1 Summary

State the aims and objectives of the experiment.

Give a brief outline of the experiments you performed.

Summarise the most important results and major findings/trends, expressed quantitatively.

State the major conclusions which can be drawn from the results of the experiment

2 Introduction

Aim of the experiment is to establish a calibration curve against which we can track and compare the progress of our bioreactor. Impedance spectroscopy is a widely used modality to establish cell composition, diagnosis of lymphatic edema and, most importantly, biological cell suspensions [1, 2]. Alternatively optical density can be used, which we in fact do use to verify our results.

Impedance (Z) is effectively resistance in an AC electrical circuit, which means that it follows the same Ohm's Law definition; where V is potential difference and I is current:

$$Z = \frac{V}{I} \tag{1}$$

We can represent a cell in extracellular liquid as capacitor in a electrical circuit, which allows us to use an important definition from AC theory; where C is capacitance (the quality of a capacitor), f is the frequency, j is the imaginary unit.

$$Z_c = \frac{-j}{2\pi f C} \tag{2}$$

In practice, we cannot determine C, but by combining equations (1) and (2), we know the following relationship

$$V \propto \frac{1}{f} \tag{3}$$

Which tells us we can alter a function generator's frequency such that the voltage output from the "cell as an electrical circuit" is the most meaningful, telling us information about its impedance, and consequently the cell growth.

Why do we run PBS? comparison to cell 20g/l **why does an increase in frequency give us better results? theory says otherwise**

3 Materials and Methods

1.

2.

3.

Variables

- Control:
  - Output voltage on function generator: 10V.
  - Probes 180º from each other. Sense leads 30º from the probe and 180º from each other. See Figure 3.
  - Gain $\frac{R_3}{R_2} = \frac{15k}{150} = 100$.
  - Liquid volume 250 ml, 60mm height measured from inside the cup.
- Independent: Frequency.
- Dependent: Voltage peak-to-peak

Considerations Due to a limited power input into the amplifier, a gain ratio of 1000 led to *gain saturation*, where we no longer observed the expected amplification.

Although we define probe orientation, there are two factors we are disregarding: the cup is not perfectly cylindrical, and the leads are not straight – so the distance between electrodes is smaller than what the experimental setup implies.

With gain of 10, the maxima appeared in different frequencies as to those of 100 and 1000. Suspect to be related to the percentage error being too large.

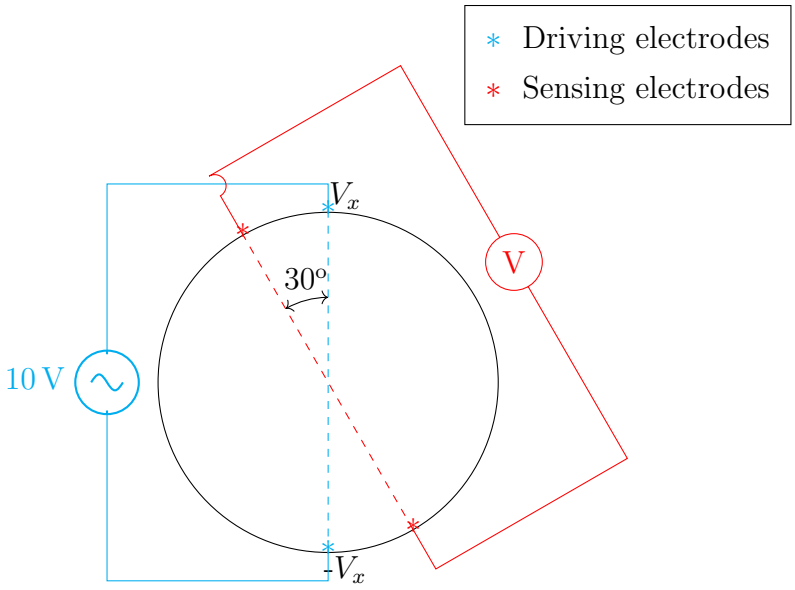


Figure 1: Orientation of electrodes

Maximum amplitude for PBS around 3000hz, maximum amplitude for yeast at 5000hz. We pick 4000 Hz. There is no concern for cell disruption at the range of frequencies we are analysing (Yerworth, R., 2019 November 28)

Uncertainty of about +/- 2ml with our beakers. Relevant in the construction of the calibration curve.

