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A Simple Electrical Technique to Demonstrate the Effect of Salting and Harmful Chemicals on Fresh Vegetables

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Abstract
The quality of vegetables for human consumption is greatly influenced by two primary factors, presence of harmful chemicals like insecticides/pesticides/chemical fertilizers and salting. Organic produce promotes sustainable use of natural resources and is a healthier option. Excessive salt stress is detrimental as it leads to the degradation of essential nutrients. A low cost experimental setup is designed that measures the electrical properties, namely resonance and bio impedance, of the organic and conventionally grown vegetables. The vegetables are excited by a low voltage ac source and their behavior is studied under varying frequency in the range 1khz to 600kHz. The results reveal that salinity and conventional methods of agriculture significantly alter the electrical properties of the raw vegetables. Monitoring the shift in the resonance frequency has proven to be an effective method for assessing the quality of the vegetables at the source level.

Keywords: Electrical properties; Salting; Harmful chemicals; Vegetables; Resonance; Bio impedance

Introduction
Two major reasons for health-related degradation of raw food products for direct human consumption are excessive use of chemicals like pesticides and fertilizers, and salting (Das et al., 2024). The importance of modulating both salt and chemicals like pesticide/insecticide/fertilizers has been amply stressed upon and realized (Bhatt et al., 2024; Mehra and Chadha, 2023; Mahajan and Randhawa, 2023). However, despite the advent of modern technology, salting has been used as a preferred method of food preservation. It utilizes the osmotic behavior of raw food when placed in saline solution by reducing the water content thus inhibiting the growth of microbes and prolonging the shelf life of raw food. Also, the unabated use of insecticides, pesticides and similar drugs have led to significantly increased cases of drug intolerance in humans, not to mention chronic effects like cancers, birth defects, neurological and developmental toxicity, and disruption of the endocrine system, to mention a few. This has led to a resounding emphasis on use of organically grown produce. However, any modification/replacement in the current food growing and processing must be substantiated both by scientific research and sensitization of world population and education the masses, outlining the results of contamination and salting on the key parameters.

The physical properties of a sample vegetable and their variation are important to evaluate their nutritive value for consumption. However, most research uses expensive equipment needing dedicated labs (Torrealba-Meléndez et al., 2016; Ling and Wang, 2017; Sosa-Morales et al., 2010; Icier and Baysal, 2004). For the content and extent studies to be performed extensively across populations, a low-cost sustainable mechanism at source will be more relevant.

The present study has been carried out with the objective of accurately measuring the contamination by salt and chemicals at high school/undergraduate labs thus also sensitizing the young population which is most susceptible to the long term harmful effects of the changes introduced in fresh produce when they are subjected to contaminants. Also, the present work primarily served a tool to integrate basic science concepts like resonance, polarizabilities and bio impedance, with food [Dekker, 1975; Omar, 1975]. This helps to promote scientific temperament and raise interest of general population by connecting food consumed by all to real agricultural practices and applications.

The present work aims to study the modulation in the bioelectrical-impedance of various raw sliced vegetables induced by chemicals, salinity stress and senescence. When a plant tissue undergoes electrical excitation, it depicts a frequency dependent behavior which can be called Bio-impedance [Ibba et al., 2020]. Electrical characterization techniques have been used in the present paper to investigate bio impedance variation and induced shift in the resonance behavior. The methodology presented offers a cost-effective non invasive solution that does not necessitate intricate circuitry, elaborate calibration, yet provides highly precise and sensitive results. The sliced vegetable sample is a part of an electrical circuit and behaves as a lumped circuit element consisting of reactive and resistive components. The bio impedance is measured in the frequency range 1kHz to 600kHz. The value of bio impedance has been monitored and correlated with the effect of senescence and salting.

Materials and Methods

Experimental Setup

A thin slice of the sample vegetable of thickness 0.5 mm, is placed between two metal plates forming the parallel plate capacitor with the vegetable serving as the dielectric. Tight packing of the dielectric within the metal plates with no air gaps is ensured by clamping the capacitor between two glass slides. The pre gelled electrode contacts are then made on the top and bottom of the metal plates as shown in figure 1.

