitive way.

METHODOLOGY AND MATERIALS

Electronics Setup

An Arduino Nano controlled a 12V Peltier heater via a relay circuit, with components like a L7805 voltage regulator, switches, and resistors.

Microfluidic Channel Fabrication

Plotter Film (Disposable): Channels designed in CAD, cut with a plotter, and sealed by lamination

PDMS (Reusable): 3D-printed moulds filled with mixed, degassed PDMS and cured.

Casing

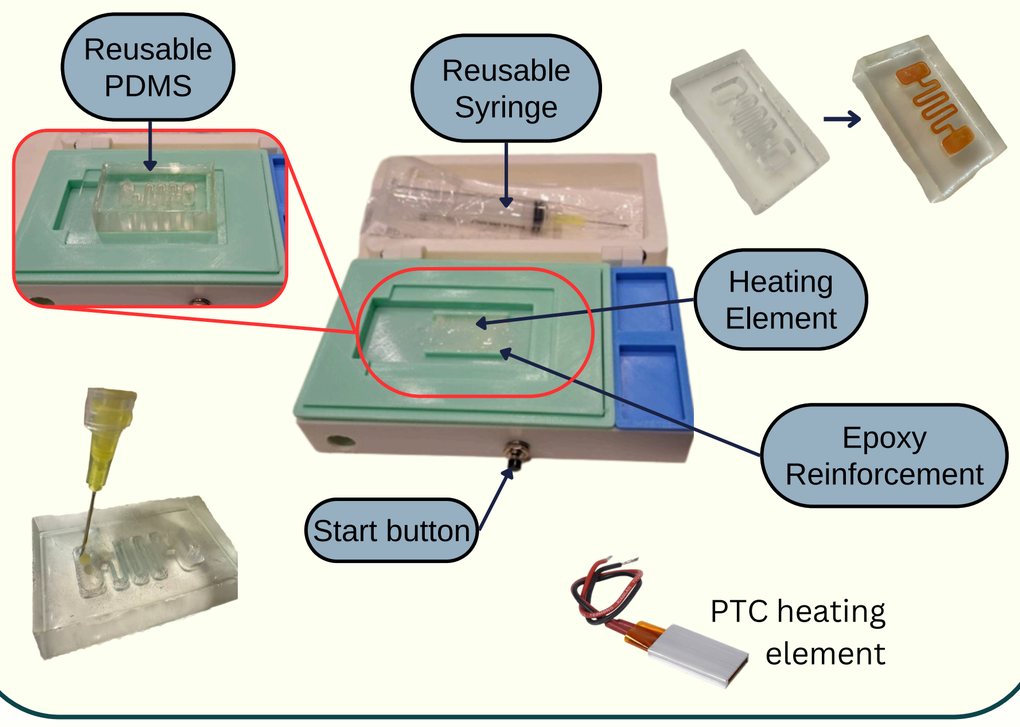
CAD-designed and 3D printed using PLA. Epoxy and fiberglass were added for heat resistance. Future versions may use Nylon.