We are creating the calibration curve without the impeller. Because it's plastic, we assume very little effects in the condutance

The frequency we inputed was also observed in mydaq's oscilloscope.

4 Results and Discussion

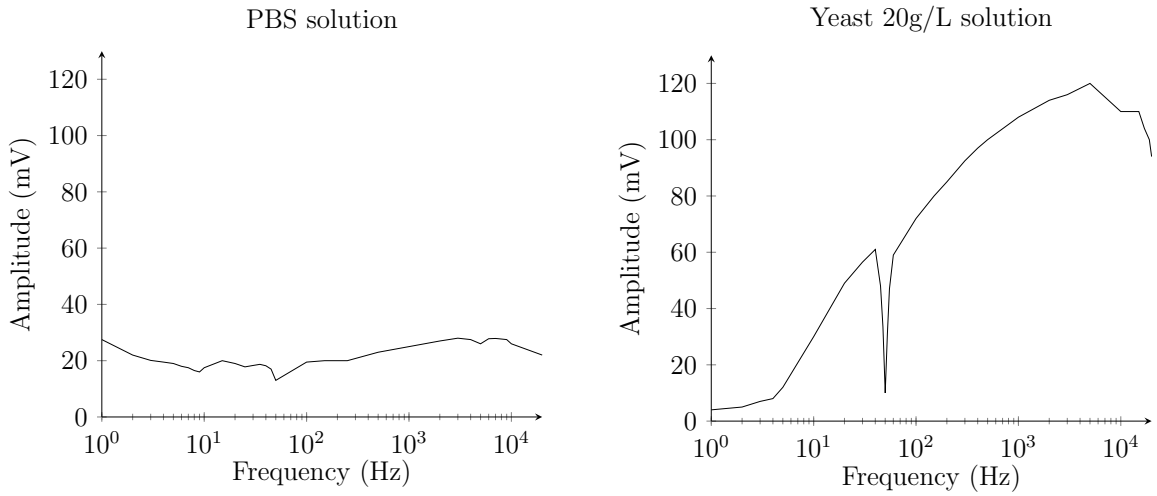


Figure 2: Amplitude based on frequency. Note the dip at 50 Hz due to the filter.

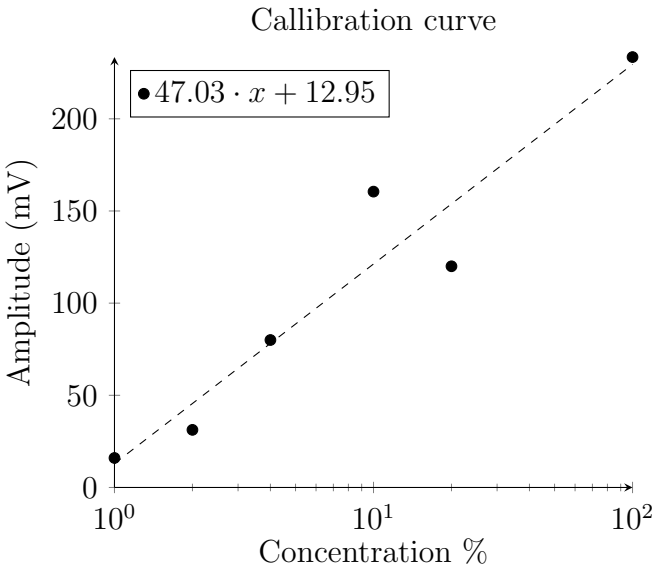
Assess performance of reactor prototype; cell density with final design

Uncertainties Consider trends vs values? Probably most important for the calibration curve.

important comments on results, relate to theory and knowledge

Limitations and improvements We would want to have more data points in our callibration curve.

We used 250ml to determine the frequency, and 300ml for the callibration curve. We don't expect The difference in ideal frequency per volume to be significant.


Callibration curve
$47.03 \cdot x + 12.95$
Amplitude (mV)
0
50
100
150
200
10^0
10^1
10^2
Concentration %

5 Conclusion

References

[1] V. F. Lvovich. *Impedance spectroscopy : applications to electrochemical and dielectric phenomena / Vadim F. Lvovich.* 2012.

[2] A. K. Polat, U. Karabacak, V. Mutlu, L. Tomak, and A. Bilgici. Early diagnosis of lymphedema after breast cancer treatment: Bio-impedance spectroscopy. *The journal of breast health*, 13(2):83, 2017.