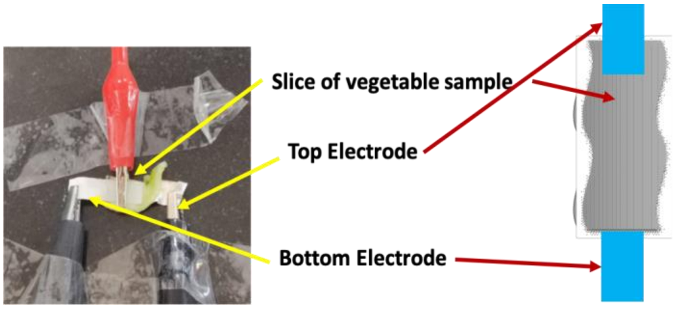


Figure 1. Schematic of the capacitor formed with the help of pre gelled electrode contact

A capacitor of known value (0.01 μF) was added in parallel to the set up to serve as a reference value as shown in figure 2. The measurements were initially carried out without the vegetable sample to calibrate the experimental set up and also to set the reference. The reference bio impedance value obtained without sample will inherently include the marginal surface-electrode capacitive and inductive contributions. These can then be negated from the final read readings.

The circuit consists of the vegetable capacitor in series with a known fixed resistor and a function generator as shown in figure 2. In the designed circuit, a series resistance of 1000 W is also used to avoid the passage of high current to the circuit. The sample capacitor setup was given an electrical excitation by applying a constant ac voltage (8V, peak to peak) throughout the experiment while the applied frequency of the input signal was varied in the range 1kHz to 600kHz. The frequency range used to analyse the data was optimized by excluding the low frequency noise and was chosen to ensure maximum electrical variation in the bio impedance. The corresponding voltage drop across the series resistance and the vegetable capacitor was then noted.

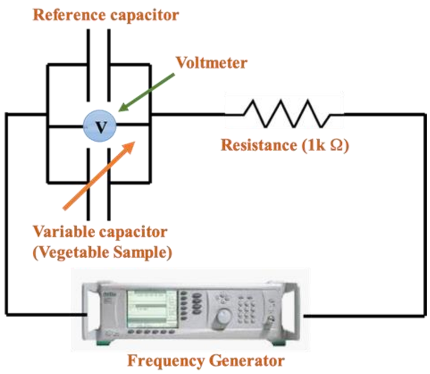


Figure 2. Experimental setup for bio-impedance measurement

The voltage drop across the sample capacitor is shown in the present manuscript as it has direct impact in understanding the presence of contaminating species on different vegetables and therefore the voltage drop across the series resistance is not included. The variation in the voltage across the sample vegetable capacitor provides important information about the dielectric properties in the given frequency range. In the following section, detailed electrical properties and bio impedance studies have been discussed for different conventional and organic vegetables. The effect of salt stress has also been monitored by dipping the vegetable in salt for specific duration of time.

Analysis

Biological materials demonstrate dielectric properties as they have an ability to store energy and can be compared to non-ideal parallel plate capacitors. The cellular membranes illicit the dielectric behavior by acting as a capacitor while the current flow through the extra and intra cellular liquid mediums can be visualized as resistive in nature. At very low frequencies the cell membranes(capacitors) act as open circuits and the current flows through the extra fluid medium around the cells. As the frequency increases the current partially invades the cell membranes and at high frequencies the entire body of the sample becomes transparent to the current flow as the capacitive cell membranes are now effectively shorted.