FLUID MECHANICS

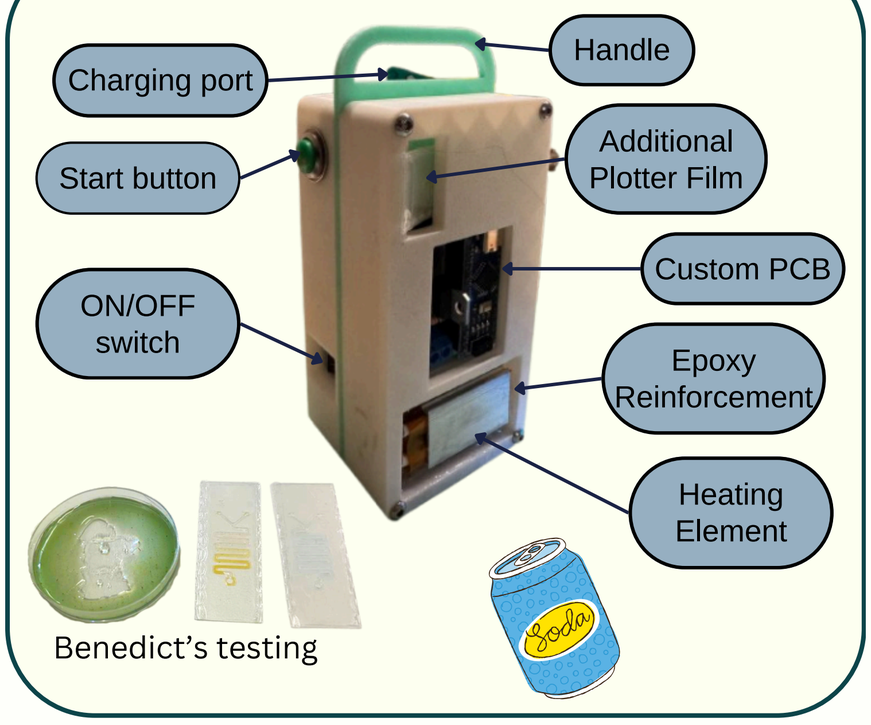
Volume: 1.47 mL
Flow: 0.7 mL in 10 s → 9.33 mm/s
Hydraulic diameter: 2.31 mm
Re ≈ 20 → Laminar
Shear stress: 0.0178 Pa

Kit Types
Temp: 95°C
PDMS:
Reusable, ~3 min per test
Plotter Film:
Disposable ~3 min per test

PROTOTYPE PDMS

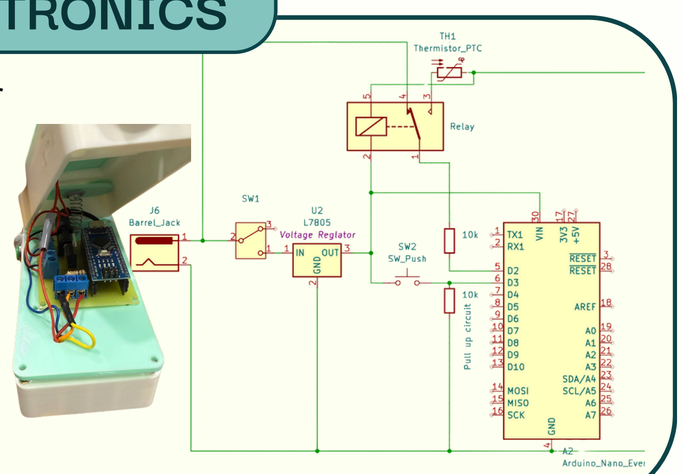


PROTOTYPE PLOTTER FILM

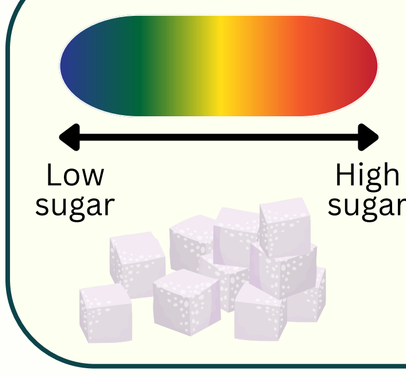


ELECTRONICS

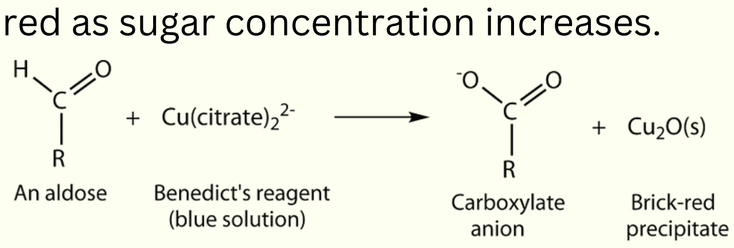
- An Arduino microcontroller was integrated to provide precise and seamless control of the heating element.
- A relay is used to supply power to both the Arduino and the heating element.



