Bioelectrical Impedance Spectroscopy (BIS) Monitoring of Lettuce during 19 Hours

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Background

A lettuce leaf was monitored using a bioimpedance spectroscopy technique for 19 hours. Plant tissues consist of resistances (R_1, R_2, R_4) and capacitances (C_3, C_5) connected in parallel or in series, as in the equivalent circuit below. From an electrical point of view, the cell membrane acts as a capacitor, and the capacitance is dependent on the frequency. the double-shell model was used because it fits well into lettuce leaves. Using this model, various components such as resistance (R_1) of the cell wall and extracellular space, resistance (R_2) of the cytoplasmic, capacitance (C_3) of the cell membrane, resistance (R_4) of the vacuole, and capacitance (C_5) of the vacuolar membrane could be determined in this study.

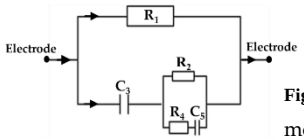


Fig.1. The double-shell model.

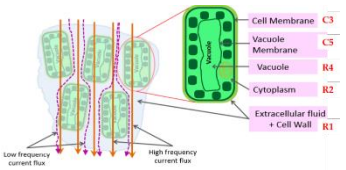
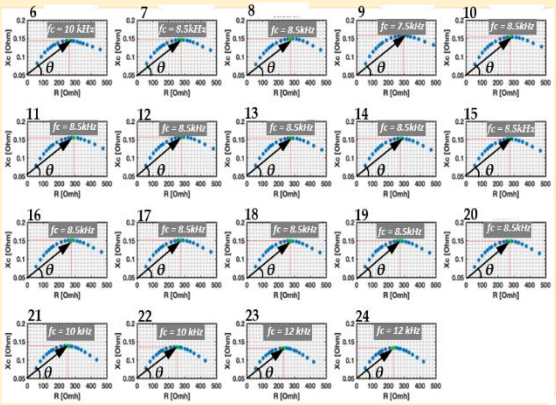


Fig.2. Current conduction through biological tissues

Results

Fig. 3. R-Xc graph, called Cole-Cole plot, measured from lettuce leaves from 6 AM to 12 PM.



The resistance (R) and the reactance (Xc) of the bioelectrical impedance measured on the lettuce leaf every hour from 6 am to midnight (12 pm). The number at the top left shows the time for measuring the impedance. The blue dots in the figure represent the Coe-Cole graph, and fc is the characteristic frequency (fc) measured for each measurement time, which reflects the physiological and pathological conditions of the cell membrane of the lettuce leaf.

Fig. 4. Characteristic frequency and phase angle measured on the lettuce leaves with an external event from 6 am to midnight.

The fc was stabilized at a relatively low value and the phase angle was relatively large between 8 am and 8 pm when photosynthesis occurred by irradiating light onto the lettuce leaves. After 8 pm when the light from the LED was blocked, the characteristic frequency increased rapidly, and the phase angle decreased rapidly. It had been found by analyzing the data that, the phase angle is more sensitive than the characteristic frequency.

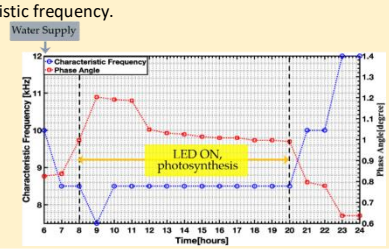
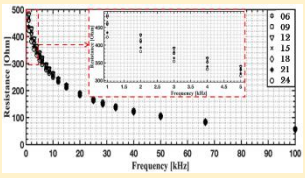
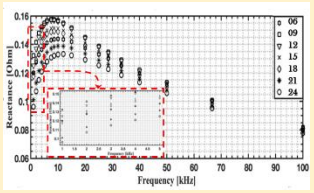


Fig. 5. (**a**) Resistance plotted after every 3 hours as a function of frequency; (**b**) reactance plotted after every 3 hours as a function of frequency



The resistance values measured at 9 pm and 12 pm were measured small. This means that lettuce leaves have the most moisture by absorbing the water best from the roots of the plants during the evening hours

The maximum value of the reactance is smaller as the measurement time later (especially at 12 pm), and these values are shifting toward the higher frequency. This is in good agreement with the fc increase rapidly after 9pm as shown in Fig 4.



Conclusion

This study proposed the monitoring of internal change of the lettuce leaf for 19 hours. The method use in this study is quasi real-time monitoring of lettuce leaf using BIS. With the simulation of the environment changed (water and LED), the analysis of the obtained data through LCR meter was achieved through four approaches. The first explained the obtained graph as Cole-Cole (*R* vs *Xc*) that showed under the action of light and water, the photosynthesis begins to occur and fc reflects the response of the plant cell membrane to the applied frequency, indicating that the cell membrane of the lettuce is in a flexible and healthy state that responds well to low frequencies.