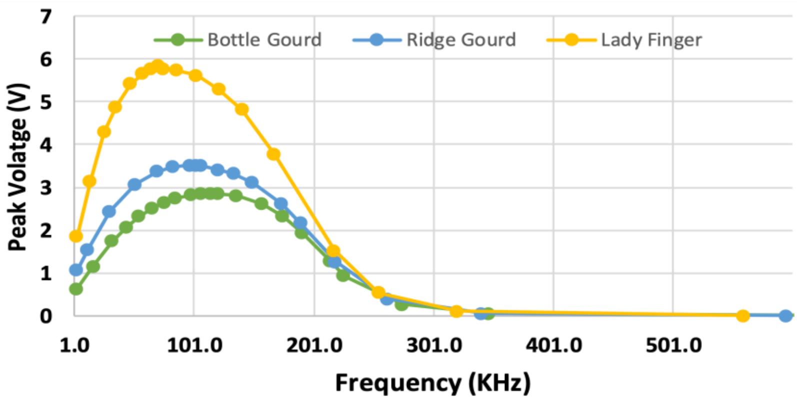
Water being a prominent component of the vegetables, the characteristics of an unsalted sample are dominated by dipolar behavior of water, superimposed on the molecular composition which is inherent to the particular vegetable. The molecular composition of a raw vegetable is dominated by minerals, vitamins, organic acids and phytonutrients besides biomolecules (lipids, proteins, and carbohydrates), each of which can act as a dipole in presence of ac stimuli. If a time varying electrical signal is applied to a substance containing dipoles, all dipoles within the sample start to oscillate, trying to match the frequency of the applied signal. When the applied frequency is equal to the characteristic natural frequency of the sample, the phenomenon of resonance is observed. Each type of dipole present in the sample will have its own characteristic frequency, dictated by the nature of elements constituting the intra and inter molecular bonds. This determines the range of frequency to be studied for each sample. At frequencies above the resonant frequency, the dipoles will become transparent to the applied signal and stop responding to the stimuli, thus effectively shorting the sample. The resonance peak(s) of a raw vegetable defines the given sample and is a characteristic of that sample. A shift in the resonant frequency can be attributed to the presence of external stimulants e.g., salt, and/or contaminants like fertilizers or pesticides. These added chemicals change the lumped circuit elements of the sample like its conductivity and reactance which leads to the variation in its bio impedance.

Results and Discussion

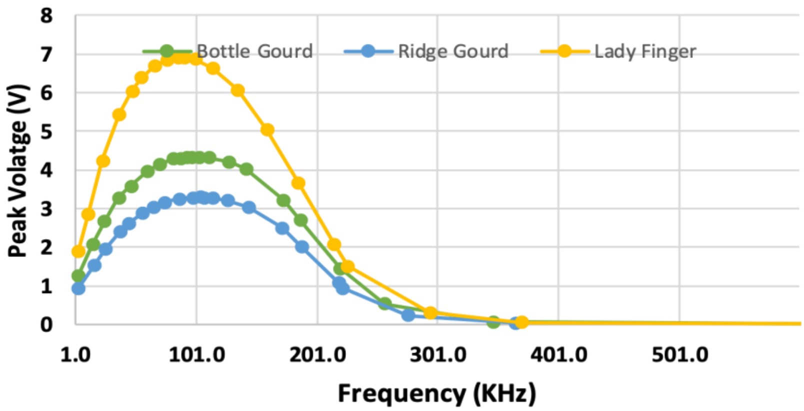
An extensive study of the electric behavior of various conventional and organic vegetables was performed to study the changes in their dielectric behavior when they are gradually saturated with salt solution and the results compared with fresh bought raw samples.

Conventional and organic vegetable samples without salting

Figure 3 (i-ii) shows the plot of peak voltage observed across the sample organic (i) and conventional (ii) fresh unsalted ridge gourd, bottle gourd and lady finger as the frequency of excitation is varied. It is readily seen that all the plots, corresponding to ridge guard, bottle guard and lady finger show resonant behavior as discussed before. For all cases, as the excitation frequency starts to increase, the voltage drop across the sample vegetable element increases, peaking at the resonant frequency characteristic of the sample vegetable. In figure 3(i), the resonance frequencies for organic bottle gourd, ridge gourd, and lady finger are observed to be 115 kHz, 97.9 kHz, 71.6 kHz respectively, while for conventional vegetables they are 103kHz, 104kHz, 87.6kHz as depicted in figure 3(ii).



(i)



(ii)

Figure 3. Variation of peak voltage with respect to frequency across (i) organic and (ii) conventionally grown fresh unsalted ridge gourd, bottle gourd and lady finger

The resonance frequency is found to be in the same frequency band for all the sample vegetables owing to the vegetables being from the same plot of land, ensuring same soil make up and similar treatment during growth in terms of manure, fertilizers and conditioning. Also, the said vegetables belong to the same physiological group of vegetables, with similar water and fiber content and nutritive value. Lady finger owing to larger fiber content and lower water content has lesser conduction losses as compared to the other two vegetables thus exhibiting highest voltage drop at the resonant frequency. Also, comparing the two graphs 3(i) and 3(ii), it is observed that the differential shift in resonant frequency of the three vegetables studied, is more pronounced in the organic vegetables. This is attributed to the fact that the conventionally grown vegetables are strongly chemical(pesticide/insecticide/fertilizer) induced to equivalent levels of contamination. This leads to the natural electrical characteristic of the vegetable being partially neutralized by the chemical induced electrical characteristic.