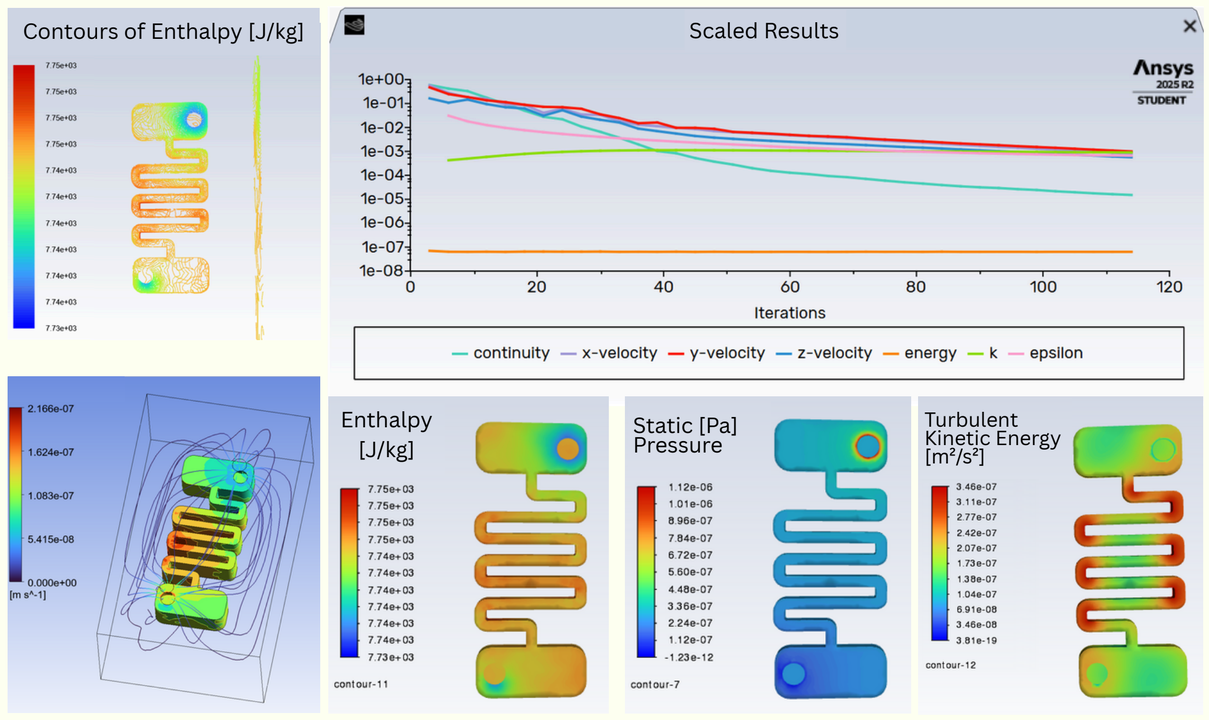
BENEDICT'S TEST



Blue Cu(II) sulfate is reduced by sugars to red Cu(I) oxide. Colour shifts from green to red as sugar concentration increases.



CFD SIMULATIONS



- Even and predictable distribution of heat, pressure, velocity and turbulence.
- Bends and turns have more fluidic resistance and higher K values.
- Smooth bends instead of miter bends to accommodate.

EXPERIMENTS/ CONCLUSION

- Despite the coloured base materials, Benedict's test results remained clear.
- Dyes burned off, and materials retained shape under heat.
- Original design was ineffective for mixing.

- CFD simulations helped redesign the structure for better flow.
- Syringe-fed fluids flowed smoothly.
- Due to laminar flow and no-slip conditions in narrow channels, air bubbles were effectively avoided.

FUTURE IMPROVEMENTS

Current prototype results are favourable however some improvements we wish to make are as follows:

- Add in temperature feedback for better control of the mixture.
- Add a vibrator to introduce mechanical work to assist in mixing the fluids.
- Explore more channelling methods for better mixing of fluids within the system.

Special thanks and acknowledgment Prof. Michinao, TA Joachim, TA Krithika, Yiliang for your unwavering support.