Figure 4 compares the results of resonance and peak voltage, for organic and conventionally grown lady finger. For organic lady finger the peak voltage drop is 5.84V while for conventionally grown lady finger the peak amplitude is 6.94V. In general, the conventionally grown vegetables have a higher content of heavier ions and other chemical species thus contributing to higher polarizability. This presence of larger number of polarizable entities in conventionally grown vegetables results in higher voltage drop as compared to organic vegetables. This is verified by the peak voltage drop values of the two cases and mentioned above. For the fresh organic vegetables, resonance is dominated by water vs fiber content and the inherent make up of the respective sample while for the conventional vegetables the same is superimposed on the presence of chemical induced heavy ions/species.

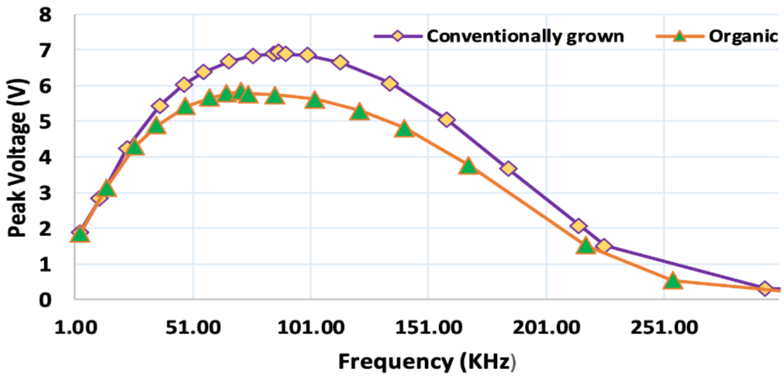
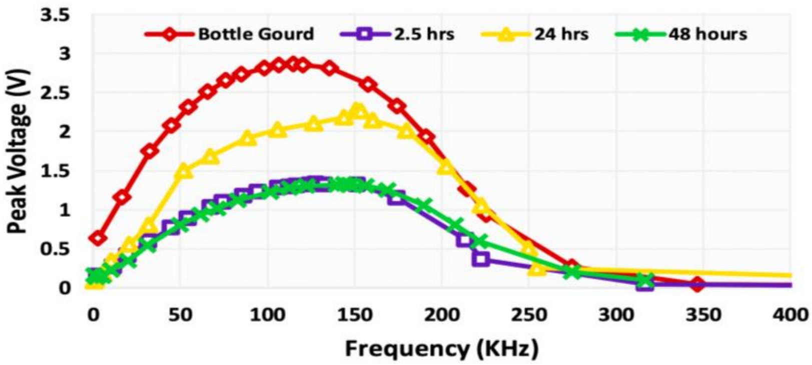


Figure 4. Comparison plot for peak voltage versus frequency organic and conventionally grown lady finger

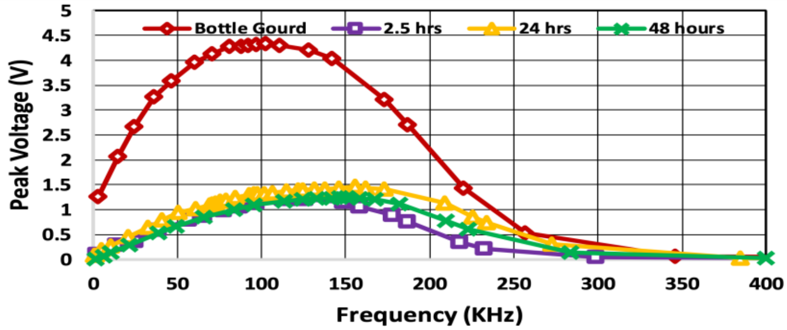
Conventional and organic vegetable samples with salting

To study the effect of salt stress, the samples were dipped in the super saturated solution of sodium chloride (NaCl, common salt), enough to ensure that the samples were just submerged. The observations for the changes in the peak amplitude and resonant frequency were then taken at intervals of 2.5 hours, overnight (24 hours) and two full days (48 hours) to gradually analyze the dielectric changes as the samples progressed from saturated stage to supersaturated stage. Figure 5 (i-ii) represents the plots for the variations observed in the resonant frequency and peak amplitude for organic and conventional bottle gourd.

Salting the sample drastically increases the ionic content. It was observed that by the end of the first 150s of salting, the water content in the vegetables is still significant and the NaCl ions have uniformly dissolved throughout. The induced ions enhance the conduction though water medium. This increased conduction by ionic content makes the samples have low bio impedance, lowering the peak amplitude. Also, the presence of ionic NaCl along with substantial water content makes the net dielectric behavior be governed by both dipolar and ionic polarizabilities, thus shifting the resonant frequency of the lumped circuit to the higher end of the spectrum.



(i)



(ii)

Figure 5. Variation of peak voltage with respect to frequency for (i) organic and (ii) conventional bottle gourd progressed from saturated to supersaturated stage.

As the salting time increases further, this results in dehydrating the samples due to osmotic property. The prolonged exposure to salting thus dries out the vegetables, super saturating them with the NaCl. The sharply decreased levels of water in the lumped circuit/sample vegetable reduces the dipolar polarizability on one hand while increasing the reactive nature of the sample on the other. Thus, at the end of two day saturation, the sample has a large capacitance as it has a lot of ions which will separate and behave like a dielectric but low conductivity owing to the reduced water content. The contributor to the polarizability after prolonged exposure is majorly ionic thus the resonant frequency is seen to increase only slightly. However, as the sample is now less conductive and more capacitive, there is an increase in the peak amplitude of the sample voltage observed across the sample. This can readily be seen in Figure 5 (i-ii).

Conclusion

NaCl being the prominent ingredient in fermented and processed food, a basic level study to show the modulation in characteristics is a must to assess the minimum acceptable levels used for preservation of fermented vegetables thus reducing the levels of NaCl necessary in packaging. Also, the conventional methods of agriculture use excessive amounts of insecticides/pesticides and fertilizers which affect the quality of food and lead to detrimental health effects in humans. A cost-effective experimental set up has been demonstrated to precisely observe the variations in the dielectric behavior of sample organic and conventional vegetables through bio impedance measurements when then are induced with salt stress coupled with senescence. A marked shift in the resonance frequency and peak amplitude indicative of the changing dielectric origin and hence resulting in observable change in physical properties of the sample vegetables namely, bottle gourd, ridge gourd and lady finger is reported.

References

Bhatt C, Saha A, Khalkho BR and Rai MK (2024) Spectroscopic Determination of Permethrin Insecticide in Environmental and Agricultural Samples Using Leuco Crystal Violet Reagent. Environ Sci Arch 3(1): 14-28.

Das K, Pramanik S, Rajak P, Biswas G and Mandi M (2024) Monocrotophos induced changes in the life cycle parameters of fruit fly. Environ Sci Arch 3(STI-1): 6-13.

Dekker AJ (1957) Solid state physics. Prentice-Hall.

Ibba P, Falco A, Abera BD, et al. (2020) Bio-impedance and circuit parameters: An analysis for tracking fruit ripening. Postharvest Biology and Technology 159:110978. DOI.org/10.1016/j.postharvbio.2019.110978.

Içier F and Baysal T (2004) Dielectrical properties of food materials—2: Measurement techniques. Critical reviews in food science and nutrition 44(6):473-478. DOI.org/10.1080/10408690490892361

Ling B and Wang S (2017) Dielectric properties of pistachio kernels as influenced by frequency, temperature, moisture and salt content. In 2017 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers. DOI:10.13031/aim.201700372.

Mahajan S and Randhawa JK (2023) Environmental Toxicity and Oxidative Stress on Gonads of Fishes. Environ Sci Arch 2(STI-2):3-17.

Mehra S and Chadha P (2023) Molecular Biomarkers as Key Factors to Evaluate the Extent of Industrial Pollution Exposure. Environ Sci Arch 2(STI-2):18-22.

Omar MA (1975) Elementary solid state physics: principles and applications. Pearson Education India.

Sosa-Morales ME, Valerio-Junco L, López-Malo A, et al. (2010) Dielectric properties of foods: Reported data in the 21st Century and their potential applications. LWT-Food Science and Technology 43(8):1169-1179. DOI.org/10.1016/j.lwt.2010.03.017.

Torrealba-Meléndez R, Sosa-Morales ME, Olvera-Cervantes JL, et al. (2016) Dielectric properties of beans at different temperatures and moisture content in the microwave range. International Journal of Food Properties 19(3):564-577. DOI.org/10.1080/10942912.2015.1038565.

Author Contributions
RG, CS, PD and AS conceived the concept, wrote and approved the manuscript.

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Competing interest
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